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Author(s): Michael S. Gazzaniga, Robert Fendrich, C. Mark Wessinger
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Blindsight Reconsidered

Michael S. Gazzaniga, Robert Fendrich, and C. Mark Wessinger

In subhuman primates, the major visual pathway projects from the retina to primary (striate) visual cortex. However, monkeys with striate lesions are not only able to localize objects in space, but also able to carry out color, luminance, orientation, and pattern discriminations.[1] These abilities appear to depend on the integrity of a secondary visual pathway, which projects from the retina to the superior colliculus, and then to extrastriate visual cortex.

Does this secondary visual pathway operate in humans? A growing literature has argued that this may be the case. Abilities ranging from simple detection to the extraction of semantic content have been attributed to a human extrastriate visual pathway. Weiskrantz coined the term *blindsight* to describe these residual abilities, because they occur although subjects deny that they actually see the stimuli to which they are responding.[2]

Ever since the original report of the phenomenon, philosophers, psychologists, and neuroscientists have been fascinated with blindsight. The original reports were intriguing and sensible. Because these activities went on outside the realm of consciousness, it looked as though an aspect of the silent dimension of cognitive life had been tapped. The unconscious was now explorable in scientific terms. In addition, visual scientists were excited because various subcortical and parallel pathways and centers could now be studied in the human brain.

As the early reports settled in, our laboratory began to examine related issues in other types of patients. Patients with intact visual cortex but neglect (i.e., a tendency to fail to acknowledge stimuli in the visual field opposite a damaged hemisphere) due to parietal lobe lesions were asked to judge if two lateralized visual stimuli, one appearing in each visual field, were the same or different. (For both eyes, the left visual field projects to the right visual cortex, and the right visual field projects to the left visual cortex.) Subjects were able to perform this task. However, when they were questioned as to the nature of the stimuli after a trial, they could easily name the stimulus in the right visual field but denied having seen the stimulus presented in the neglected left field.[3]

We observed another curious finding in split-brain patient J.W. In a simple two-choice task, his right hemisphere was able to program the left hemisphere for a spoken or written response indicating which of two stimuli had been presented to the right hemisphere, or left visual field. However, in a subsequent experiment, the left hemisphere could not use a pointing response to identify which of two stimuli in the right visual field matched the stimulus in the left visual field.[4] Thus, the left hemisphere did not know the identity of the stimulus presented to the right hemisphere. It seemed that the verbal responses could occur in the absence of conscious awareness of the stimuli.

Data from split-brain patients have also shown that subcortical systems such as the superior colliculus can mediate the transfer of visual information between the cerebral hemispheres. Early studies of spatial attention indicated subcortical mechanisms would allow cues presented to one hemisphere to direct spatial attention in the other. Some preliminary studies even provided indications of interhemispheric semantic priming (i.e., semantic facilitation of a right-visual-field stimulus by the prior presentation of a left-field stimulus).[5]

In the light of reports of blindsight, it hardly seemed surprising that subjects could make use of visually presented information not accessible to consciousness. Subcortical networks with their interhemispheric connections provided a plausible anatomy to explain the behavioral results. In fact, it would be difficult to argue against the concept that perceptual decisions or cognitive activities routinely result from processes outside conscious awareness.

LIMITATIONS AND UNCERTAINTIES

As our studies progressed, however, the data failed to support the notion that higher order information interacts between the hemispheres following surgical section of the corpus callosum. When new reports of high-level hemispheric interactions following full commissurotomy (surgical section of the corpus callosum and anterior commissure)[6] prompted us to reexamine our split-brain patients carefully, we could find no interhemispheric interactions of this kind. This was the case even when we used stabilized images to permit extended stimulus presentations. Moreover, we could not reproduce our original findings on semantic priming, and have been forced to conclude that this report was in error.

Michael S. Gazzaniga is Director of the Center for Neuroscience at the University of California, Davis. **Robert Fendrich** is an Assistant Professor of Neurology at Davis, and **C. Mark Wessinger** is a graduate student in neuroscience there. Address correspondence to Michael S. Gazzaniga, Center for Neuroscience, University of California, Davis, CA 95616.

It has also become apparent that subcortical systems may not explain blindsight. For example, hemispherectomy patients (i.e., patients with one hemisphere surgically removed) who have limited residual vision in their blind field have been held up as evidence for subcortical mediation of residual vision.[7] However, the residual vision found in these patients may well be due to cortical reorganization, which might have occurred if the brain damage had taken place during prenatal or early postnatal development. Certainly, these patients do not demonstrate blindsight: They can generally report the phenomenal basis for their decisions when they perform above chance in visual tasks. G.Y., an extensively studied patient, also can be viewed as possibly having experienced cortical reorganization, because his traumatic injury to the left occipital lobe came early in life. Like the hemispherectomy patients, he is frequently aware of stimuli within his scotoma (i.e., blind patch). It should also be pointed out that, contrary to published reports that all striate cortex was missing, G.Y. has now been shown to have remaining striate cortex.[8]

Similarly, there is a need for caution in interpreting studies that demonstrate wavelength discrimination within scotomas. Such studies often make use of stimuli that are positioned close to areas of intact vision,[9] without controlling eye motions. In addition, large stimuli may be employed in such studies,[2] which increases the probability that areas with spared, but not fully functional (i.e., dysfunctional), islands of vision will be included in the visual field regions tested.

