Prosopometamorphopsia:
Face distortions as a window into face perception

Brad Duchaine
Department of Psychological and Brain Sciences
Dartmouth College
Hanover, NH, USA
bradley.c.duchaine@dartmouth.edu

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Abstract
Reports of distortions affecting the perception of faces have been published since the early 20th century, but investigations of face distortions, a condition known as prosopometamorphopsia (PMO), have had almost no impact on theories of face perception. Here, PMO is introduced with descriptions of cases who experience face distortions, along with an overview of its perceptual characteristics, neural basis, onset, and psychological effects. The second part of the chapter presents results from PMO that demonstrate its value for our understanding of face perception and visual recognition. Recent findings show that face perception depends on face-centered representations, and a review of hemi-PMO cases indicates that high-level mechanisms in the left hemisphere represent the right half of the face (from the viewer's perspective), whereas the right hemisphere encodes the left half and right half of the face independently. Finally, formal testing with two PMO cases, who have only seen face distortions in daily life, generated some of the strongest evidence for face-specific processes. Looking ahead, I am optimistic that continued efforts will transform research involving PMO from a clinical curiosity into an approach that is frequently used to advance our understanding of face processing.

Prosopometamorphopsia (PMO) is one of the most striking disorders in neuropsychology. People with PMO see faces distorted in shape, texture, and/or color, and faces often transform as they are viewed. Distortions can affect the whole face (bilateral-PMO), only the left or right half (hemi-PMO), or just a particular region of the face (Blom et al., 2021; Herald et al., 2023). Not surprisingly, face distortions can have a major impact on mental health and functioning (Blom et al., 2021). Findings from PMO can be used to significantly advance theories of face perception and visual neuroscience more generally, but few studies with PMO participants have conducted thorough testing aimed at addressing theoretical questions in visual neuroscience, and the minimal impact of PMO on theories of face perception is a major missed opportunity. However, over the last five years, my laboratory has shifted much of its focus to investigating distortions that affect the perception of faces and other visual stimuli. Through our research website, we have established contact with 250 individuals who have experienced face distortions. We are investigating their distortions to advance our understanding of theoretical issues while also attempting to develop interventions that reduce face distortions.

This chapter will first introduce face distortions by discussing cases our laboratory is working with, and then will review the many forms of face perception distortions, their neural correlates, and their psychological impact. The second part of the chapter will review three theoretical issues that studies of face distortions have shed light on: reference frames in face perception, the separate representations of left and right half-faces and their hemispheric basis, and the long-standing question of whether the visual system contains mechanisms specialized for faces.

Examples of cases with face distortions

Below, I provide brief summaries about four individuals with PMO. In addition to introducing the kinds of distortions seen in PMO, these summaries touch on some of the theoretical inferences that can be drawn from cases with face distortions. Then, to give readers a broader sense of the variety of distortions in PMO and the extraordinary nature of some distortions, Table 1 provides information about other individuals in contact with my laboratory.

V.S.

V.S., a man in his early 60s from the United States, has experienced face distortions for five years. Since waking one morning, every face he has seen in person has had a uniform set of distortions — features are stretched toward the back of the head and prominent grooves are present: two on the forehead, three on each cheek, and one on the chin (Figure 1, left)(Mello et al., 2024a). V.S. describes the faces as demonic, and at first, he wondered if he had died and gone to hell. Like many of our participants, the onset of V.S.'s distortions was not clearly tied to an event. He may have suffered carbon monoxide poisoning four months before the distortions began, and he has a history of closed-head injuries. V.S. finds the distortions disturbing and tends to avoid crowds, but he has grown accustomed to them. Extensive testing demonstrated a surprising link between color perception and face perception: warm colors amplify V.S.'s distortions, whereas cool colors reduce them (Mello et al., 2024b). Unlike most PMO cases, V.S. does not see distortions on faces on screens, which indicates a qualitative difference between 2D and 3D face perception (Mello et al., 2024a). V.S.'s normal 2D face perception provided us with a unique opportunity to visualize face distortions, because, unlike cases who see distortions in both 2D and 3D faces, he can accurately judge if a 2D representation of his distortions matches the distortions he is perceiving on a 3D face. As V.S. described the distortions he saw on a 3D face, we modified a digital 2D photo of the face while he provided real-time feedback on the correspondence between the distortion and the altered 2D image, until he was satisfied with the match (Figure 1)(Mello et al., 2024a).

Figure 1: Visualizations of distortions for V.S., Nagel, and Zed. The dissociation V.S. experiences between distorted 3D faces and undistorted 2D faces provided a means to generate an especially representative visualization (left). Nagel (center) and Zed (right) see dynamic distortions, so their visualizations rely on memories and aim to capture the momentary appearance of distorted faces. In addition, because they see distortions in 2D faces, they cannot assess the match between the visualization and the distortion they perceived as confidently as V.S. can, so their visualizations are likely to be less accurate.

