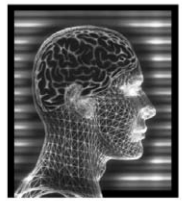

Agnosia

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GLOSSARY

alexia An acquired condition, usually as a result of brain damage (such as follows strokes in adults), marked by an impairment in reading, in which reasonable vision, intelligence, and most language functions other than reading remain intact.

apperceptive agnosia A form of visual agnosia in which a person cannot reliably name, match, or discriminate visually presented objects, despite adequate elementary visual function (visual fields, acuity, and color vision).

associative agnosia A form of visual agnosia in which a person cannot use the derived perceptual representation to access stored knowledge of the object's functions and associations but is able to copy and match the drawing even though unable to identify it.

Balint's syndrome Agnosic syndrome that results from large bilateral parietal lesions and is composed of three deficits: (i) paralysis of eye fixation with inability to look voluntarily into the peripheral visual field, (ii) optic ataxia, and (iii) disturbance of visual attention such that there is neglect of the peripheral field.

dorsal simultanagnosia An inability to detect more than one object at a time, with difficulty shifting attention from one object to another.

dorsal stream The stream of cortical visual projections from primary visual cortex to posterior parietal cortex, concerned primarily with the visual control of action and representation of spatial information.

inferotemporal cortex Inferior surface of the temporal lobe that is particularly important for object recognition.

Klüver–Bucy syndrome A group of impairments, including visual agnosia, resulting from bilateral damage to the temporal lobes.

optic aphasia A condition in which a person cannot name a visually presented object, despite being able to indicate the identity of the object through gesture and to sort the visual stimuli into categories.

prosopagnosia A form of visual agnosia in which a person cannot recognize faces, despite adequate elementary visual function (visual fields, acuity, and color vision).

ventral simultanagnosia A reduction in the ability to rapidly recognize multiple visual stimuli, such that recognition proceeds in a part-by-part fashion.

ventral stream The stream of cortical visual projections from primary visual cortex to the inferotemporal cortex, concerned primarily with representing the identity of stimuli by such characteristics as shape and color.

Visual agnosia is a disorder of recognition confined to the visual realm, in which a person cannot arrive at the meaning of some or all categories of previously known visual stimuli despite normal or near-normal visual perception and intact alertness, intelligence, and language. This article takes a multidisciplinary approach in discussing this impairment and considers clinical and neurological studies in humans as well as neurophysiological data in nonhuman primates.

I. CASE STUDIES

JW is a relatively young man, in his early forties, who, despite many preserved cognitive abilities, fails to recognize many common objects. In August 1992, JW suffered a severe cardiac event while exercising and was subsequently anoxic. A computed tomography (CT) scan revealed multiple hypodensities in both occipital lobes with minor hypodensities in his right parietal lobe. Although JW has normal visual acuity as well as intact color and motion perception, Behrmann and colleagues have shown that he recognizes approximately 20% of black-and-white line drawings and a slightly higher percentage of color pictures. He is almost totally unable to recognize photographs of famous people. He is poor at copying simple line drawings presented to him (Fig. 1), at matching rectangles and squares of various dimensions, at simple shape detection (e.g., deciding that an "X" is present among a background of visual noise), and even at detecting symmetry in a visual image. Despite these impairments, he is able to recognize objects well from tactile/haptic input and from definitions that are read to him. These findings suggest that his long-term knowledge of objects is preserved. This is further confirmed by his ability to generate visual images in his "mind's eye" and to describe those in detail. Needless to say, this impairment significantly limits his ability to interact with objects and his world. Whereas JW was the owner of a hardware computer company (and had a master's degree in computer science), currently he works as a volunteer and provides instruction on computer use to people who are blind.

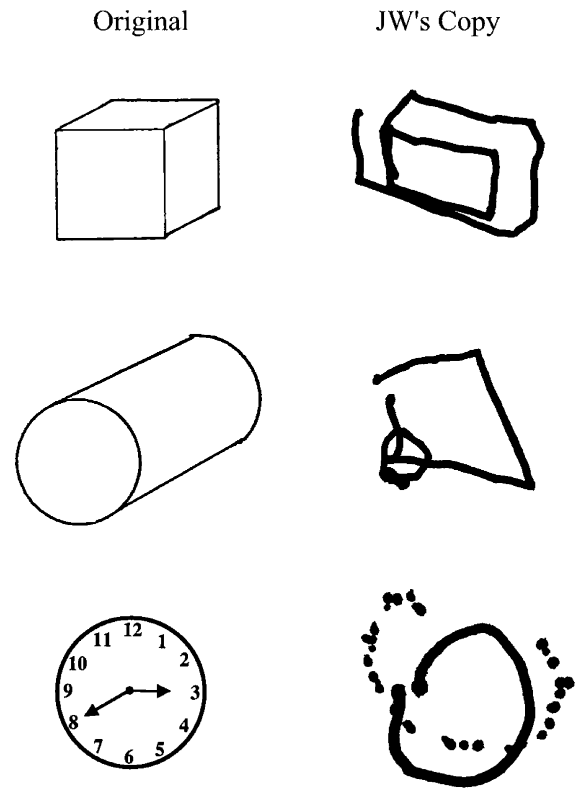

Figure 1 Patient JW's copies of simple line drawings.

