Focus Article

Blindsight: recent and historical controversies on the blindness of blindsight

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The phenomenon 'blindsight' has received much interest from neuroscientists, philosophers, and psychologists during the last decades. Several researchers seem to agree that blindsight might be of great importance in the ambition to find neural correlates of consciousness. However, the history of blindsight is a history of changing experimental paradigms and very few patients. In late 19th century, researchers debated why lesions to primary visual cortex seemingly left some visual abilities intact in animals, while human patients reported to be blind. From the 1970s until today, experiments have attempted to compare measures of conscious and unconscious perception, suggesting a distinction between visual functions and visual experience. However, more recently, newer methods and an interest in introspective reports have cast doubts about the 'blindness' of blindsight. A cautious conclusion is suggested, though current research can be interpreted in different ways.

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INTRODUCTION

Blindsight refers to a 'visual capacity in a field defect in the absence of acknowledged awareness'.[1] The phenomenon seems to occur after lesion to the primary visual cortex, and shares as such all important features of other lesions leading to cortical blindness, apart from one crucial issue: patients have intact visual functions, regardless of their reports of total blindness.

The discovery of blindsight has been described as one of the most important contributions to philosophy of mind from experimental psychology.[2] Blindsight has been of particular interest to several researchers interested in neural correlates of consciousness as it arguably represents a distinction between phenomenal consciousness, i.e., subjective experience, and functional aspects of cognitive processes.

Nevertheless, and as stressed in a recent review by Alan Cowey,[3] even after 35 years since its discovery blindsight remains controversial. In this review, experimental studies will be discussed, arguing that the controversy remains because the diagnosis is strongly tied to the intense study of only few patients, and because blindsight seems to be observed dependent on certain methodologies.

THE DISCOVERY OF BLINDSIGHT AND BEFORE

It is difficult to decide what should count as a 'starting point' in the history leading to the discovery of blindsight, but in late 19th century, researchers experimented with lesioning primary visual cortex in animals. Repeatedly, it was found that aspects of visual discrimination were left intact.[4] At the time, the leading hypothesis was that the human visual system was importantly different from visual systems in animals.[5] So, despite the high degree of similarities in anatomy, it was concluded that in the case of humans, no aspects of vision survived a complete lesion to V1.[6] Prevailing theories in neuroscience argued that human visual cortex is more functionally specialized as lesions in this case would lead to hemianopia, i.e.,

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total blindness in both phenomenal and functional terms. A few findings did seem to contradict this conclusion, without, however, changing the general paradigm. For instance, Riddoch reported aspects of still functioning vision in spite of occipital lesions in injured soldiers, as in one case of a patient able to detect moving but not stationary stimuli.[7]

However, in the 1970s, different methods to study human visual perception were introduced in the study of patients with occipital lesions, which to some degree resembled the methods used in animal studies. As verbal reports are obviously not applicable to animal studies, researchers typically used different reaching paradigms, where animals touched or reached for objects. In a study performed by Pöppel, Held, and Frost, a similar method was applied to humans.[8] Eye movements were recorded to examine four patients with scotomata in their visual field. They were asked to localize the position at which a visual target had appeared by moving their eyes to the position where they would guess, the light was. The patients performed poorly, but nevertheless with a statistically significant accuracy. Shortly after, Weiskrantz, Warrington, Sanders, and Marshall reported five experiments with the now famous patient DB.[9] Weiskrantz and coworkers adopted the eye movement procedure suggested by Pöppel, Held, and Frost, and DB was asked to shift his eyes from a fixation point to the position he would guess a light was flashed. The experiment showed a weak correspondence between target position and eye movement, much like the experiment by Pöppel, Held, and Frost. In a second experiment, DB had to reach for a target with a finger instead of relying on eye movements alone. With this different method, results showed a very clear correlation between target and finger position, especially for larger stimuli. Further experiments studied DB's ability to discriminate between two possible stimuli (X vs O, horizontal vs vertical lines, etc.) and found that he was able to do so well above chance level with increased performance as a function of stimulus size.

Weiskrantz invented the term 'blindsight' to refer to this strange phenomenon that DB seemingly was able to see in at least a 'functional' sense while he insisted on being blind in a 'phenomenal' sense.[1] Crucially, this distinction of two 'aspects' of mental states was made apparent by the introduction of a new method to study human subjects. The previously dominant view on the neural substrate of conscious perception was altered as consequence.

