Agnosia☆

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Glossary

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 (1) paralysis of eye fixation with inability to look voluntarily into the peripheral visual field, (2) optic ataxia, and (3) 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.

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

Integrative agnosia A form of visual agnosia in which one retains the ability to recognize elements of objects but is unable to integrate these elements together into comprehensible percept.

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 sort the visual stimuli into categories.

Posterior Cortical Atrophy PCA, also called Benson's syndrome, is a form of dementia which is usually considered an atypical variant of Alzheimer's disease. The disease causes atrophy of the posterior part of the cerebral cortex, resulting in the progressive disruption of complex visual processing.

Prosopagnosia A form of visual agnosia in which a person cannot recognize familiar 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.

Introduction

Visual agnosia can be broadly conceptualized as an impairment in the higher visual processes necessary for object recognition, with relative preservation of elementary visual functions. This impairment occurs in the absence of dementia or loss about object

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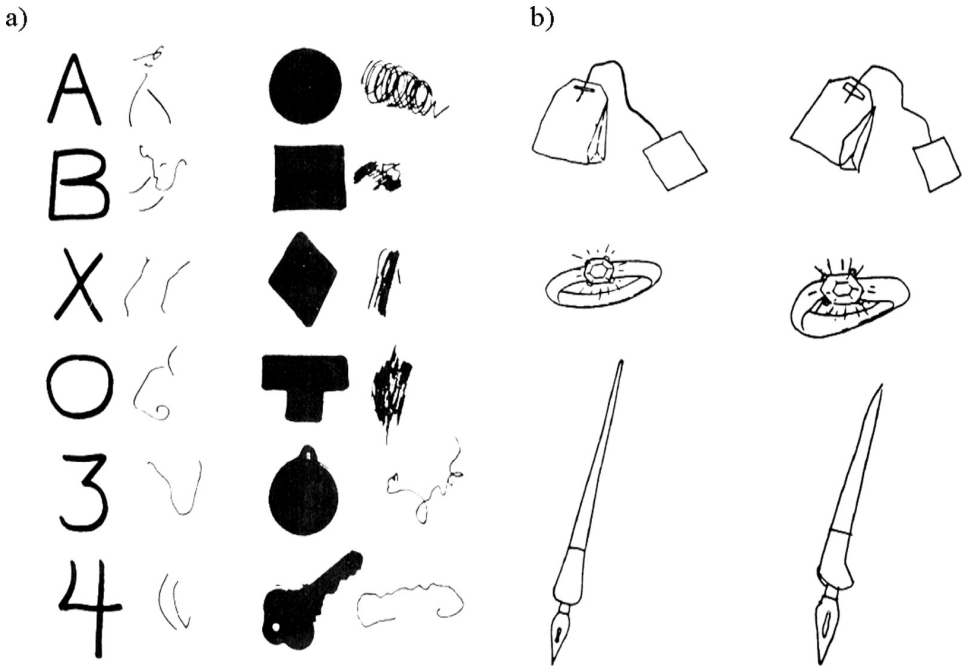

Figure 1 Demonstrates the copying abilities of individuals with (A) apperceptive agnosia and (B) associative agnosia.

knowledge, as patients are typically able to recognize objects through other modalities such as through touch, audition, or verbal descriptions. Historically, Lissauer (1890) suggested that there were two general categories of object recognition deficits following brain damage, apperceptive and associative agnosia. Apperceptive agnosia patients were described as having early perceptual processing deficits, which caused an inability to form a complete conscious percept of the stimulus. Associative agnosics, on the other hand, were characterized by an inability to recognize objects, despite having intact early level representations. Typically, these impairments were assessed by having the patients copy simple pictures of objects; individuals with apperceptive agnosia were unable to copy or identify the picture while individuals with associative agnosia could produce a copy of the presented object but were unable to recognize or name it (Fig. 1).