CK, like JW, is impaired at recognizing objects and has been studied extensively by Behrmann, Moscovitch, and Winocur. CK sustained brain damage in a motor vehicle accident in 1988; he was struck on the head by the side mirror of a truck while he was jogging. Except for a hint of bilateral thinning in the occipitotemporal region, no obvious circumscribed lesion is revealed on magnetic resonance imaging (MRI) or CT scan. This may not be surprising given that his lesion was sustained via a closed head injury which often results in shearing of axons or more microscopic neuronal damage. Despite his deficits, CK functions well in his life; he has a responsible managerial job and makes use of sophisticated technology that allows him to translate written text into auditory output.

When asked to identify line drawings, CK misrecognized a candle as a salt shaker, a tennis racquet as a fencer's mask, and a dart as a feather duster, presumably because of the feathers on the end (Fig. 2). As illustrated by these examples, CK, like JW, is clearly not blind. However, despite his intact visual acuity, he fails to recognize even familiar and common visually presented objects. This deficit holds irrespective of whether the objects are drawn in black-and-white on a piece of paper or whether they are shown in slides or even as real three-dimensional objects, although the addition of information such as color and surface texture does assist recognition to some extent.

CK, like JW, can also use tactile/haptic information to recognize objects; he was perfectly able to recognize a padlock and a paper clip by touch alone. CK can also provide detailed definitions for an object whose name is presented to him verbally; for example, he defined a pipe as "a long cylindrical hollow object to convey liquid or gas" and a card of matches as "a cardboard container containing long sticks or matches which are struck against cordite." These definitions clearly demonstrate that his deficit is not attributable to a failure to name objects nor a loss of semantic knowledge.

CK is unable to read and, although he writes flawlessly, he cannot read his own writing presented to him at a later point in time. CK's hobbies have also

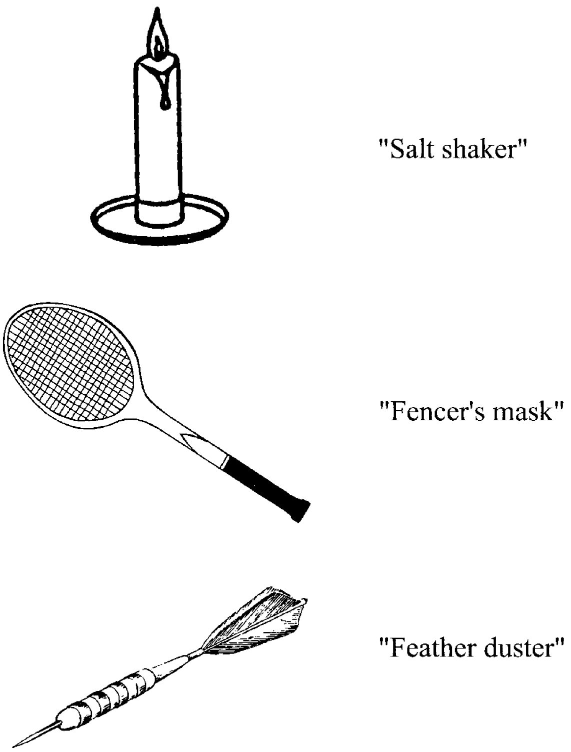

Figure 2 Line drawings misnamed by patient CK.

been affected; he is no longer able to design complex configurations of his large plastic soldier collection or visually differentiate airplanes, a domain in which he had rather extensive knowledge premorbidly.

II. BACKGROUND

Despite the behavioral differences between JW and CK, they have a dramatic deficit: They are unable to recognize even common, familiar objects—a disorder termed "agnosia" by Sigmund Freud (coined from the Greek "without knowledge"). Visual agnosia is a disorder of recognition, in which a person cannot arrive at the meaning of some or all categories of previously known visual stimuli, despite normal or near-normal visual perception and intact alertness, intelligence, and language. Despite the visual recognition problems associated with agnosia, there is normal recognition of objects through modalities other than vision (touch, auditory, and verbal definitions or description of their function), which suggests that the deficit is not simply a difficulty in retrieving names or in accessing the necessary semantic information. Visual recognition has been more extensively studied than recognition in other modalities, although similar deficits have been observed in patients with auditory (auditory agnosia) or tactile (tactile agnosia) deficits.

The traditional view of agnosia as a specific disorder of recognition has undergone considerable challenge in the past, with critics contending that all visual agnosias can be explained by a subtle alteration in perceptual functions likely accompanied by a generalized intellectual deterioration. Despite this early skepticism, there is now widespread acceptance of this disorder as a legitimate entity and detailed case studies have been concerned with characterizing both the underlying mechanisms that give rise to this disorder and the overt behaviors.

Lissauer was the first to classify visual object agnosia into two broad categories: apperceptive "mindblindness" and associative mindblindness. These impairments were evaluated by requiring patients to (i) describe the formal features of a pattern, (ii) reproduce it by drawing, and (iii) recognize it among similar alternatives. Using Lissauer's classifications, a person with apperceptive agnosia is assumed to be impaired at constructing a perceptual representation from vision and subsequently is unable to copy, match, or identify a drawing. In contrast, a person with associative agnosia is one who cannot use the derived perceptual representation to access stored knowledge of the object's functions and associations but is able to copy and match the drawing even though he or she is unable to identify it.