The segregation of functional and phenomenal aspects of mental states in the study of subliminal perception was at this time already quite developed and experiments indicated that even 'high-level' cognitive functions such as semantic categorization could occur in the total absence of conscious experience.[10,11] One ambition underlying this particular interest is the idea that one might find neural correlates of consciousness when contrasting cases of being conscious of one particular content with cases with all things equal except this particular conscious content.[12,13] The ambition of isolating a neural correlate of consciousness is broadly shared by several researchers in neuroscience, psychology, and philosophy, as it seems a necessary part of, though not sufficient for, an explanation of consciousness. 'Pure contrasts' are particularly difficult in consciousness research, as functional aspects of cognition will typically covary with changes in conscious content.[14] For this reason, some researchers are particularly fascinated by blindsight, considering it a good candidate for a pure contrast.[15] In other neurological conditions, patients typically seem to lack access to the information, they are not conscious of. For instance, in hemianopia or visual agnosia, patients are not conscious of (aspects of) visual information—but they are also unable to report about or act on this information. Arguably, blindsight represents a case in which patients lack conscious experience of visual information, yet have preserved abilities to report or act on it. Thus, the difference between affected and unaffected hemifields in blindsight subjects could be interpreted as a 'pure constrast'—a rare opportunity to treat visual conscious experience as a variable.[16]

Perhaps unsurprising, blindsight received immediate criticism from the surrounding scientific community. For instance, Campion et al. showed that some of their patients seemingly were responding to a bright target in the blind part of their visual field while in fact detecting light scattered from the subject's nose into the seeing part of the retina.[17] King et al., however, defended the notion of blindsight by placing a half-patch over the viewing eye so that the blind retina is obscured.[18] In this way, King et al. showed that 'blindsight' in four hemispherectomized subjects was entirely based on light scattered into the seeing hemifield, whereas in the frequently studied blindsight patient GY, it was not. The result is supplemented by experiments using other methods, such as the presentation of stimuli in the retinal blind spot in healthy subjects as control. Such experiments, rather convincingly, argue that the effects cannot be due to light diffusion onto the sighted hemifield.[19]

NEUROBIOLOGY AND BLINDSIGHT

As mentioned, when it comes to the anatomy of vision, humans are more similar than different to other mammals, not least primates. The retina passes

its output to the LGN in the thalamus, which again projects to the V1 (striate cortex). When the striate cortex is removed or blocked in monkeys, the animals can still carry out some visual discrimination tasks. In and of itself, this is not surprising because LGN projects directly to other cortical cites involved in visual processing, bypassing V1.[20,21] What, however, is surprising is that these processes, in humans where reports can be collected, seemed to occur in the total absence of any conscious experience thereof. However, animals with V1 lesions may in fact also have blindsight: With behavioral measures only, how could we know? To some researchers, blindsight seems to give rise to the hypothesis that primary visual consciousness is part of the neural correlate of visual consciousness[22] (Figure 1).

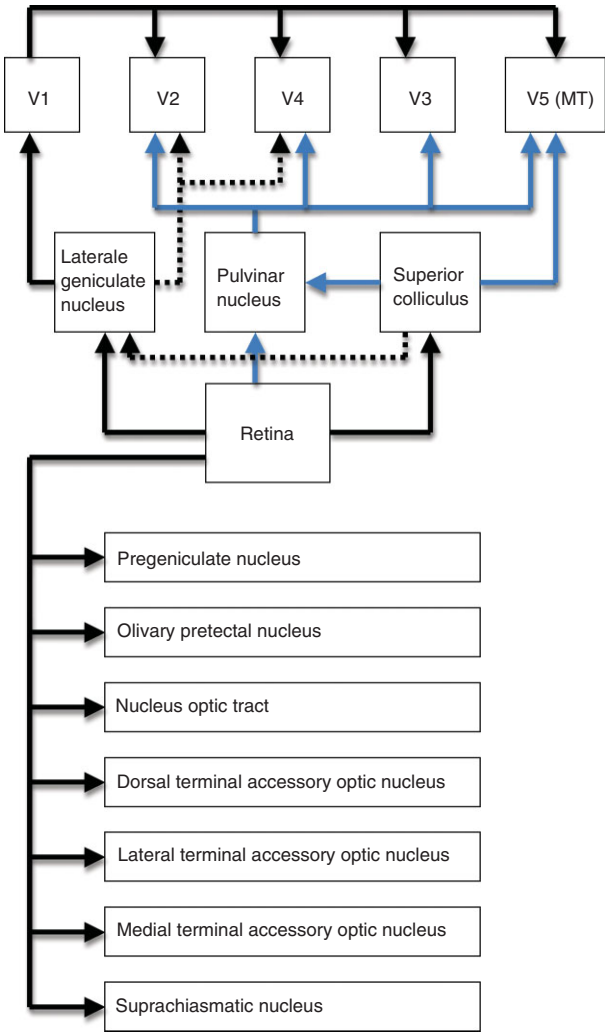

FIGURE 1 | The primary and alternative routes from the retina to various regions in the brain. The black arrows indicate primary routes and the dotted lines indicate very sparse routes. (Reprinted with permission from Ref 21. Copyright 1993 Elsevier)

LIMITS TO PERFORMANCE?