Although Lissauer's classifications of agnosia remain in current neuropsychological theories of object recognition today, we are now aware that the simple dichotomy of associative vs. apperceptive agnosia cannot account for all forms of object recognition deficits reported in the literature. The neural mechanisms supporting different aspects of perception have been well explored, and depending on the specific area of damage, diverse agnosic characteristics have been shown. Although this article limits the topics to object recognition agnosias, tactile, auditory, face (prosopagnosia) and color agnosia have been reported in the literature.

Neuroanatomy

Diverse methodology, including animal, lesion, functional magnetic resonance imaging (fMRI), and behavioral studies, have been employed to identify the underlying visual mechanisms involved in object perception and recognition. Indeed, two distinct, but interconnected, cortical visual pathways have been shown to process the visual information needed for visual perception and visually guided action. The dorsal stream, projecting from the primary visual cortex (V1) to the posterior parietal lobe, deals with moment to moment information about the location of objects and is primarily involved in the visual control of skilled movements directed at those objects. In recent years, there has been an increasing acceptance of further division of the dorsal visual stream into a dorso-dorsal stream and a ventral-dorsal stream. Based on a combination of anatomical, functional imaging, and patient studies, there is mounting evidence for the presence of a "grasp" and "use" system within the dorsal stream. A dorso-dorsal pathway running from V3a to areas V6, V6a and medial intraparietal area (MIP) within the superior parietal lobule (SPL), and ultimately to dorsal premotor regions, that is primarily concerned with online planning of grasp. In contrast, a ventro-dorsal pathway running from the medial superior temporal (MT/MST) area onto the inferior parietal lobule (IPL), and ultimately ventral premotor cortex where it provides information processing of sensorimotor information based upon longer-term object use representations, known as action semantics. It is, therefore, the ventro-dorsal visual stream which is thought to be especially important in skilled tool use and the ability to recall information related to an object's function, pantomiming the correct use, and classifying objects along dimensions of functionality.

The ventral stream, on the other hand, projects from V1 to the temporal lobe and provides us with our visual perceptions of objects and events in the world as well as codes this information for storage and for use in cognitive processes like imagining, planning, and recognition (Fig. 2).

Ventral stream function is associated with object recognition and form representation. Investigations with nonhuman primates have shown that this system has strong connections to the medial temporal lobe, which is associated with long term memories, and the limbic system, which is involved in emotional processes. Thus, the role of the ventral stream seems to be to form our perceptual and cognitive representations of the world, providing both the characteristics of objects and their significance to us.

The primary pathway of ventral information from V1 is through visual association areas V2 (involved in the processing of simple properties such as orientation, color, and spatial frequency), V4 (tuned for properties such as orientation, spatial frequency, color, and simpler geometric shapes), and finally to the inferior temporal lobe. fMRI studies in normal individuals have shown activations in the ventral stream during identification of form, texture, and color, as well as during recognition of objects and faces.

As information moves from the visual association areas to the temporal lobe, the cells show remarkable specificity in their responses to visual stimuli. For example, the lateral occipital complex (LOC), which is a region located bilaterally on the occipitotemporal cortex, is more activated when viewing objects when compared to viewing textures or scrambled objects. Within the temporal lobe, many of the cells have large receptive fields which allows for generalization across the visual field and the coding of intrinsic object features, independent of object location. Lesion studies in monkeys provide further evidence for the role of the ventral stream in object perception. For example, when monkeys have lesions to the temporal cortex, performance on shape discrimination tasks are compromised.

Since the original introduction, and later refinement of the two-stream theory, it has become clear that the cortical visual streams must interact in a multitude of visual tasks. Specifically, information from the ventral visual stream is likely used to identify a particular goal for future interaction, followed by dorsal stream processes that can be utilized to mediate the performance of a skilled interaction with that object. Additionally, tools may pose unique requirements in terms of the interaction between ventral and dorsal streams, as perceptual mechanisms within the ventral stream are critical in identifying a tool that one is to interact with, followed by the dorsal stream carrying out real-world calculations to form the grasp. Of importance, is the fact that the required hand-posture would only be selected after an appropriate identification of the tool, most likely via the ventral visual stream, is accomplished. Neuroantomical studies have provided substantial evidence of connections between the dorsal and ventral visual streams within nonhuman primates, with human diffusion tensor imaging work largely supporting the presence of a connection between the middle temporal gyrus and supramarginal gyrus. When taken together, this work indicates that bidirectional pathways between dorsal and ventral streams are present, allowing the two streams to work together to allow for the effortless perception of and interaction with our surroundings on a daily basis.