Nagel

Nagel is a 41-year-old South African man with right hemi-PMO[1]. His distortions began in 2006, possibly due to a severe case of infectious mononucleosis. Nagel typically sees a distortion in which the right eye moves to the side, the right half of the mouth droops, the skin darkens around the right eye and on the forehead, and the right cheek expands and darkens (Figure 1, center). He sees the distortion on his own face when looking in the mirror, and for years, Nagel felt that his face was unattractive until he realized that his perception of faces was distorted. Nagel's distortions grow as he views a face, and if he looks away, the face will often shift back to a less distorted or even undistorted face. His face distortions are face-centered in that they occur whether the face is located in the left or right hemifield, and they affect the same parts, irrespective of picture-plane rotation (e.g., 0°, 90°, 180°)(Figure 2 below). The effects of colors on Nagel's distortions are similar to V.S.'s, in that cool colors reduce their intensity and warm colors exacerbate them (Mello et al., 2024b). Unlike V.S., Nagel also sees distortions in hands and some objects (Mello et al., 2025). The distortions in hands and objects are also on the right side of the object from his perspective, but they are not object-centered, in that the region of distortion on the hand or object changes when the object is presented in different picture-plane rotations.

A.S.

A.S. is a 48-year-old American woman who, for 15 years, has had severe face distortions that affect the shape and position of face parts (Dalrymple et al., 2014). Every face that she views appears distorted, causing her substantial distress. To cope during social interactions, A.S. often directs her gaze to her conversational partner's shoulder rather than to the face. A.S. had childhood epilepsy and suffered a concussion in 2007, but her distortions began suddenly without a known neurological trigger. Both halves of the face are distorted, and she believes that asymmetries between the left and right halves are positively correlated with the intensity of her

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[1] "Right" and "left" refer to the subject's viewpoint. In right hemi-PMO, the distorted half is in the right visual field when the subject is fixating the nose, corresponding to the left side of the person's face.

distortions. A.S. sees distortions in every face she views, but she has never seen a distortion in an object. A.S.'s face-selective areas responded normally in an fMRI face localizer study, and the face-selectivity of her N170 EEG response was normal (Dalrymple et al., 2014), but diffusion-weighted imaging revealed white matter abnormalities, including in tracts in the occipitotemporal lobe.

Zed

Unlike the cases described above, Zed, a teenager from the U.S., appears to have experienced lifelong face distortions (Fortner et al., under review). His mother recalls Zed mentioning "curvy mouths", "drooping eyes", and "disappearing features" when he was in kindergarten. The dynamic shape and position distortions that Zed sees affect the entire face (Figure 1, right) and are among the most intense distortions reported by our participants. Features sometimes disappear, with either a skin-like texture replacing them or a hole appearing in the face. Zed also experiences misidentification illusions in which he sees one face rather than another. For instance, in a public setting, Zed approached a person he thought was his mother, but it was actually a man in his sixties. Even after Zed's sister pointed out his error, Zed continued to perceive his mother's face. Zed's scores on tests of facial identity memory were in the prosopagnosic range, and he has difficulty recognizing people from their faces in daily life. Interestingly, though, he performed normally on tests requiring him to sort faces on the basis of age or sex (Chatterjee et al., 2012). It is unclear how Zed was able to make the subtle discriminations needed to score well on the sorting tasks, and we plan to follow up with additional testing. The combination of severe face distortions and potentially intact perceptual judgments is consistent with a hypothesis that proposes that the representations supporting conscious awareness of faces are different from the representations underlying judgments about faces (Blom et al., 2021).

PMO participants display a wide variety of distortions

Table 1 consists of brief descriptions of the distortions seen by the four participants described above and 17 other participants, along with the duration of their distortions and the cause (or potential cause). These descriptions show pronounced heterogeneity. This variability often

Table 1: Characteristics of 21 participants with face distortions interviewed by my laboratory.