Recent neuropsychological accounts by Humphreys and Riddoch as well as by Warrington and colleagues and computational accounts such as that of Marr and colleagues have sought to extend Lissauer's dichotomy for two reasons. The first reason is the growing understanding that visual object recognition comprises many distinct steps not captured by the simple dichotomy. For example, it has been suggested that apperceptive processes include encoding the primitive dimensions of shape and segmentation of figure from ground. Associative processes may also be subdivided to include access to stored visual knowledge of objects, followed by access to stored associative and functional (semantic) knowledge from the description derived from the image. The second reason for further differentiation of the underlying processes, and the lesion types, derives more fine-grained neuropsychological analysis. One such example is of patients who show impaired access to knowledge of associative and functional properties of the object but have well-preserved understanding of the object's shape, as reflected in a high-complexity object decision task (differentiating real objects from novel objects that are composed of parts of real objects). Other patients perform relatively poorly at object decision but are still able to carry out many high-level perceptual tasks, such as matching objects across different viewpoints and sorting pictures into basic categories. These developments have forced a further refinement of our understanding of visual processing and the types of breakdown that are possible. Despite the simplicity of Lissauer's dichotomy and its clear inadequacy, it provides a coarse framework that has proved useful in describing agnosia, as illustrated in the book *Visual Agnosia* by Farah. Following Farah, we adopt this dichotomy as a starting point and describe these two forms of agnosia, we also provide a detailed discussion of the patients described previously and the implications of such disorders for our further understanding of visual object recognition. Before we continue our exploration of these types of agnosia, however, we first identify the underlying neuromechanisms responsible for this visual perceptual processing.

III. NEUROANATOMY

Milner and Goodale proposed that the two prominent cortical visual pathways that have been identified in the primate brain (after Mishkin, Ungerleider, and Macko) are each involved in two very different processes. The underlying mechanisms in the ventral stream, which projects from primary visual cortex to the inferotemporal cortex (via many routes involving areas V2, the ventral portion of V3, V4, and TEO) are thought to be involved in visual perception, whereas the dorsal stream, which projects from primary visual cortex (and the superior colliculus via the pulvinar) to the posterior parietal cortex is thought to be involved in the visual control of action (Fig. 3). Both streams are thought to process information about object features and their spatial locations, but each stream uses this visual information in different ways. The transformations carried out by the dorsal stream deal with moment-to-moment information about the location and orientation of objects and thereby mediate the visual control of skilled actions, such as manual prehension, directed at those objects. In contrast, visual information is transformed in the ventral stream to deliver the enduring characteristics of objects and their relations, permitting the formation of long-term perceptual representations of the world. Such representations play an essential role in the recognition and identification of objects and enable us to classify objects and events, attach meaning and significance to them, and establish their causal relations. Such operations are essential for accumulating a knowledge base about the world.

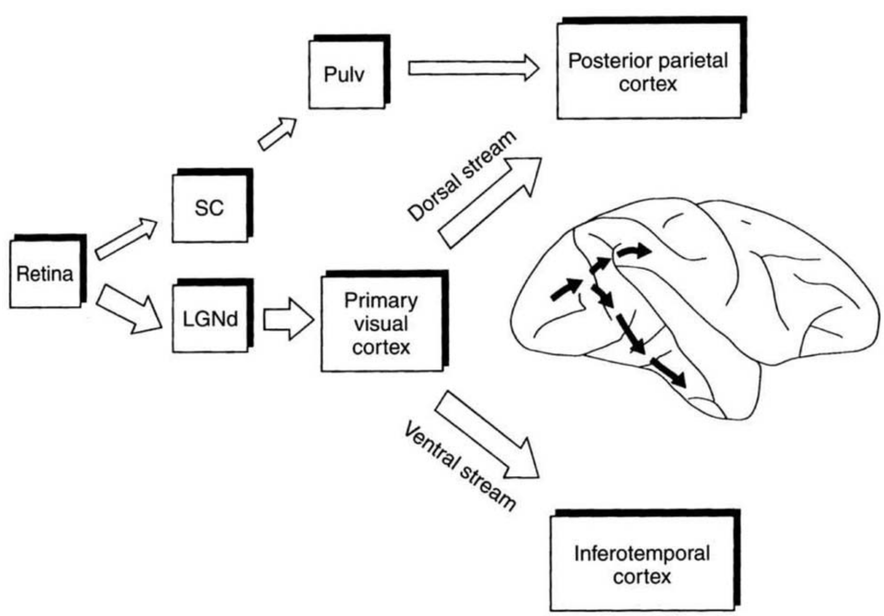

Figure 3 Diagram of the major routes leading from the retina into the dorsal and ventral streams. LGNd, lateral geniculate nucleus, pars dorsalis; Pulv, pulvinar; SC, superior colliculus. Reprinted from *Current Biology* **4**(7), Goodale, M. A., Meenan, J. P., Bulthoff, H. H., Nicolle, D. A., Murphy, K. J., and Racicot, C. L., Separate neural pathways for the visual analysis of object shape in perception and prehension, pp. 604–610, copyright 1994, with permission from Elsevier Science.