The possible inclusion of visual field regions that project to areas of surviving but dysfunctional cortex is also a problem with the classic blindsight case, D.B. Over the years, D.B.'s scotoma has receded from a full hemianopia (half-field blindness) to a partial lower left quadrantanopia (quarter-field blindness) with a peripheral rim of normal vision. Moreover, an area of partially preserved vision approximately 10° in diameter is embedded within the scotoma that remains. Thus, the extent of D.B.'s cortical damage appears to have been overestimated initially. Many of the studies on D.B. were conducted without monitoring or controlling eye movement, so that one must simply have faith that stimuli were placed properly.[2]

Finally, the preliminary mapping of a patient's visual fields is normally carried out with techniques that test for the detection of a stimulus with a simple "yes" response. As Campion and his colleagues[10] pointed out, this procedure assures the fields are vulnerable to criterion effects (especially failures to respond when uncertain), so that the true sizes of scotomas are likely to be overestimated. When such assessments are followed by criterion-free, two-alternative forced-choice measures of residual function, it is not surprising that visual capacities are found in regions where they remained unreported during the initial visual field testing, or perimetry.

In the early 1980s, Holtzman,[11] in our lab, began to study blindsight per se. Accurately examining visual capacities following cortical damage is difficult. Conventional manual perimetric methods lack efficiency. Also, they often yield artifactual detections because of unstable observer fixation, which allows the target to stray into functioning parts of the visual field.[12] In our lab, we have made use of a purkinje image eyetracker, which provides very stable, high-resolution information on a subject's eye position. This information allows us to compensate for eye position instabilities, so we can present stimuli precisely within the scotoma.

We first studied a 34-year-old woman with a left hemianopia subsequent to surgery. Magnetic resonance images of her visual cortex revealed an occipital lesion that ablated primary visual cortex, but clearly spared prestriate regions as well as the colliculus. If blindsight is based on subcortical function, then these intact areas should have been able to support many of the blindsight phenomena commonly reported. However, although this subject performed accurately when required to localize targets by looking at them in her perceptually intact right visual field, her performance did not exceed chance levels for stimuli in her blind left visual field. These results support the notion that localization of stimuli requires an intact geniculostriate system (the projection from the lateral geniculate nucleus to the striate cortex).

IMPLICATIONS OF RECENT PROGRESS

Recently, we began to reexamine blindsight armed with a newly acquired image stabilizer, which allows us to keep images steady on the retina despite the observer's eye motions, and an interesting patient. C.L.T. is a robust, 55-year-old outdoorsman who suffered a right occipital stroke 6 years ago. Magnetic resonance images were used to assess the extent of this patient's lesion. They revealed a lesion that includes damage to the calcarine cortex, although some tissue in the region of the calcarine fissure is spared, and the colliculus is intact.

Standard perimetry indicated C.L.T. had a left hemianopia with lower quadrant macular sparing. Using our more exacting methods, we replicated this finding, but found additional regions of residual vision. Specifically, using high-contrast retinally stabilized stimuli and an interval two-alternative forced-choice procedure (which requires the subject to report which of two temporal intervals contained the stimulus presentation), we found an isolated island of vision about 1° in diameter in the upper left quadrant of C.L.T.'s left visual field.[13] Because C.L.T. reports no awareness of stimuli presented to this island, his vision at this location is blindsight. The retinal regions surrounding this island are totally blind. This residual vision is restricted to a very small retinal region, so the likely explanation is a corresponding remnant of spared striate cortex, rather than a more general secondary visual system.

Thus, before one can assert that blindsight is due to subcortical or extrastriate structures, one must first be extremely careful to rule out the possibility of spared striate cortex. When sufficiently careful mapping is carried out within a scotoma, regions of vision that would almost certainly go undetected with conventional perimetry can be found. We have continued to examine additional patients and have now identified other patients with islands of residual vision.

This aspect of our recent work, however, speaks more to issues in the visual sciences than to the more integrative questions about the relationship of sensation and perception to conscious awareness. Because it is common to find subjects remain largely unaware of their capacities in human performance tasks, this latter issue continues to be of considerable interest.

PERFORMANCE OUTSIDE CONSCIOUS AWARENESS

Blindsight demonstrates vision outside the realm of conscious awareness. This point has been taken as support for the view that perception can occur in the absence of sensation,[14] because sensations are presumed to be experiences of impinging stimuli. Advocates of this view have argued that sensations are processed by primary visual cortex, but attribute blindsight to alternative visual processing pathways. But is this formulation necessary or even plausible?