Experiments on blindsight have not just tried to consolidate the phenomenon and argue for its existence, they have also investigated limits to the visual abilities of blindsighters. Kentridge et al.[23] found that patient GY's attention could be directed by cues in the residual part of the visual field as well as in the blind field. Cues in the blind field could even direct his attention to locations in the healthy field, from which the authors conclude that spatial information selection and conscious experience rely on different processes, and that blindsight patients may have fully or partially intact visual attention without visual experience. It seems a very broadly accepted view that blindsight differs from normal vision in this regard that it needs cueing and prompting in order for the patient to react to the visual information.[24]

A few studies indicate, however, that some of the differences between blindsight and normal vision may be exaggerated. Stoerig, for one, showed that performance was equally accurate in two blindsight patients with and without cues.[25] Even more striking, de Gelder et al. found intact navigation skills in patient TN who was able to walk down along a corridor, avoiding barriers and turning around blockages.[26] Such findings indicate that the typical assumption that prompting is necessary to reveal preserved functions is not necessarily an intrinsic feature of blindsight.

A large part of the blindsight literature has focused on very few case histories with GY as the absolutely most 'popular' patient in experimental studies. This has resulted in peculiar phenomena, arguably the result of an 'intense training' of the blind field, e.g., the discovery that GY performs better when discriminating stimuli with a short duration than using his blind than his healthy field.[27]

CHANGING FINDINGS AND DEFINITIONS FOR BLINDSIGHT

As pointed out by Cowey[3] and ffytche and Zeki,[28] one reason for the controversial status of blindsight has been its changing criteria based on findings that challenge the original definition by Weiskrantz.[1] While new terms for distinguishing remaining functions keep appearing, e.g., 'action blindsight', 'attention blindsight',[29] and even 'blindsight in normal subjects',[15,30] the core challenge is the relatively large number of subjective reports, which have been reported in parallel to the behavioral methods, indicating that blindsight patients may in fact have conscious experiences closely related to their preserved functions.

As reviewed in more detail elsewhere,[14] some patients (including DB) refer to 'feelings',[9] yet others seem to refer to some sort of perceptual content, e.g., 'visual pin pricks',[31] 'dark shadows',[32] or 'white halos'.[33]

While GY in one qualitative interview fully denied he ever had experiences in his 'blind' field,[34] other studies find the exact opposite. In one experiment, Stoerig and Barth investigated GY's reports of 'feelings' related to visual stimuli.[35] GY was asked to match a visual stimulus presented to the blind field with one of different image transformation of the same stimulus in the healthy field. When using high-contrast stimuli, GY deemed the stimuli as 'visual' and as 'no match at all' compared with the 'feeling' in the blind field. However, with moving stimuli, GY accepted the match as long as they were sufficiently blurred and appeared as 'motion only'. The results match with GY's verbal descriptions of his 'feelings' as 'similar to that of a normally sighted man who, with his eyes shut against sunlight, can perceive the direction of motion of a hand waved in front of him'.[36] Stoerig and Barth conclude that even though GY's vision is clearly degraded and different from normal vision, his experiences are still basically visual in nature.

Other experiments have suggested that blindsight is different from normal vision, though not necessarily 'totally blind'. Azzopardi and Cowey[37] performed a signal detection analysis on GY's yes/no-detection judgments and forced-choice detection tasks and found that his sensitivity was significantly higher during the forced-choice task. This is different from the performance of healthy subjects when having 'near-threshold vision', indicating that visual stimuli in blindsight are processed 'in an unusual way' (Ref 37, p. 14190).

In another study, Morland et al. demonstrated that GY is able to match some but not all aspects of visual stimuli when asked to compare stimuli presented to the blind and healthy hemifields.[38] In the experiment, GY associated color and motion correctly, but not brightness, based on which the authors argue for an anatomical separation of these functions. Morland et al. suggest the results indicate that GY has visual awareness of those stimulus properties for which he gave correct reports, yet, as they somewhat ambiguously put it, he is not visually aware due to lacks of or limited processing of brightness.