Many of the cells in inferotemporal cortex, the terminus of the ventral stream, respond best to complex visual stimuli, such as hands and faces; in particular, the more anterior parts of the inferotemporal cortex are remarkably selective in their responses to object attributes. The receptive field of virtually every cell in the inferotemporal (IT) cortex, a complex of areas lying ventrally below the superior temporal sulcus, including various subdivisions of area TE along with area TEO, includes the foveal region, where fine discriminations are made. These cells also have large receptive fields that allow for generalization across the entire visual field and for coding the intrinsic features of an object independent of its location. The critical features that activate cells in the anterior IT cortex are moderately complex and can be thought of as partial features common to images of several different natural objects. There are also neurons in the IT cortex that demonstrate properties consistent with object constancy in that they remain selectively responsive to a visual stimulus despite changes in stimulus viewpoint, retinal image size, or even color. Thus, the ventral stream is uniquely set up to process visual information into perceptual representations to which meaning and significance can be attached and stored. Damage to the ventral stream is believed to cause the disturbances of object recognition that are characteristic of visual agnosia.

Evidence for this derives from nonhuman primate work, in which large bilateral resections of the temporal lobe result in a form of visual agnosia, Klüver–Bucy syndrome. Lesions of the IT cortex impaired the monkey's ability to identify objects when the discriminations required use of color, pattern, or shape. These monkeys had difficulty using vision to learn associations with objects and could no longer recognize objects or distinguish between objects on the basis of their visual dimensions. They were unable to distinguish food from nonfood objects using vision alone and were unable to learn new visual discriminations between patterns for food reward. Although they incessantly examined all objects in sight, these animals recognized very little and often picked up the same item repeatedly. Klüver–Bucy syndrome can also be achieved with just the removal of IT but, like human visual agnosia, the IT monkey's recognition deficits cannot be explained by "low-level" sensory impairments since large bilateral lesions of IT have been found to have no residual effect on visual acuity.

Recent functional neuroimaging studies of regional blood flow in normal human subjects have revealed many different visual areas beyond primary visual cortex that appear to correspond to those in the ventral stream of the monkey brain that are specialized for the processing of color, texture, and form differences of objects. These studies have shown that face-matching tasks involve the occipitotemporal regions, detection of shape activates regions along the superior temporal sulcus, and the ventral region of the temporal lobe, and the perception of color is associated with activation of the lingual gyrus (V4).

IV. APPERCEPTIVE AGNOSIA

Individuals with apperceptive agnosia, such as patient JW, have profound difficulty recognizing and naming line drawings; their ability to recognize, copy, or match simple shapes as well as more complex objects is severely impaired. However, their elementary visual functions, such as acuity, brightness discrimination, and color vision, are relatively preserved, along with reasonable sensory and semantic memory functioning in the visual domain. These patients have normal visual fields and can maintain fixation on a visual target. The fundamental deficit involves an inability to process features, such that they are not fully available for developing a percept of the overall structure of an object.

One of the classical cases of apperceptive agnosia, described by Benson and Greenberg, was thought to be blind for several months following carbon monoxide-induced anoxia until he was seen successfully negotiating his wheelchair down a passage. Testing revealed that his fields were full to a 3-mm stimulus, that he could reach accurately for fine threads placed on a piece of paper and detect small changes in size, luminance, and wavelength, and that he was aware of small movements. Despite these fundamental abilities, he was unable to recognize objects, letters, or numbers and was unable to discriminate between any visual stimuli that differed only in shape.

Even though recognition of real objects is also impaired in these individuals, it is often better than recognition of line drawings; identifications of objects are typically inferences, made by piecing together color, size, texture, and reflectance clues. These individuals can often make accurate guesses about the nature of objects from such cues, such as the shininess of the glass and metal on a salt shaker or the color of an apple. A striking feature of this disorder is that many patients spontaneously use quite laborious and time-consuming tracing strategies of the hand or head to aid in the recognition of visual objects. These strategies, although helpful, may not always produce an accurate result because one needs a reasonably good visual image in the first place for the purposes of tracing.

Apperceptive agnosia corresponds to the breakdown at the stage at which the sensory features of the stimulus are processed and its structural description is achieved—a relatively early stage of the visual recognition networks in the human equivalent of the ventral stream. The deficit appears to be at the level of shape or form discrimination. Some apperceptive agnosic patients are more impaired at perceiving curved than straight lines. JW, for example, is poor at deciding whether two line features are the same or different unless their orientations are very different. He also does not show ''popout'' of a target that differs from the background distractors if the difference is one of curvature or orientation (unless the differences are very great). Some patients may also fail to achieve perceptual constancy, interpreting a circle as an ellipse.

Interestingly, at least one apperceptive agnosic patient, DF, reported in the literature by Milner and Goodale appears to have implicit knowledge of object attributes that is not available for explicit report. As a result of carbon monoxide-induced anoxia, DF sustained damage to her occipital lobes bilaterally that extends into ventral occipital and dorsal occipitoparietal regions, while largely sparing primary visual cortex. Even though DF's ''low-level'' visual abilities are reasonably intact, she can no longer recognize common objects on the basis of their form or even the simplest of geometric shapes. Nevertheless, despite her profound inability to perceive the size, shape, and orientation of visual objects, DF can direct accurate and well-formed grasping movements, indistinguishable from those shown by normal subjects, toward the very same objects she cannot identify or discriminate. It has been argued that this intact visuomotor function is mediated by relatively intact parietofrontal cortical mechanisms (accessed via the dorsal stream) in DF, which continue to operate efficiently despite severely damaged occipitotemporal (ventral stream) structures. At this point, it is worth noting that DF also appears to have implicit knowledge of visual attributes even though she appears not to have this information available to her when tested directly. The critical evidence comes from studies that show that DF is influenced by the McCullough effect. This is a color aftereffect that is contingent on the orientation of grating patterns. When shown white-and-black line gratings in horizontal or vertical orientations, DF is poor at reporting orientation explicitly. However, after she was adapted to a green-and-black vertical grating alternating with a red-and-black horizontal grating, she reported seeing color on white-and-black gratings with the horizontal subcomponent appearing greenish and the vertical component appearing pinkish. As in control subjects, the effect was strongly dependent on the congruence of the angles in the testing and adaptation phase. In a follow-up, DF revealed a preserved McCullough effect with oblique gratings, indicating more fine orientation discrimination ability than simply vertical and horizontal.