Participant	Distortions	Onset	Cause
A.C.	Faces look flat; the left half appears closer to AC than the right half	Five months ago	Unknown
A.S.	Severe shape distortions and feature position shifts	15 yrs ago	White matter deficits
Aurora	Eyes and mouth appear black; chin and ears extended; features often displaced and tilted	1 year ago	Right occipital stroke
A.X.B.	A semi-transparent face is seen in front of viewed faces	Age 8; 22 yrs ago	Unknown
B.S.	Left eye and sometimes both eyes look "dead", "no mind behind eye"	1 year ago	Right occipital stroke
Blackstone	Monstrous distortion: pig-like head; deep pits with eyes on tiny stalks; sea elephant-like nose	2 years ago	Unknown
C.A.	Features, particularly on the right side, droop	8 months ago	Unknown
D.D.	Shape distortion in which nose & eye region are projected forward	3 yrs ago	Unknown
Ezri	Faces expand and contract cyclically; bilateral texture and color distortions	Lifelong	Developmental
Gloria	Teeth appear to have dirt on them; missing teeth; cheeks are bright red	3 yrs ago	Unknown
Gretchen	Shape distortions, severe texture distortions (e.g., skin like tree bark); palinopsia	12 yrs ago	Sulfa reaction?
J.F.	Bilateral distortions that are more pronounced on J.F.'s left	4 yrs ago	White matter deficits
J.S.	Faces swell and distort; depth distortions	Since childhood	Closed head injury?
Leona	Right hemi-PMO (see Fig 3)	5 years ago	Unknown
Nagel	Right hemi-PMO (see Fig 1)	20 yrs ago	White matter deficits
Norma	Faces look similar to TV static. The static can affect the whole face or only the eye region	2 yrs ago	Multiple strokes
S.M.	Left hemi-PMO; features droop	2 yrs ago	Unknown
Terry	Left hemi-PMO; sometimes bilateral PMO; shape distortions	4 yrs ago	COVID
Willie	Face-centered mouth-specific distortions and mouth duplications	5 yrs ago	Unknown
V.S.	Features stretched back; grooves on forehead, cheeks (see Fig 1)	5 yrs ago	Unknown
Zed	Intense shape distortions; feature dislocations; discoloration	Lifelong	Developmental

requires researchers to adapt testing methods to each participant's unique profile, but the diversity of their face distortions creates opportunities to investigate multiple facets of face perception and visual cognition.

One of the most fundamental differences between these cases is the region of the face impacted by the distortions. In a review article (Herald et al., 2023), we used stringent inclusion criteria that led us to restrict our survey to 51 previously published cases. Among those 51 cases, two-thirds had distortions limited to either the left or right half of the face (hemi-PMO). The remainder had distortions on both the left and right halves. Near the end of the chapter, I discuss some implications of the existence of hemi-PMO as well as the revealing relationship between the affected half and lesion location. Here, I note that the proportions in our review (hemi: 2/3; bilateral: 1/3) contrast sharply with the proportions among the participants in Table 1 and in the larger group of participants who have contacted us. In Table 1, only four of the 21 cases have hemi-PMO, whereas 17 have distortions on both halves of the face. It's not clear what factors contribute to this difference, but two possibilities seem plausible. One is that distortions limited to one-half of the face are understandably perceived by clinicians and researchers as a more extraordinary disorder, and so descriptions of hemi-PMO cases are more likely to be reported. Another factor may be that the participants in the reviewed publications are drawn from a population of PMO individuals who differ in some key manner from the individuals who contact our laboratory. In support of this possibility, the section below about the neural correlates of face distortions discusses evidence suggesting that individuals with gross neural abnormalities are overrepresented in the published literature.

A second salient difference between PMO cases is whether the distortions are static or dynamic. V.S. observes a consistent distortion (Figure 1) that is present the moment he views a face and remains unchanged as he continues to look at the face. Among the 21 participants in Table 1, ten perceive static distortions. In contrast, Nagel, Zed, and A.S. see distortions that become more intense as they look at a face. As a result, they tend to limit the time they spend looking at a face. Nagel, like many of our participants, reports that looking away and then returning to a face often resets the face to its original state. Six participants in Table 1 have dynamic distortions. In the remaining five cases, it is unclear if their distortions are dynamic or static, in some cases because their distortions are so intense (e.g., Norma). The factors driving static and dynamic distortions are currently unknown, but we suspect that these qualitative differences reflect differences in the neurophysiological mechanism underlying each type of distortion.

Two other variations in the characteristics of the distortions are worth noting. Evidence from both behavioral studies in humans (Bruce & Young, 1986; Young & Burton, 2018) and neurophysiological work in macaques (Landi et al., 2017; Landi & Freiwald, 2021) and humans (Deen et al., 2024) indicates that unfamiliar faces and familiar faces engage different mechanisms. Studies of PMO reinforce that conclusion. In one case, distortions were present only on familiar faces (Heutink et al., 2012). The patient refused to allow her grandchildren to sit on her lap because she found them "strange or even repulsive"; in contrast, strangers' faces looked normal to her (Heutink et al., 2012). Conversely, in another case, only unfamiliar faces were distorted (Seron et al., 1995). A third patient reported that unfamiliar faces were more distorted than familiar faces (Jiang et al., 2017), and several cases in Table 1 report modulation by familiarity (e.g., Nagel, A.S.).

Then there is the difference between faces in real life and images. V.S. sees distortions in all faces in daily life, but during the five years that his distortions have persisted, he has not seen distortions in faces on screens, except under one specific condition, which I describe below (Mello et al., 2024a). Several of our participants have reported the opposite pattern: they see distortions almost exclusively in faces viewed on screens and in printed photographs. The double dissociation between 2D and 3D faces in these participants suggests a qualitative difference in the mechanisms engaged by faces in daily life and those on screens, which has interesting implications for laboratory research investigating face processing (Eng et al., 2017; Liu et al., 2020).