The following article will examine some of the more profound, and in our opinion, more interesting forms of agnosia that have been reported. While our discussion will be primarily limited to agnosias within the visual domain, it is important to note cases have been reported in other sensory modalities as well (such as auditory and tactile). A broad approach has been undertaken, highlighting key findings in all disciplines of behavioral neuroscience including case studies, animal models, lesion studies, and systems theory. It is hoped that by offering such a broad treatment the reader will develop an accurate depiction of the current state of knowledge about agnosia, and what it has taught us about the human visual system.

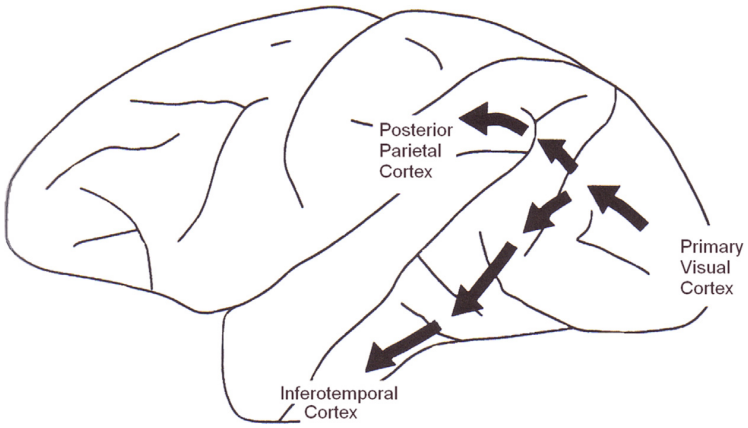

Figure 2 Depicts the two streams of visual processing in the primate cerebral cortex. The brain illustrated is that of a macaque monkey.

Apperceptive Agnosia

Individuals with apperceptive agnosia are characterized by a difficulty forming a complete visual percept. In extreme cases, termed visual form agnosia, even simple shape discriminations cannot be made as these patients lack the ability to group local visual elements into contours, surfaces and objects. This type of agnosia is associated with diffuse bilateral damage to the lateral occipital lobes, critical structures involved in visual perception. Individuals with such diffuse damage typically have preserved visual acuity, brightness discrimination, and color vision, and are able to maintain fixations on objects. However, despite the preservation of these elementary visual functions, their ability to point to objects in the environment and match, copy or discriminate simple and complex geometric shapes is often compromised. Impairments in object identification does not, however, reflect a general impairment in object recognition as patients are still able to accurately identify objects upon tactile presentation and verbal descriptions. Additionally, object identification improves when these patients are looking at real objects where cues such as color and texture can aid in recognition.

Despite general impairments in object perception, patients with apperceptive agnosia have been reported to recognize actions depicted in line drawings, such as someone pouring water into a glass, objects whose functions are pantomimed by an experimenter and objects either in motion or drawn in front of them. The dissociation between impaired perceptual representations of static objects and a preserved ability to perceive motion in these individuals is likely the result of intact parietal and parietofrontal visual networks. As previously described, visual processing in the dorsal stream deals with information about the location of objects and is primarily involved in the visual control of skilled movements and motion perception. Additionally, this network forms connections with frontal areas critical for understanding actions performed by others. Despite obvious perceptual deficits, individuals with apperceptive agnosia retain the ability to accurately interact with objects around them and maneuver through their environment. For example, DF, one of the most extensively tested patients with visual form agnosia, clearly demonstrates intact visuomotor control for manual actions on the basis of object size, orientation, and shape, despite her inability to consciously perceive these same details. Indeed, DF can use these intrinsic object properties to accurately scale her grasp when picking up objects with accuracy equal to that of normal controls. Recent work with DF, combined with earlier neuropsychological, neuroimaging, and neurophysiological studies, supports the idea that DF's preserved visuomotor abilities are mediated by intact mechanisms in the dorsal stream, thus allowing accurate visuomotorcontrol in the absence of conscious perceptual detail.