The neurological damage in apperceptive agnosia tends to be diffuse and widespread and can involve damage to the posterior regions of the cerebral hemispheres, involving occipital, parietal, or posterior temporal regions bilaterally. This damage is often the result of cerebral anoxia, where a lack of oxygen to the brain produces neuronal death in ''watershed'' regions or regions lying in the border areas between territories of different arterial systems. Carbon monoxide-induced anoxia not only produces multifocal disseminated lesions but also affects the interlaminar connections between neurons. Mercury poisoning, which is also known to give rise to apperceptive agnosia, affects the white matter, thereby compromising connections between neurons rather than the neurons themselves.

V. SIMULTANAGNOSIA

A person with simultanagnosia can perceive the basic shape of an object but is unable to perceive more than one object, or part of an object, at a time. Thus, these patients appear to have limited ability to process visual information in parallel, although they are relatively good at identifying single objects. Farah distinguished between two forms of simultanagnosia according to whether the patients had lesions affecting the dorsal or ventral visual stream. Each is discussed in turn here.

Although a person with dorsal simultanagnosia is able to recognize most objects, he or she generally cannot process more than one at a time, even when the objects occupy the same region of space. These individuals often have counting deficits and their descriptions of complex scenes are slow and fragmentary. The underlying impairment in dorsal simultanagnosia appears to be a disorder of visual attention so severe that these individuals cannot explicitly report perceiving the unattended objects. Dorsal simultanagnosia is often observed in the context of Baliant's syndrome, is accompanied by oculomotor deficits and optic ataxia, and results from a bilateral parietooccipital lesion.

Individuals with apperceptive agnosia and those with dorsal simultanagnosia share many characteristics. In some cases, they may act effectively blind, being unable to negotiate visual environments of any complexity, and their perception appears to be piecemeal and confined to a local part or region of the visual field. The piecemeal nature of their perception, however, differs in significant ways. In apperceptive agnosia, only very local contour is perceived, whereas in dorsal simultanagnosia whole shapes are perceived, but only one at a time. Individuals with apperceptive agnosia use color, size, and texture to guess at objects but cannot use shape information. In contrast, individuals with dorsal simultanagnosia have intact shape perception. In contrast to apperceptive agnosia, the deficit in dorsal simultanagnosia appears to be attention related rather than shape related.

A person with ventral simultanagnosia usually has a lesion to the left inferior temporooccipital region. Although such a patient is generally able to recognize a single object, he or she does poorly with multiple objects and with single complex objects, irrespective of their size. Although they cannot recognize multiple objects, they differ from individuals with dorsal simultanagnosia in that they can perceive multiple objects. These individuals can count scattered dots and, if given sufficient time, can also recognize multiple objects. They respond slowly and often describe explicitly individual elements of the picture without appreciating the whole scene. This is also true in reading, and these patients are classified as letter-by-letter readers because they only recognize one letter of a word at a time, and hence show a linear relationship between reading speed and the number of letters in a word.

A recent reconceptualization of simultanagnosia by Humphreys and colleagues suggests that the two different forms are well characterized in terms of impairments in constructing different forms of spatial representations. Although those with ventral lesions are limited in the number of parts of an object they can represent, those with dorsal lesions are limited in the number of separate objects they can represent.

VI. HIGHER ORDER APPERCEPTIVE DEFICITS

Many patients have been identified who, although still classified as having apperceptive agnosia, appear to have some residual visual processing ability and can copy and match objects to some degree. These patients have object recognition difficulty under challenging conditions and do somewhat better in more optimal conditions. For example, they are impaired at recognizing objects under poor lighting conditions when shadows are cast, creating misleading contours. An additional manipulation that proves difficult for these patients is recognition of foreshortened or degraded objects. They are also poor at recognizing objects from unusual viewpoints or unconventional angles relative to more standard viewpoints. The classification of these patients is unclear because there is ongoing debate regarding the mechanisms that give rise to such deficits and whether, indeed, these deficits arise from a common source. Warrington and colleagues argued that the failure to identify objects from unusual but not conventional views is consistent with a deficit that occurs once sensory information has been processed and is attributable to a problem in categorizing two instances of the same stimulus as identical. Some patients appear to be impaired at deriving viewpoint-independent representations, despite the fact that they are able to construct a viewpoint-dependent representation. This distinction between viewpoint-dependent and -independent representation parallels the distinction made by Marr in his well-known theory of vision.