Several cases in Table 1 stand out. Aurora has seen distortions on every face since January 2024, several months after she suffered a right occipital stroke. Her distortions are extremely intense. Faces have black eyes and lips, misshapen and displaced features, discolored skin, and pointy chins and ears, which give them a witch-like appearance. Like all of our participants, Aurora recognizes that the distortions do not correspond to reality, yet they remain profoundly distressing. Aurora's distortions are immediate and so intense that she is usually unable to determine age, race, or sex from the face. On the neck, Aurora sees a clear division between discolored skin above a border and normal skin below it. Cases like Aurora's, in which faces are severely distorted and seen as threatening, sometimes resembling supernatural beings such as devils and werewolves, have been referred to as paraprosopia (Kemp et al., 2003; Whiteley & Warrington, 1977).

Norma is another case with severe distortions that preclude her from extracting information about the face she views. In the region where Norma would normally see a face, she instead sees what she likens to the static on an old television. Sometimes, though, the affected region is limited to a horizontal swath over the eyes. Finally, two people in Table 1 see another face superimposed in front of the actual face. A.X.B. sees three different types of semi-transparent superimposed faces a few inches in front of the actual face. She also occasionally sees outlines of shapes over facial features that have a similar structure (e.g., a triangle in front of a nose). At the age of 7, while looking at her father, A.X.B. saw the nose and forehead of Sitting Bull, the Native American leader, overlapping the corresponding regions of her father's face. In the period leading up to this experience, A.X.B. had viewed a well-known photograph of Sitting Bull. She continues to see this distortion more than 20 years later when a face has features that resemble Sitting Bull's. In addition to Sitting Bull's face, A.X.B. sometimes sees a superimposed celebrity or animal face that resembles the face she is viewing.

Neural correlates of face distortions

In the 51 cases reviewed by Herald et al. (2023), the results of structural scans were available for 48 cases, and lesions to visual regions were present in 44 cases (92%). This percentage differs markedly from what we observe in the PMO participants tested in my laboratory and in our PMO contacts. None of the six PMO participants we scanned has visible lesions in visual regions, and only around 10% of my laboratory's 250+ PMO contacts are aware of events that may have triggered their distortions. We suspect that the discrepancy between the literature and our PMO pool is due primarily to the different means by which these two groups have come to the attention of researchers. Most individuals reported in the literature have experienced a neurological event that led to hospitalization or at least a clinic visit. On the other hand, anyone with distortions can contact my laboratory through our website. Consequently, we believe the literature substantially overrepresents the proportion of people with PMO who have suffered neurological problems requiring clinical attention, though we cannot rule out that they are underrepresented in our cohort.

In those cases without easily detected lesions, the distortions may result from more subtle neural abnormalities. What are those? Face localizer studies using fMRI in A.D. (Almeida et al., 2020), V.S., Nagel, A.S. (Dalrymple et al., 2014), and Leona (Table 1) revealed no functional abnormalities in posterior face-selective areas. Zed, however, had reduced face-selectivity in the right occipital face area (Gauthier et al., 2000) and the right posterior fusiform face area (Kanwisher et al., 1997; Grill-Spector & Weiner, 2014), which resulted from a weak response to faces (Fortner et al., under review). Other areas in Zed's face network exhibited normal face-selectivity. It is worth noting, though, that in addition to his face distortions, Zed scored in the prosopagnosic range on tests of face memory (Fortner et al., under review) and therefore may have concomitant developmental prosopagnosia, in which reduced face selectivity is common (Furl et al., 2011; Jiahui et al., 2018; Stehr et al., in press). Although A.S.'s face localizer results were unremarkable, a second fMRI study found that the strength of the response in the right OFA and the right FFA to a face was positively correlated with the perceived intensity of the distortion (Dalrymple et al., 2014). While we need far more fMRI data from PMO participants for firm conclusions, Zed's and A.S.'s results suggest that the right OFA and right FFA may be significant contributors to face distortions. That tentative conclusion is consistent with studies of direct intracranial stimulation to face-selective areas. Stimulation of left hemisphere face areas has only rarely generated face distortions (Rangarajan et al., 2014). Stimulation of the face area in the anterior fusiform gyrus (Rossion et al., 2024) disrupts the ability to recognize facial identity but does not seem to impact the appearance of faces (Jonas et al., 2015; Jonas & Rossion, 2021). However, stimulation of the right OFA and the right posterior fusiform gyrus has been shown repeatedly to distort the appearance of faces (Jonas et al., 2012, 2014, 2018; Mundel et al., 2003; Parvizi et al., 2012; Rangarajan et al., 2014; Schalk et al., 2017; Schrouff et al., 2020).