In addition to apperceptive patients with severe perceptual deficits, such as those with visual form agnosia, there are also individuals that present with higher order apperceptive impairments known as perceptual categorization deficits. While these patients can typically recognize most objects, their perceptual deficits become apparent when trying to recognize or match objects seen from unusual orientations or under poor lighting conditions. In the past, this impairment has been attributed to the breakdown of the mechanisms involved in object shape constancy. Such mechanisms allow us to recognize objects presented at any orientation or in degraded lighting conditions. However, others have disputed this interpretation. Since patients with this deficit do not have problems with everyday object recognition, and only object recognition at some, rather than all perspectives is impaired, the deficit may reflect a general loss of visual problem solving abilities rather than impairment of shape constancy mechanisms.

Simultanagnosia

Simultanagnosia is characterized by an inability to appreciate the overall meaning of a complex picture or stimulus, with preserved perception of isolated elements or details within the stimulus. Simultanagnosia patients present some visual deficits similar to those seen in apperceptive agnosia, such as an inability to identify an array of stimuli or a tendency to look at parts of an object to guess the objects identity on the basis of local features. However, unlike apperceptive agnosics, patients with simultanagnosia can use shape information to aid in identification. Two broad classes of simultanagnosia (dorsal and ventral) have been established by Farah (1990) based on both the presentation of the disorder and the corresponding lesion sites to the dorsal and ventral cortical visual pathways.

Despite being able to recognize most objects, patients with dorsal simultanagnosia cannot detect more than one object at a time and have difficulty shifting attention from object-to-object. For example, when presented with a series of overlapping line drawings, such a patient my only report seeing one of the objects. Additionally, these patients are often confused with blind individuals as they frequently walk into objects and grope for things as if they were in the dark. Attentional impairments, resulting from impaired spatial attention systems, have been shown to be the root underlying cause of dorsal simultanagnosia. Such impairments result in an inability to disengage attention from a specific object or a region of space, thus these patients can only attend to one stimulus at a time. However, if individual objects are placed close enough together, dorsal simultanagnosics can combine the individual elements to recognize the larger "global" structure and, in rare cases, perceive multiple objects. This perceptual impairment is typically resultant from bilateral lesions to the posterior parietal cortex and occipital regions and frequently occurs in the context of Balint's syndrome, where impaired visuomotor control (optic ataxia), eye movements and spatial coding deficits are observed.

Ventral simultanagnosia, on the other hand, is characterized by the reduced ability to recognize multiple visual stimuli rapidly. Although these patients are able to see multiple objects at once, like individuals with dorsal simultanagnosia they are only able to recognize one object at a time and often do this on a part-by-part basis. That is, while patients with dorsal simultanagnosia have mainly deficits in *perceiving* more than one stimulus, patients with ventral simultanagnosia have deficits in *recognizing* more than one stimulus, even though other objects are seen. Indeed, patients with this visual disorder are most noticeably impaired while

reading as they must identify each word letter by letter. The underlying cortical damage for this disorder has typically been associated with left posterior temporal or temporo-occipital cortical lesions.

Posterior Cortical Atrophy

Posterior Cortical Atrophy (PCA), also referred to as Benson's disease or the visual variant of Alzheimer's disease, is a progressive neurodegenerative disorder characterized by prominent higher-order visual dysfunction, with preserved memory and reasoning in the early stages of the disorder, but later an insidious, often presenile onset occurs. The initial symptoms of PCA can vary broadly (e.g., achromatopsia, prosopagnosia, object agnosia, environmental agnosia, alexia, agraphia, left-right disorientation, optic ataxia, magnetic misreaching, oculomotor apraxia, dressing apraxia, visual neglect, and simultanagnosia). However, early onset symptoms are often related to difficulties with a person's ability to process visual information. For example, PCA patients often demonstrate impairments in global processing or the ability to view the visual world as a coherent whole. Traditionally, this deficit in PCA has been labeled as simultanagnosia. The responses of individuals with PCA to basic perceptual tasks, such as object identification using line drawings, suggest that they are unable to take into account all of the available information when viewing an image. PCA patients persistently attempt to identify images based on very select information extracted from a small part of the overall picture. When viewing faces, for example, there is often a focus on nondiagnostically useful locations suggesting that individuals with PCA have difficulty processing the face at either the featural or configural level. In fact, it appears that the decreased effective field of view in PCA patients is so severe that it results in an extreme dependence on local processing, such that a feature-based approach is not even possible.