VII. ASSOCIATIVE AGNOSIA

Unlike apperceptive agnosia, a person with associative agnosia can make recognizable copies of a stimulus that he or she may not recognize subsequently and can also successfully perform matching tasks. Teuber elegantly referred to this deficit as "perception stripped of meaning." As in the case of apperceptive agnosia, recognition is influenced by the quality of the stimulus and performance on three-dimensional objects is better than on photographs, and performance on photographs is better than on line drawings. The recognition deficit appears to result from defective activation of information pertinent to a given stimulus. There is a failure of the structured perception to activate the network of stored knowledge about the functional, contextual, and categorical properties of objects that permit their identification. In effect, this is a deficit in memory that affects not only past knowledge about the object but also the acquisition of new knowledge. Unlike individuals with apperceptive agnosia, who guess at object identity based on color and texture cues, people with associative agnosia can make use of shape information. When these individuals make mistakes in object identification, it is often by naming an object that is similar in shape to the stimulus. For example, FZ, a patient of Levine, misidentified a drawing of a baseball bat several times. Interestingly, his answer differed on each occasion, referring to it as a paddle, a knife, or a thermometer.

Although these patients can copy drawings well, the drawings are not necessarily normal; the end product might be a fairly good rendition of the target but the drawing process is slow and slavish and they can lose their place if they take their pen off the paper since they do not grasp component shapes. As can be seen in Fig. 4, a copy of a geometric configuration by patient CK, an individual with associative agnosia, was reasonably good, although the process by which he copied indicates a failure to bind the contours into meaningful wholes.

One of the important claims of associative agnosia is that perception is intact and it is meaning that is inaccessible. Much effort has been directed at evaluating this claim and the general finding is that even patients with associative agnosia have some form of visual impairment. For example, LH, a well-known and thoroughly documented agnosic patient studied by Levine and Calvanio, was moderately impaired on several tests of perception. He was considerably slower than normal subjects in making rapid comparisons between shapes or in searching for a prespecified target figure. His performance was also poor on tasks that required him to identify letters that were fragmented or degraded by visual noise, relative to control subjects. Based on the findings from LH and other associative agnosic patients, it is clear that their perception is not normal. Although it may be considerably better than that of apperceptive agnosic patients, it is still impaired to some extent.

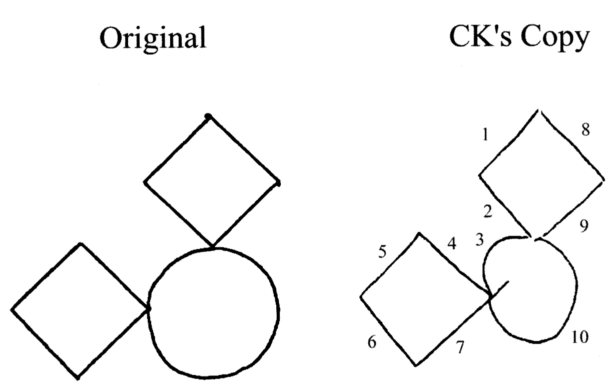

Figure 4 Patient CK's copy of a geometric configuration. The numbers assigned to his copy indicate the order in which the lines were drawn and show that he copies in a very literal fashion, failing to integrate lines 1, 2, 8, and 9 into a single shape.

The brain damage in associative agnosia is more localized than in apperceptive agnosia. Some cases appear to involve only unilateral damage to the occipital lobe and bordering posterior temporal or parietal lobe. The lesions are often more circumscribed, sometimes involving the left inferior longitudinal fasciculus, which connects fusiform gyrus to temporal structures, or the bilateral posterior hemispheric areas in posterior cranial artery territory.

VIII. INTEGRATIVE AGNOSIA

Lissauer's dichotomy makes provision for two main stages of processing, apperception and association. Object recognition, however, involves more than matching stimuli coded in terms of primitive features such as line orientation to stored knowledge. Instead, the spatial relations between the lines and features need to be coded, the object needs to be segregated from its ground, and parts of an object need to be related and integrated. These processes are typically thought of as serving intermediate-level vision. There have been several recent detailed reports of patients with deficits due to poor perceptual integration of form information ("integrative agnosia"). Patient HJA, studied by Riddoch and Humphreys, appears to oversegment identify objects piecemeal. For example, when presented with a paintbrush, HJA responded that "it appears to have two things close together or else you would have told me." CK's descriptions of errors reveal a similar pattern; he is able to perceive and report some part of the image but not the whole. Indeed, CK appears to oversegment the image, as illustrated in his copying performance. Whether or not integrative agnosia might previously have been considered an apperceptive or associative form of agnosia is difficult to determine. On the one hand, these patients appear not to be able to exploit Gestalt grouping principles, in which case the problem is closer to that of apperceptive agnosia. On the other hand, these patients perform well on standardized testing of perceptual processes, suggesting that they are more akin to associative agnosic patients. For example, these patients can discriminate between Efron shapes (squares and rectangles that have the same surface area but vary in aspect ratio) and can make orientation and size matching judgments at a normal level. Given the uncertainty of the classification, a separate category is obviously warranted.

The hallmark of integrative agnosia is an impairment in integrating elements, which are well detected, into a perceptual whole. For example, these patients do more poorly at recognizing overlapping objects than when the same objects presented nonoverlapping, presumably because of the difficulty in segregating and assigning boundaries in the former case. Counterintuitively, these patients perform better when the stimuli are silhouettes rather than line drawings. This finding suggests that the lines that usually enhance perception and add information to the display disrupted the patients' ability to recognize objects. This is likely a consequence of their inability to group elements into a whole and this process is less taxing in the case of silhouettes. These patients also do more poorly when the exposure duration of stimuli is limited. Finally, the performance of the patients improves under limited exposure duration. This is not surprising because it has been suggested that the segmental visual processing is done in a serial fashion and limiting the exposure of the items likely affects this adversely.