White matter deficits are a common feature in cases with face distortions. Few of the cases in the literature have undergone diffusion-weighted imaging (DWI) scans to precisely measure white matter characteristics, but the descriptions of the lesions in many cases often note white matter damage. Twenty out of the 34 cases with hemi-PMO in our recent review had damage to the splenium (Herald et al., 2023), the most posterior section of the corpus callosum, which carries visual information between hemispheres. We have found clear white matter abnormalities in three of the six PMO cases we have conducted DWI scans with. Zed, who has lifelong face distortions, had reduced white matter integrity in three tracts, most substantially in the left inferior front-occipital fasciculus (Fortner et al., under review). In unpublished results from Willie (Table 1), who experiences mouth-specific distortions (Kidder & Duchaine, 2023), and from A.S., deficits were observed in several white-matter tracts, including the splenium and body of the corpus callosum.

Evidence for a developmental variant of PMO

The overwhelming majority of cases with face distortions in the literature acquired their distortions as adults, and the same is true for my laboratory's PMO contacts. However, many neuropsychological disorders impacting the brain can be caused by either acquired damage or developmental factors, and the acquired form is usually documented in the literature before the developmental variant. In the case of prosopagnosia, it was recognized relatively early on that brain damage could produce severe face recognition deficits (Bodamer, 1947; Hoff & Pötzl, 1937; Wilbrand, 1892; see Barton & Moritz, 2025 for English translations of these three articles). While there were a few early hints of developmental prosopagnosia (Bornstein, 1966; Wigan, 1844), the first article about it was published in 1976 (McConachie, 1976) and it was not until the start of the 21st century that developmental prosopagnosia received sustained research attention (Behrmann & Avidan, 2005; Bentin et al., 1999; Duchaine, 2000; de Haan, 1999; Nunn et al., 2001). To date, only one article has described an individual with lifelong facial distortions (Blom et al., 2014). However, we have encountered more cases, which suggests that lifelong, developmental PMO may be more common than the literature indicates. Zed reports experiencing face distortions throughout his life with no identifiable onset (Fortner et al., under review). Similarly, Ezri, a woman in her early thirties, experiences bilateral-PMO affecting both the shape and texture of faces and has no recollection of ever not seeing these distortions (Mello et al., 2024b). Intriguingly, when both Ezri and another PMO participant with lifelong facial and body distortions discussed their experiences with family members, they discovered that relatives also reported high-level visual distortions. Ezri's mother recalled experiencing salient facial distortions on at least five occasions, while two of the other woman's teenage daughters had had episodes of distorted arm length and faces. These family histories suggest that genetic factors contribute to face distortions in some cases.

Psychological impact of face distortions

Face distortions have a profound impact on the well-being of people who experience them. PMO's detrimental effects are clear from the literature (Blom et al., 2021) and from conversations we have had with people suffering from it. Distortions during face-to-face interactions are unsettling and distracting, and they push people with PMO to pull back from social situations. Terry (Table 1) rarely left his flat for a year after his distortions emerged. We spoke with a college-aged woman who withdrew from her classes and avoided meeting friends after she began seeing faces with tiny eyes and large foreheads. She feared she was "going crazy". Several of our participants, including Terry, were prescribed anti-psychotic drugs because their distortions were mistakenly considered a sign of a psychiatric disorder. Some participants have not told others about their distortions for fear of what others might think, and one person informed his partner about his intense, daily distortions only after they had been together for 15 years. V.S. was in shock after he woke up one morning to a world of faces like those in Figure 1. A woman from Belgium told us, "I had the impression of being in a horror movie." A.S. fell into a suicidal depression due to feelings of isolation and hopelessness brought on by her distortions. These effects motivate investigations of interventions that can reduce or eliminate face distortions, and as mentioned above, we have results demonstrating that certain colors ameliorate distortions in some participants (Mello et al., 2024b). In addition, the presence of eyeglasses on the face being viewed reduces the intensity of distortions in some individuals.

Using face distortions to investigate theoretical questions

In the remainder of the chapter, I review three topics for which PMO studies can address questions about face processing and visual recognition in typical visual systems. Research on face distortions offers three advantages over other neuropsychological conditions affecting face perception. First, salient distortions make PMO easier to investigate than prosopagnosia. Studying the latter often necessitates the development of sensitive behavioral measures. This process involves multiple stages: iterative pilot testing and task refinement, data collection from matched controls, and interpretation of prosopagnosic performance in comparison to control performance, which can be challenging for some results (Garrido et al., 2018). For most PMO studies it is not necessary to create tasks with appropriate levels of difficulty or to test control subjects, because others do not see distortions when viewing faces or other visual stimuli. Instead, researchers can simply present PMO participants with stimuli and ask them to describe what they see or rate the intensity of their distortions. The unmistakable nature of severe distortions also means that a small number of trials can produce clear results (e.g., Figure 2).

Second, many participants with PMO see distortions in almost all the faces they encounter in daily life. When some faces are not distorted or are less distorted, participant are sometimes able to identify factors that modulate their distortions. When these observations are shared with researchers, they can prompt new investigations. Our lab was first alerted to the possibility that eyeglasses can reduce distortions by Nagel and Terry. Many participants have mentioned that the degree of asymmetry between the left and right halves of a person's face is positively associated with the intensity of their distortions for that face. Early results from studies investigating these factors indicate that both eyeglasses and asymmetry influence distortions in many cases.