PCA is characterized by progressive bilateral atrophy in the posterior areas of the brain (e.g., occipito-parietal and occipito-temporal areas), often with a predominance in the right hemisphere. In the majority of cases, Alzheimer's pathology is the underlying cause, but cases have been documented as a result of corticobasal degeneration, dementia with Lewy bodies, and prion diseases such as Creutzfeldt-Jakob disease.

Associative Agnosia

Individuals with Associative agnosia have difficulty recognizing visually presented objects despite having an intact percept of that object. As such, and in comparison to apperceptive agnosias, an associative agnosic can adequately perform figure copying tasks, even though they may be unable to identify the very picture they just copied. Further, associative agnosics usually perform significantly above chance at matching tasks. A third similarity, both apperceptive agnosics and associative agnosics are affected by the quality of the stimulus they are trying to identify, with performance on three dimensional objects superior to two dimensional photographs, and line drawings being the poorest performance. Unlike apperceptive agnosics, a person with associative agnosia can use shape cues to try to identify the presented object (as opposed to color and texture). Therefore, an associative agnosic is likely to mistake an object for one that is similar in shape. Patient FZ is known to have misidentified a drawing of a baseball bat as a paddle, knife, and thermometer (all objects that have a shape similar to a baseball bat). Since form information seems to be, at least partially, intact there must be a failure of the structured perception to appropriately activate the network of knowledge about the functional, contextual, and categorical properties of objects that aid in their correct identification.

Of course, one of the highlighted symptoms of associative agnosia is that perception remains intact and that it is meaning that becomes inaccessible. However, recent research has demonstrated that, at least some, associative agnosics do indeed have at least some form of visual impairment. For instance, patient CK's figure copying was quite adept in terms of final product, however the process employed to reach that point was substantially different from what would normally be observed. CK was slow, and often lost his place if he had to take his pen off of the paper. Levine and Calvanio report further perceptual difficulties observed in patient LH, who was significantly slower in matching tasks and visual search tasks. While in comparison to other agnosics it may seem that those suffering from associative agnosia are displaying "perception without meaning", as coined by Teuber, few would wholly subscribe to the notion that these patients have fully intact perceptual abilities.

An interesting subset of associative agnosia may manifest in some which recognition is not equally impaired for all classes or categories of object. Category Specific Visual Agnosia (CSVA) usually distinguishes between biological and nonbiological objects, with patients showing preserved recognition for all categories and a deficit for the biological. For example, someone with CSVA may have correct recognition of tools, but demonstrate marked difficulties in recognizing fruit and vegetables. Similar to associative agnosia, it is thought that the deficit is rooted in a dissociation between the mechanisms underlying visual perception and those that provide access to the semantic information associated with objects. However, the exact mechanisms are at present not fully understood. Some have theorized that the split in performance between biological and nonbiological items may be a result of biological items depending on specialized neural-mechanisms that are unused (or underused) when recognizing nonliving objects. Neurological evidence has for the most part substantiated this line of theory, with deficits in identifying biological objects following inferior-temporal lobe damage.