It is commonplace to design demanding perceptual tasks in which nonneurologic subjects routinely report low confidence values for tasks they are performing above chance. However, it is not necessary to propose secondary visual systems to account for such data because the primary visual system is intact and fully functional.

As previously noted, it is also the case that patients with parietal lobe damage but spared visual cortex can carry out perceptual judgments outside conscious awareness. These subjects can compare two stimuli, although they deny awareness of one of them. The failure of these patients to consciously access the information they use to compare the stimuli should not be attributed to processing within a secondary visual system because their geniculostriate pathway is still intact.

Many other examples can be found of phenomena involving, as Block says, impaired or nonexistent conscious access to brain events.[15] The vast staging for human mental activities happens largely without monitoring. It is to be expected that this situation can be identified in various experimental venues.

It is important to note that blindsight has been documented in a relatively small number of patients. An initial inspection of the literature conveys the impression that blindsight is a common phenomenon, but many of the reports are based on a few select patients. Two cases have provided a wealth of reports: D.B., who has been studied extensively by Weiskrantz and colleagues,[2] and G.Y., who has been studied by a number of investigators.[16] Studies employing wavelength manipulations have relied on three cases with incomplete visual field defects due to damage to visual cortex.[9] The overall rarity of the phenomenon is underscored by two group studies of 20 and 25 patients, respectively.[17] In these studies, there were indications of blindsight in only 20% of the subjects.

Nonetheless, the study of blindsight does afford important insights. First, it underlines a general feature of human cognition: specifically, that many perceptual and cognitive activities can and do go on outside the realm of conscious awareness. However, our studies suggest this feature need not be dependent on subcortical or secondary processing systems.

Second, the careful study of both primates and humans with lesions of the primary visual cortex serves as a reminder of the important differences in the brain organization between species. It is clear that such lesions in the monkey allow for far more visual capacity then do similar lesions in the human.

Finally, patients with residual visual capacities become an interesting source for studying the possible modular nature of visual processes. In our recent study,[13] the spared islands supported some visual capacities and not others. While one island could process form and color information, it was not able to elicit a correct eye movement response. Other points of residual capacity were able to elicit eye movement responses but were unable to carry out pattern discriminations. These intriguing dissociations need further study.

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When What Meets Where

Maggie Shiffrar

How does the visual system determine in which direction an object moves? This question has fascinated generations of researchers because it encompasses so many of the fundamental issues in psychology. One of these concerns how the human perceptual system uniquely solves patterns of stimulation having an infinite number of possible interpretations. For example, in the case of vision, a single two-dimensional projected image is often consistent with an infinite number of different three-dimensional physical objects. Nonetheless, human observers are able to uniquely interpret such underdetermined images. What enables observers to systematically interpret inherently ambiguous visual images?

Maggie Shiffrar is an Assistant Professor in the Department of Psychology and the Center for Molecular & Behavioral Neuroscience at Rutgers University. Address correspondence to Maggie Shiffrar, Center for Molecular & Behavioral Neuroscience, 197 University Ave., Rutgers University, Newark, NJ 07102; e-mail: mag@cortex.rutgers.edu.

Many researchers have argued that the visual system uses constraints to limit the number of possible interpretations of a projected image.[1,2] A constraint can be defined as an assumption or prior knowledge about the nature of the physical world. A visual system reduces the number of possible image interpretations by rejecting any interpretation inconsistent with the system's previously defined constraints. Most current models of the visual system describe it as a multilayered, richly interconnected hierarchical structure.[3] Because so much information is lost in the imaging process, constraints are required at many different levels within the visual system. Some constraints are needed during the earliest stages to interpret small, local regions of an image. These low-level constraints play a role in the analysis of relatively small object segments or features. An edge detector that analyzes small parts of an image is one example of a low-level visual constraint. Later stages in the visual system must combine the outputs of the earlier, spatially restricted analyses. Object-based constraints may be applied during some of these later stages so that information regarding entire objects can be recovered uniquely. Object permanence (i.e., the tendency to assume the continued existence of an object even when it disappears momentarily) is an example of a higher level, object-based constraint that the visual system appears to use in the interpretation of motion.[1]

The proposal that the visual system uses a hierarchy of various constraints leads to numerous questions. How do constraints interact within and across levels of analysis? Are some constraints applied to all images and others reserved for particular classes of images? To address these questions, my colleagues and I have constructed dynamic stimuli that place different constraints in conflict with one another. By examining how people interpret these images, we can ascertain how visual constraints are organized, invoked, and applied. The purpose of this article is to examine when object-based constraints control the interpretation of moving images. I begin with a discussion of how low-level, feature-based motion constraints compete with higher level, object-based motion constraints. I then examine the conditions under which

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