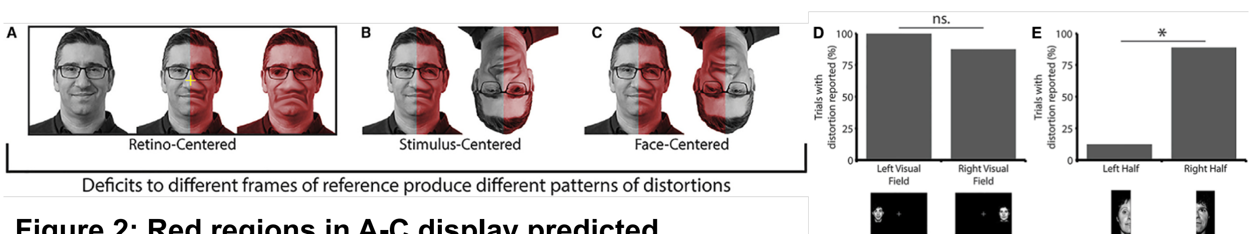
Finally, some evidence from the literature suggests that representations supporting awareness of faces may differ from those supporting judgments based on face information (Blom et al., 2021). If this distinction actually exists, it would be similar to the perception / action dissociation first revealed through investigations of D.F. (Milner & Goodale, 2006). When research on face processing abnormalities such as prosopagnosia relies on comparisons of behavioral performance between neuropsychological participants and controls, it is unclear if the relevant representations influence the appearance of faces. Research into face distortions in PMO, however, is unambiguous: it is always an investigation of representations that give rise to conscious awareness of faces.

Distortions reveal the reference frames used for face and object perception

A reference frame refers to the coordinate system in which a visual representation is encoded. All visual stimuli must be represented within a coordinate reference frame, yet little is known about the reference frames that support face perception. Word recognition is the one area of visual recognition in which significant progress has been made toward understanding reference frames (Caramazza & Hillis, 1990; Hillis & Caramazza, 1995; Vallar et al., 2010). The methods and resulting theories from this work provide a framework for studying reference frames for faces and other stimuli (Almeida et al., 2020).

Reference frames for word representation have been investigated in neglect dyslexia. Patients with this condition have difficulty reading one-half of a word. For example, a patient might read the word 'butter' as "jitter". Some cases of neglect dyslexia exhibit retino-centered deficits, meaning that the location of the word in the visual field influences performance (Hillis & Caramazza, 1995). However, in stimulus-centered and word-centered neglect dyslexia, the disrupted representation is allocentric, in that the visual field position of the word makes no difference (Vallar et al., 2010). In right-sided stimulus-centered neglect dyslexia, the word "reef" might be read as "real", but if presented mirror-reversed horizontally, it could be read as "chef". Thus the error is always on the right side, whether the word is written from left to right or right to left. In contrast, a deficit in a word-centered representation causes consistent errors in the first half or the second half of the word, regardless of how the word is presented. Hence, "reef" might be read as "chef" or "fief", regardless of whether it was written in a typical manner, mirror-reversed horizontally, or vertically-oriented. At the stage that is disrupted in word-centered neglect dyslexia, the word is still encoded spatially, but this representation is divorced from the manner in which the word is presented.

This approach has been adapted for participants with face distortions to identify reference frames used in face representation (Almeida et al., 2020). Through simple stimulus manipulations with a patient with right hemi-PMO, we tested predictions made by three frames of reference: retino-centered, stimulus-centered, and face-centered (Figure 2, A-C). The retino-centered account suggests distortions should be present on parts of faces in the right visual field and absent on parts of faces in the left visual field. In contrast, both the stimulus-centered and the face-centered frames predict that visual field position will not affect distortions. However, they make different predictions about left and right half-faces and for faces presented at different picture-plane orientations. Disruption in a stimulus-centered representation should produce distortions on the viewer's right-hand side of both left halves, right halves, and full faces seen at different picture-plane orientations (Figure 2B). Distortions in a face-centered



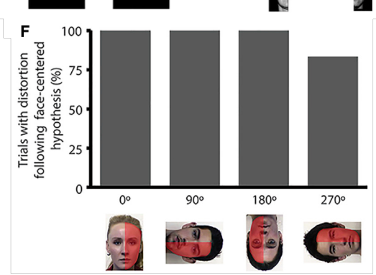


Figure 2: Red regions in A-C display predicted distortions for each of the three reference frames for right hemi-PMO. Patient A.D. sees distortions on the right side of the face regardless of visual field position (D) or face half (E). Panel F shows that, on trials in which A.D. saw distortions, the distortions affected the red-shaded region of the presented face on every 0°, 90°, and 180° faces and nearly all 270° faces. Together, the findings demonstrate that A.D.'s distortions occur in a face-centered reference frame (C).

representation should affect the same region of the face regardless of how the face is presented (Figure 2C). A.D.'s face distortions were unaffected by visual field position (Figure 2D), far more common on right halves than left halves (Figure 2E), and present on the same region of the face regardless of picture-plane orientation (Figure 2F). Hence, A.D.'s hemi-PMO affects a face-centered representation (Almeida et al., 2020). Structurally, A.D. has a selective lesion to the left splenium. As a result, his distortion seems to reflect disrupted hemispheric transmission, potentially between face-selective areas.