Integrative Agnosia

While Lissauer's pioneering work dichotomizing forms of recognition disorder (apperceptive vs. associative) is still often cited, we are now fully aware that object recognition is a far more complicated process than Lissauer could have intuited. Rather than

simply matching stimuli coded in terms of primitives (like line orientation) to previously acquired knowledge, the visual system must code the spatial relations between lines and features, the object must be parsed from the background, and individual parts of the object need to be related to one another. Problems with this intermediate level of vision can result in poor overall perceptual integration of form information. Perhaps the best studied patient was described in detail by Riddoch and Humphreys, H.J.A., who had bilateral occipito-temporal damage following an infarct of the posterior cerebral artery. Following the lesion, H.J.A. demonstrated profound impairments in a number of higher-level visual tasks including, face recognition, word recognition, and visual navigation. When attempting to identify objects, H.J.A.'s descriptions generally consisted of fragmented reports of various form-based features, with correct identification of an object seemingly hinged on either an elongated process of deduction or the presence of a highly diagnostic feature. For example, when asked to identify a line-drawing of a pig, H.J.A., he began identifying features such as having four short legs and a powerful body. Once he realized the mystery animal possessed a small curly tail, he was quick to correctly identify the stimulus. Typically, integrative agnosics over-segment stimuli, with parts of the same object being classified as separate. For example, while describing a paintbrush, H.J.A. suspected there may be two objects close together, rather than the single paintbrush presented. These patients typically perform best when identifying real-world objects than still photographs, and have the poorest performance when required to identify line drawings. Such findings suggest that the addition of surface information and depth information appears to increase performance via benefiting the processes involved in integrating elements of the stimuli into a perceptual whole. Interestingly, when H.J.A. incorrectly named an object, his errors were visually related to the target objects and never seemed to be a result of semantic association, suggesting a deficit before access of item specific stored knowledge has been retrieved. Such difficulty may be suggestive of cortical damage to both the ventral and ventro-dorsal visual stream, or to a common visual area shared before these pathways form distinct processing routes. This notion is furthered by findings that integrative agnosics are unable perform matching tasks that require semantic information, or to gesture the correct use of misidentified objects. In sum, the deficit truly is one of object identification, rather than object naming. Although the disruption in processing is undoubtedly before higher visual processes, such as the attachment of meaning, most integrative agnosics perform quite well on standardized test of early perceptual processing. For example, H.J.A was able to accurately reproduce etchings presented to him, as can be seen in Fig. 3 (although his order of drawing lines was abnormal).

Additionally, H.J.A performed well on a task requiring the perceptual discrimination of objects that are matched for overall area and brightness, that patients suffering from impairments in the encoding of basic visual properties fail. In order to account for all features of performance found in integrative agnosics, basic, local visual elements are though to be processed in a normal way, but the integration of these elements into unitary wholes is impaired. In more concrete terms, integrative agnosia appears to be a deficit located between the stage of visual processing concerned with shape processing and the visual access to memory representations. Since the human visual system is limited to recognizing one object at a time, any deficiencies in the ability to properly segment/group the visual field will lead to the deficits observed in integrative agnosia by way of perception breaking down into a parts-based analysis of objects. More recent work has provided evidence that apperceptive agnosia may, at least in some cases, be a result of deficits in early visual processing, specifically line orientation. Work by Serino et al. (2014) with patient SDV (whom suffered bilateral occipital damage due to anoxia) demonstrated via psychophysical experimentation SDV's visual recognition deficits could not be explained by spatial acuity or crowding effects, typical explanations for the perception deficits observed in apperceptive agnosics. Rather, SDV demonstrated a severe deficit in line orientation processing, a characteristic of primary visual cortex essential in building an accurate perception of a visual stimulus. Therefore, some cases of apperceptive agnosia may be the result of deficits in basic visual functions affecting low-level visual functioning.