Because these patients are impaired at grouping, they appear to be oversensitive to segmentation cues and to parse stimuli inappropriately into parts. In fact, grouping and segmentation are likely two sides of the same coin, with the grouping impairment leading to piecemeal and fragmented image processing. The integrative agnosia deficit appears to affect a stage of visual coding intermediate between basic shape coding and visual access to memory representations, concerned with parallel perceptual grouping and the integration of parts into wholes. It is revealed most strikingly under conditions when segmentation or grouping are stressed.

IX. OPTIC APHASIA

Like agnosic patients, patients with optic aphasia have a modality-specific (visual) recognition deficit and can recognize objects from both auditory and tactile presentation. The critical distinction between agnosia and optic aphasia, however, is that optic aphasic patients can recognize objects. This is evidenced by their nonverbal identifications (e.g., through gesture) and their ability to sort a visual stimulus with other stimuli of the same category. Additionally, these patients are also not particularly sensitive to the visual quality of the stimulus and performance is approximately equivalent for object, photographs, and line drawings, unlike the case for associative agnosic patients. Another important distinction concerns the error types. The errors made by patients with optic aphasia are usually semantic in nature and hardly ever visual, whereas in associative agnosia the errors are primarily visual. One of the best studied patients by Lhermitte and Beauvois, Jules F., when shown a picture of a boot correctly gestured pulling on a boot but called it a hat. Optic aphasia patients also appear to make many perseverative errors, reproducing the error response from previous trials and sometimes producing ‘‘conduites d'approache’’ or progressive approximation to the target.

X. CATEGORY-SPECIFIC VISUAL AGNOSIA

For some patients with associative agnosia, recognition is not equally impaired for all categories of objects. Category-specific visual agnosia (CSVA) is a deficit in which the boundary between impaired and intact recognition can be approximately defined along the semantic criterion of biological vs nonbiological objects. In other words, these patients can show severely impaired visual recognition of objects from biological categories while recognition of most other categories is largely spared. For example, a patient may be able to recognize all manners of tools or artifacts but show marked difficulties in recognizing even the most common fruits or vegetables. CSVA is believed to be a semantic disorder, in which patients have problems associating the view of an object, in a specific category, with stored knowledge of its identity. The mechanisms underlying visual perception do not appear to have access to the semantic knowledge of certain categories of objects.

It has also been proposed that this dissociation may be the result of the recognition of living things depending on some specialized neural mechanisms that are not needed for the recognition of nonliving things. Evidence for this derives from the findings that CSVA for biological objects usually follows inferior-temporal damage. Moreover, recent studies have found that defective recognition of persons was associated with damage to right temporal regions, defective recognition of animals was associated with damage to the right mesial occipital/ventral temporal region and left mesial occipital region, and defective recognition of tools was associated with damage in the occipital–temporal–parietal junction of the left hemisphere. As we discuss later, these studies have helped to reveal the extent to which there is modular organization in the visual system.

XI. RELATIONSHIP BETWEEN VISUAL OBJECT AGNOSIA AND WORD AND FACE RECOGNITION

One of the interesting recent developments in our investigations of object agnosia concerns different forms of category specificity, but here the category refers to different forms of visual stimulus recognition, such as face and word recognition. The critical issue is whether agnosia can be restricted to object recognition or whether it is reflects a broader form of visual impairment. In an extensive review of the literature, Farah suggested that the latter is more correct and that because visual recognition procedures for objects, words, and faces are not neurally separated, not all pure forms of visual deficit are possible. This argument was based on the fact that some but not all patterns of dissociation have been observed between these three classes of stimuli. In particular, Farah argues that there have been no convincing reports of patients with visual object agnosia without alexia or prosopagnosia or with prosopagnosia and alexia without visual object agnosia. The failure to find these two patterns of deficit has been taken to suggest that, instead of there being independent and separate mechanisms subserving objects, words, and faces, there may be a continuum of recognition processes. At one end of this continuum is a more holistic or gestalt form of processing that is optimized for processing nondecomposable perceptual wholes, such as faces, and at the other end is a process that is optimized for processing multiple perceptual parts, such as letters of words. Object recognition may be mediated by either process depending on the nature of the stimulus and its perceptual characteristics. By this account, patients may be selectively impaired as a consequence of damage to one of these two processes. Thus, in its pure form, damage to the more holistic process will result in prosopagnosia in isolation, whereas damage to the more part-based processes will result in alexia in isolation.