Whereas, such findings have led some researchers to debate the nature of blindsight and its status of 'total blindness',[28] others have defended the original interpretation, and divided blindsight into two 'subtypes' instead: type 1 and 2.[1] The latter type is arguably somehow conscious of visual stimuli, while type 1 patients are not. The very reason to stick to the term 'blindsight' in the case of type 2 seems to be the idea that these experiences are not 'visual' in nature.[28]

Others, however, conceptualize the same findings differently. For instance, Schoenfeld et al. diagnose patients with preserved visual experiences as having 'Riddoch Syndrome'[39] (coined by Zeki and ffytche[40]), rather than 'blindsight type 2'.

FURTHER METHODOLOGICAL DEVELOPMENTS

Crucially, the discussion above arises the moment new methods are introduced. Intuitively, this seems very identical to the 'blindsight revolution' in the 1970s where the introduction of new methods changed our understanding of the human visual system. In the behavioral experiments, on which blindsight fully relies, reports seem to have a very specific status: In most cases, they derive from open self-reports in which the patient describes him- or herself as 'partly blind', and in very different dichotomous reports (did you see this yes or no?) during actual experiments.

In an experiment with healthy subjects, Ramsøy and Overgaard asked the participants to create the categories, they themselves were to use to report experienced clarity of visual stimuli in a following experiment.[41] Thus, the researchers did not decide the scale to report subjective experiences prior to the experiment, but had subjects to device their own scale with the instruction that each scale point should fit a subjectively identifiable experience. In the following experiments, participants were asked to report what they were shown and how they experienced stimuli in terms of clarity, using their own scale. Subjects conformed to a four-point scale (named the Perceptual Awareness Scale, or PAS) categorized as 'not seen', 'weak glimpse' (meaning 'something was there but I had no idea what it was'), 'almost clear image', and 'clear image'. Ramsøy and Overgaard showed that in an experimental design where one should expect to find subliminal perception, subjects were completely at base chance when reporting 'not seen'. In a later study, dichotomous reports were compared directly with PAS.[42] Using the dichotomous report, subjects showed subliminal perception, whereas none was present at PAS = 'not seen'. In further studies, PAS was found more sensitive to subjective experience than other four-point scales.[43] Generally, PAS fitted better with objective measures such as stimulus duration and correctness than did the dichotomous report.

Several experiments on healthy subjects have shown that masked stimuli systematically influence behavior even though subjects with current methods

do not report any conscious experience hereof. The experiments using PAS are of course insufficient to argue against the existence of unconscious perception *per se*. However, they do inspire further investigations into blindsight to see if they might result in similar findings.

Overgaard et al. performed a study on a 31-year-old hemianopic with left-sided injury to primary visual cortex.[44] In the first experiment, letters were briefly flashed at different locations on a computer screen and GR's only task was to respond to every stimulus, revealing that she was blind to everything presented in the upper-right quadrant. In a second experiment, GR was presented with different visual figures and asked (1) which figures were shown and (2) if she actually saw the figure—yes or no. GR reported only very rarely that she saw stimuli in the upper-right quadrant, yet she was able to report correctly about these stimuli more often than chance. In the healthy part, her reports were significant predictors of correctness, based on which the authors concluded that she had blindsight. The third experiment was identical to the second, except she now should respond with PAS rather than in a binary fashion. As a consequence, her blindsight seemingly 'disappeared' in the sense that, even though she reported much more vague experiences in the upper right compared to the upper-left quadrant, the relationship between correctness and reported experience was identical. All correctness above chance seemed related to vague yet conscious vision when using PAS. So, the first experiment indicates that GR is a 'cortically blind hemianopic', the second experiment indicates that she has blindsight, perhaps, type 1, and the third that she has blindsight type 2 if blindsight at all. One might be tempted to conclude that blindsight in deed is closely related to the methods used to study conscious perception. This, however, is presently a strong conclusion based on only one such observation.

The finding is closely related to previous experiments by Zeki and ffytche[40] who report crude visual experiences in GY. In a more recent paper, ffytche and Zeki[28] report definite visual experiences in three patients with lesions to V1. In a discussion of the patients' 'phenomenology', more elaborate than typically found in more behaviorally oriented experiments, they argue that V1 may not be necessary for visual consciousness. Again, it seems the case that the interpretation of blindsight and the role of V1 are adjusted based on choice of methodology.