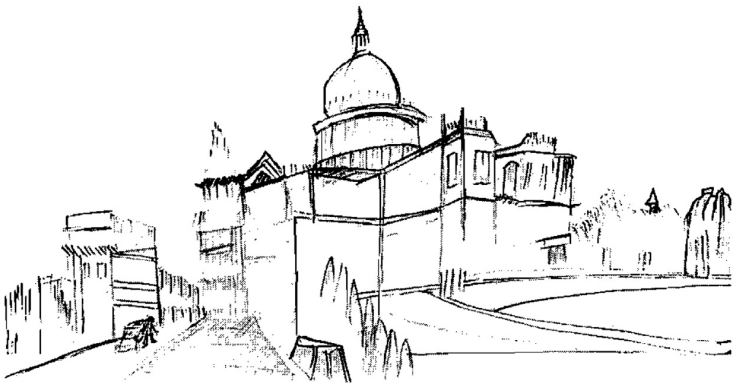

Figure 3 Copy of an etching of St Paul's cathedral by patient H.J.A.

Optic Aphasia

Optic aphasia is typically described as having an inability to name a visually presented object, despite being able to identify the object through alternate means such as gesturing the appropriate use. With associative agnosics and optic aphasics often displaying similarities in their deficits, some have argued a classification of a single syndrome, perhaps allowing for varying degrees of severity. Both of these patient populations have profound difficulty in naming visually presented objects, with intact recognition persevering within the other senses, such as touch or sound, suggesting damage to the ventral visual stream. Additionally, both "types" of patients have relatively intact low level visual processing and an ability to copy presented line drawings. When examining optic aphasics, however, a number of important distinctions are readily apparent. Firstly, and perhaps most importantly, optic aphasics are able to nonverbally identify an object through gesturing the intended use, a skill associative agnosics lack. Patient Jules F., who was extensively studied after suffering a posterior left hemisphere stroke, would often pantomime the use of an object correctly, even if his verbal identification was incorrect. For instance, when shown a picture of a boot Jules F. correctly mimed putting the boot on his foot, but incorrectly identified the object as a hat. Such a preservation of functional knowledge may very likely represent an intact ventro-dorsal cortical stream providing the knowledge required to pantomime actions associated with objects, to match objects which serve the same purpose, or to match objects to action demonstrations, all skills which are disrupted by lesions that affect the ventro-dorsal visual stream.

The nature of the disorder is further elucidated when one examines the *types* of errors seen in optic aphasia in comparison to associative agnosia. While an associative agnosic commonly makes errors related to visual dimensions of the target object, whereas as an optic aphasic is likely to make errors with a semantic underpinning. As is evident from the example above, Jules F. chose a response from a similar semantic category (clothing, for example), even though a hat and a boot share few visual features in common. Another common finding associated with optic aphasia, although are much less frequently observed in associative agnosics is an insensitivity to the visual quality or nature of the stimulus. That is, optic aphasics perform equally well (or equally poorly) on identifying photographs, 3-dimensional pictures, and line drawings of objects. Finally, optic aphasics are far more likely to perseverate once an answer is produced, repeating error responses from previous trials.

It is important to close with a caveat regarding the dichotomy created between optic aphasia and associative agnosia: There have been a number of reported cases where both conditions seem to be present in a single patient, indeed, even Lissauer's seminal patient had features of both apperceptive and associative agnosias preventing his categorization.

Summary

This article has served as a brief introduction to the collection of disorders termed visual agnosia. Despite relatively normal visual perception, attentional mechanisms, intelligence and language these patients have a marked deficit in the recognition of previously known visual stimuli. The condition is modality specific, with the other senses (touch, hearing, etc.) providing a route to relatively unimpaired recognition performance. Despite the pedagogical role these interesting cases can fulfill, there is another, arguably more useful role for the study of visual agnosia within neuropsychology. As should be apparent from the provided discussion of neuroanatomy, the visual system as a whole is far more complicated that one would intuit. Indeed, one of the primary impediments to understanding how object recognition is achieved is the contradiction between how easily we accomplish it, and the underlying complexity. By studying individuals who demonstrate impairment, we have not only been able to identify major distinctions between stages of object recognition, but also verify the modular organization of the visual system. The dissociations seen within the various subtypes of agnosia discussed here are compelling cases of how distinctions between "early," "intermediate," and "late" stages of object recognition can have explanative power in accounting for the many, seemingly distinct, forms of agnosia one may encounter. Of course, this relationship is two-directional, with the study of patients with visual agnosia guiding our investigation of the visual system as a whole.

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