An obvious claim of this account is that it should not be possible to observe a patient for whom the recognition of objects is impaired, in isolation, given that object recognition is subserved by one of the two other processes. Despite this interesting hypothesis, there have been several recent case studies that challenge it. Thus, for example, there have been several detailed studies of patients who have a selective deficit in object recognition with retained face and word recognition. The presence of such a pattern undermines the two-process account of visual recognition and is more consistent with a view in which there is neural differentiation between all types of visual stimuli. Whether this differentiation refers to the fact that different mechanisms are involved in encoding the three stimulus types or in accessing their stored knowledge remains unclear. The proposal that the three types of visual stimuli are differentiated to some extent is generally (although not perfectly) consistent with recent functional neuroimaging data that shows that different brain areas are activated for the different stimulus types. Thus, for example, word recognition is associated with an increase in cortical activation in the left medial extrastriate region, whereas face recognition is associated with increased activation in the right fusiform gyrus. Object recognition is a little more problematic. Although enhanced activity is observed in a host of regions in the left hemisphere and some in the right hemisphere, some of these activations appear to overlap those associated with face recognition and the extent to which there is some sharing of mechanisms for faces and objects remains controversial.

XII. AGNOSIA AND ACTION

Previously we discussed patient DF, who developed a severe form of apperceptive agnosia following carbon monoxide-induced anoxia. Although DF's visual system is unable to use shape information to make perceptual judgments and discriminations about an object, she is able to use the same information to accurately guide her prehensile movements to those same targets. For example, even though DF is unable to discriminate solid blocks of differing dimensions, she accurately scales her grasp when picking up the blocks, opening her hand wider for larger blocks than she does for smaller ones, just as people with normal vision do. DF also rotates her hand and wrist appropriately when reaching out to objects in different orientations, despite being unable to describe or distinguish the size, orientation, and shape of the different objects. It appears that although the perceptual mechanisms in DF's damaged ventral stream can no longer deliver any perceptual information about the size, orientation, and shape of objects she is viewing, the visuomotor mechanisms in her intact dorsal stream that control the programming and execution of visually guided movements remain sensitive to these same object features.

Although the discussion of the dorsal and ventral streams in this article has emphasized their separate roles, there are many connections between the two streams and thus the opportunity for "cross-talk." Recent investigations have shed light on the role that the communication between these two streams plays in object recognition. In some cases of associative agnosia, it has been reported that the ability to identify actions and to recall gestures appropriate to objects could play a significant role in preserving recognition of certain objects. Sirigu suggested that sensorimotor experiences may have a critical role in processing information about certain objects. It has been reported that the object categories that individuals with associative agnosia have difficulty reporting are those that they could not recall their action. The objects that they do not recognize would thus appear to be those that they do not associate with their sensorimotor experiences. The objects that they do recognize may be those whose action plays a critical part. This could help explain the "living" versus "nonliving" dissociation seen in CSVA. Action is certainly an important element for knowing tools, kitchen utensils, and clothes. In contrast, most animals do not evoke any gestures, and the only action linked with most fruits and vegetables is a simple gripping. It also appears that the recognition of action is well preserved in these individuals. The impairments in recognizing static objects perceived visually in associative agnosia sharply contrast with the relatively better ability to recognize objects from gestures illustrating their use and to recognize actions shown in line drawings.

It appears that the dorsal stream not only provides action-relevant information about the structural characteristics and orientation of objects but also is involved in the recognition of actions and in the recognition of objects when sensorimotor experience is evoked. This suggests that the dorsal pathway is involved in conscious visual perception and in the interpretation of goal-oriented action, even when shown in a static way. It is possible that when ventral stream damage in agnosia prevents direct access to representations of an object for perception, sensorimotor information from the dorsal stream may provide a limited mechanism for recognition. In other words, semantic information about objects may be accessed by the dorsal stream and passed onto the ventral stream for recognition. The preservation of how to manipulate an object may play a crucial part in assisting object recognition in patients with associative agnosia.

XIII. WHAT AGNOSIA TELLS US ABOUT NORMAL VISION

A major obstacle to understanding object recognition is that we perform it so rapidly and efficiently that the outcome belies the underlying complexity. One approach to discovering the processes that mediate object recognition is to study the performance of individuals who have an impairment. This breakdown approach has proven extremely illuminating and has provided important insights into the mechanisms involved in normal object recognition. The breakdown approach as reflected in the study of neuropsychological patients with agnosia is related to other approaches that also examine the system in its nonoptimal state. These approaches include the study of visual illusions in which the perception of normal subjects is distorted through some stimulus manipulation and the study of perception when cues are reduced, such as in monocular versus binocular vision.

Neuropsychological studies of agnosia have not only identified a major distinction between "early" and "late" stages of object recognition, as well as differentiated more discrete impairments within each of these stages, but also uncovered deficits associated with "intermediate"-level vision. Additionally, investigations with patients have allowed us to address issues such as category specificity both within the domain of objects and across visual domains, relating faces and words to objects. Finally, how perception might be related to action has been a focus of neuropsychological research and important observations have been gleaned from the detailed and thorough study of these patients with agnosia.

Studies of patients with agnosia have also shed light on the extent to which there is modular organization in the visual system. Although we have been concerned only with deficits of object recognition following brain damage, there are also patients with selective deficits of depth, motion, and color processing. One interpretation of these selective deficits is that there are independent regions of the brain that are specialized for certain functions. An even more extreme view, but one that has been tempered recently, is that these independent regions are exclusively dedicated for particular visual functions. At a higher level, whether there are truly independent areas for recognition of different categories of visual objects (living/nonliving) or for different types of stimuli (faces, words, or objects) remains a matter of ongoing investigation.

Perhaps most important is that these studies of patients with visual object agnosia have constrained our theories of object recognition and, in turn, these theories have guided our investigation of these interesting and illuminating deficits.

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