The study of A.D.'s distortions was the first to demonstrate face-centered distortions, but since then, we have collected results indicating that other three participants also have face-centered distortions. Willie (Table 1) perceives distortions to mouths, such as elongation and even mouth perseveration, in which the mouth seen a few seconds before is superimposed on the current view of the mouth. Distortions limited to the mouth region in upright faces could reflect a disruption of face-centered representation of the mouth region, or a stimulus-centered distortion that affects the lower part of the face stimulus regardless of whether a face is upright or inverted (e.g., the mouth in an upright face; the eyes in an inverted face). To determine if Willie's distortions reflect stimulus-centered or face-centered distortions, we examined the effect of manipulating the picture-plane orientation of faces (Kidder & Duchaine, 2023). Willie saw mouth distortions at all orientations and did not see distortions to the lower part of the stimulus in the faces rotated 90°, 180°, and 270° from upright. This is consistent with a face-centered account, rather than a stimulus-centered one. Similarly, V.S. perceives the same set of bilateral distortions in both upright and inverted faces (Mello et al., 2023), which implicates face-centered representations. Finally, testing of Nagel's right hemi-PMO (Figure 1), which was modeled on the studies with A.D., yielded results comparable to those displayed in Figure 2. Nagel saw distortions regardless of visual field position, only saw distortions to the right half of the face, and perceived distortions to the same part of the face across all picture-plane orientations (Mello et al., 2025).

These results provide strong evidence that face perception involves face-centered reference frames. However, there is some evidence for stimulus-centered frames in a few patients. Two hemi-PMO cases tested with faces rotated in the picture plane experienced distortions consistent with disruptions to stimulus-centered representations (Hishizawa et al., 2015; Nagaishi et al., 2015). For example, following an infarct of the right splenium, the patient in Nagaishi et al. (2015) saw a variety of distortions on the side of faces to the left of fixation regardless of picture-plane orientation. Further testing of potential stimulus-centered cases is needed, as evidence of a stimulus-centered reference frame for faces would not only demonstrate a previously unknown stage of face processing but would also indicate that, even though face and word representations depend on dissociable mechanisms, the two processes depend on similar types of reference frames (Almeida et al., 2020).

Many participants report seeing distortions only in faces (e.g., A.D., Aurora, Willie), but those who see distortions in other stimuli provide a means to explore the reference frames in object recognition. Nagel, our participant with right hemi-PMO, also perceives distortions on the right-hand side of hands and some objects (Mello et al., 2025). Testing with hands similar to the testing with faces revealed that Nagel sees distortions in both visual fields and only on the right side of the hand. These results are comparable to his face results. However, when Nagel saw hands at different picture-plane orientations, the distortion appeared on different parts of the hand at different orientations because he saw distortions almost exclusively on the right side of the hand from his viewer-centered perspective. Thus, while Nagel's face distortions are face-centered, his hand distortions appear to be stimulus-centered (Mello et al., 2025). Similar testing at different picture-plane orientations with objects that have clear canonical orientations also indicates that Nagel's object distortions are stimulus-centered.

Representations of face halves and the hemispheric organization of face perception
One of the most noticeable differences between PMO cases is the region of the face affected by distortions. In bilateral-PMO, distortions are~~ present on~~ both the left and right halves of the face (Blom et al., 2021; Herald et al., 2023), whereas ~~in~~ hemi-PMO, distortions are limited to one half of the face (Almeida et al., 2020; Grüsser & Landis, 1991; Saito et al., 2014). Figure 1 shows that Nagel's stereotypical distortion impacts only the right half of the face. When he was presented with 18 upright faces at fixation, he saw distortions in the right half of every face and no distortions in the left half (Mello et al., 2025). Nagel's case also demonstrates that distortions in hemi-PMO can affect even individual facial features in a partial manner, with basic components such as the nose or mouth showing alterations on only one side of the feature. Figure 3 presents Leona's (Table 1) drawing of her right-sided distortions, providing a depiction of the positional shifts she experiences. As she views a face, features on the right half shift position; the eye and eyebrow usually move up, and the cheek and mouth can also be affected.