As our terminology and methods to study subjective experience are still underdeveloped, experimental results are consequently difficult to interpret. Persaud et al. performed an functional magnetic resonance imaging experiment with GY, in which he was asked to perform a visual discrimination task.[45] When GY correctly reported visual stimuli in his 'blind' field compared with correct reports in the 'healthy' field, there was relatively less activity in prefrontal cortex. Prefrontal cortex has in previous fMRI studies shown related to reports of conscious perception.[15] Persaud and coworkers interpret their finding sounds that GY might have a superior metacognitive capacity associated with stimuli in his healthy field, as GY was better able to distinguish his own correct and incorrect responses in his healthy field than in his 'blind' field. However, some prefrontal cortex activity was related to stimulation in the 'blind' field as well. Several researchers, however, would argue that one only has metacognitive, or at least introspective, thoughts about conscious states, like perceptions.[46] Thus an alternative interpretation would sound that the degraded but still existing prefrontal activity was indirectly related to degraded but still existing visual experiences.

ARE PRESERVED CONSCIOUS EXPERIENCES VISUAL?

The existence of some sort of conscious experiences in at least some blindsight patients is seemingly admitted by all blindsight researchers. Weiskrantz, in a paper entitled 'Is blindsight just degraded normal vision'?[46] seems also to agree to this—at least that type 2 blindsight is essentially a matter of visual yet somehow distorted experience, e.g., the experience of 'afterimages' of stimuli.[47]

Brogaard raises the argument that in spite of what seems as empirical evidence of the opposite, GR, if not also the healthy participants of the previous experiments, are in fact not conscious of visual stimuli.[48] She points out that even though the study on GR shows that reported visual clarity and correctness are significantly correlated, we are left without knowledge about what GR is conscious of. In other words, she argues, GR may not be able to distinguish visual experiences from other kinds of experiences, e.g., thoughts. Brogaard concludes that blindsight patients are visually unconscious.

Overgaard and Grünbaum respond to this discussion and raise the question which criteria to use in order to decide whether something is (1) conscious and (2) visual.[49] They agree with Brogaard that in order to decide whether something is conscious or unconscious, one needs introspection. They note that in order to decide whether a representation is conscious or unconscious we need only one criterion. We would not be able to make sense of one criterion

to be used in order to decide whether something is conscious and another, totally different, criterion to decide whether something is unconscious. However, in order to decide whether something is visual or not, we arguably need a different criterion. Brogaard, along with several other researchers not least in the blindsight literature such as Cowey,[3] believes that visual perception can occur unconsciously—obviously, as this is a central to the phenomenon of blindsight. So, whether something is visual or not, cannot be decided introspectively. Were we to argue that such decision was a purely introspective matter, we would not be able to decide whether an unconscious perception was visual or something else. Consequently, again, we need only one criterion (or set of criteria) to decide whether or not a representation is visual. That is, the same criterion (or set of criteria) is used across cases of conscious and unconscious perception.

Unconscious visual perception is established whenever a subject is able to react to a visual stimulus, according to Overgaard and Grünbaum.[49] Consequently, a visual process is one in which a subject at some level reacts to something visual. From this argument, it should follow that if there is any kind of preserved conscious experience in blindsight subjects caused by visual stimuli, as all or most seem to agree, those experiences should be conceived of as visual. Even in the case that a subject has experiences usually associated with tactile (or some other kind of) perception: if the experience is the result of a visual processing, it is a case of visual perception with a distorted, gradual, or transformed kind of conscious experience.

CONCLUSION

As had been repeated here and elsewhere, blindsight is a controversial topic with disagreeing interpretations. For this reason, it is difficult if not impossible to give one very clear conclusion.

It seems clear from a wealth of experiments that people, if not animals, with lesion to primary visual cortex have distorted or changed experiences of seeing while at least some visual functions are preserved.

Some will argue that it seems less clear whether blindsight is fully blind. Some experiments have found that at least a few blindsight subjects, when using a systematic approach to subjective reports, describe vague experiences when they give correct reports about stimuli. As this has not been found, nor tested, in all blindsight patients, one might be tempted to conclude that there are different types of blindsight.[50] However, while famous blindsight patients have reported that they never have any experiences in their 'blind parts', elsewhere and under different conditions the same patients have reported the opposite.

One conclusion that seems in line with current empirical findings is the suggestion that 'blindsight' is a condition in which some level of preserved visual abilities correlate with severely degraded, abnormal visual experiences.[14] At least, with this type of interpretation, none of the existing empirical findings is impossible to explain or integrate.

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