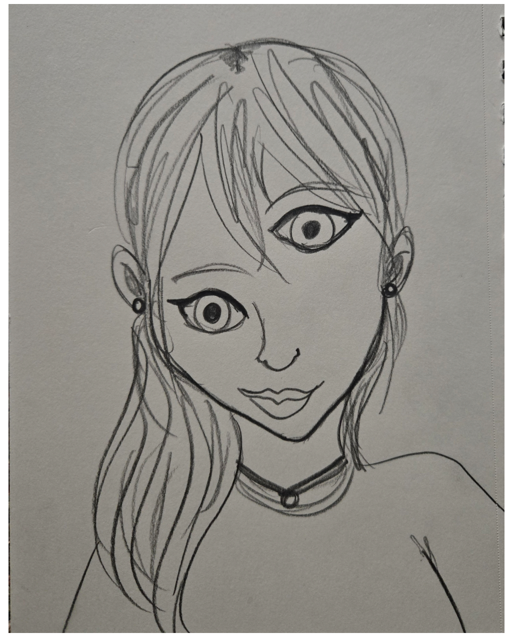


Figure 3: Leona's sketch illustrating her right hemi-PMO. Her distortions vary in intensity; she considers this an example of an intense distortion.

Hemi-PMO indicates that each half of the face is represented independently, at least early in the face processing stream, and that the vertical meridian of the face is a critical representational division. This division in face perception exhibits some similarities to the role of the midline in two other visual processing disorders. Patients with neglect dyslexia have difficulty reading one-half of written words, as described in the previous section (Caramazza and Hillis, 1990). For N.G., who had right neglect dyslexia, nearly all reading errors occurred at or to the right of the word's center, and the errors followed a gradient pattern in which letters positioned further from the midline on the neglected side exhibited progressively higher error rates. Similarly, the midline is critical in cases of object-based neglect, as in P.P., who would copy only the left halves of objects regardless of whether they appeared on the left or right side of the screen (Driver and Halligan, 1991). Although forms of neglect are usually conceptualized as attentional disorders whereas hemi-PMO appears to be a representational deficit, these findings across face processing, word reading, and object perception suggest that the vertical meridian serves as a fundamental division in high-level vision.

The position of distortions in cases with unilateral lesions also provides evidence about the neural basis of half-face representations (Herald et al., 2023). Figure 4 shows that all 14 PMO cases with unilateral left hemisphere lesions had distortions only to the right half of the face (Almeida et al., 2020; Anbarasan & Howard, 2012; Cho et al., 2011; Ganssauge et al., 2012; Imai et al., 1995; Jiang et al., 2017; Jung et al., 2018; Lee, 2015; Nijboer et al., 2008; Safran et al., 1999; Satoh et al., 1997; Trojano et al., 2009). In contrast, in cases with right hemisphere lesions, nine had distortions to the left half (Brust & Behrens, 1977; Ebata et al., 1991; Ganssauge et al., 2012; Miwa & Kondo, 2007; Nagaishi et al., 2015; Nijboer et al., 2008; Ogawa

		Side of Distortion		
		Left Face	Right Face	Bilateral
Lesion Location	Left Hemisphere	0	14	0
	Right Hemisphere	9	7	7

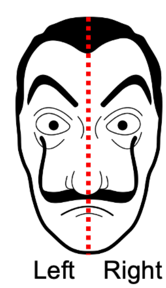


Figure 4: Table showing the relationship between the side of the face that is distorted and lesion location in PMO cases with unilateral lesions. The sketch of Salvador Dalí on the right displays the half of the face affected by left- and right-sided distortions.

et al., 2020; Saito et al., 2014; Schroeder et al., 2017), seven to the right half (Cho et al., 2011; Funatsu et al., 2017; Hishizawa et al., 2015; Phua et al., 2019; Tokida & Tagawa, 2014; Jung et al., 2018; Kamikubo et al., 2008), and seven had bilateral distortions (Bala et al., 2015; Heo et al., 2004; Hwang et al., 2012; Jung et al., 2018; Kim et al., 2016; Seron et al., 1995; Whiteley & Warrington, 1977). This pattern implies an organization in which high-level face processes in the left hemisphere, possibly posterior face-selective areas, represent only right halves of faces, regardless of visual field position. In contrast, left halves are exclusively represented in high-level right-hemisphere areas. The occurrence of bilateral distortions with right hemisphere lesions indicates that the two face halves are fused in this hemisphere.

Little behavioral testing, however, has been done to understand the distortions of most hemi-PMO cases who have unilateral lesions. Some cases may actually have retino-centered distortions due to early visual damage (Fig 2A)(Ganssauge et al., 2012; Safran et al., 1999). In addition, we have tested some individuals who believed that their distortions were limited to one half of the face until they noticed distortions on both halves during formal testing. To test the organization suggested by the patterns in the table in Figure 4, it will be crucial to assess more cases with unilateral lesions using approaches similar to those conducted with A.D. (Almeida et al., 2020) and Nagel. When reporting test results, it is critical to indicate unambiguously which side of the face was distorted, since some studies define the side from the participant's point of view, others from the perspective of the face being observed, and some fail to make the distorted side clear. Handedness may be important to record as well. The fusion of face halves may occur in the left hemisphere in some left-handers (Bukowski et al., 2013), which may be evidence for reversed laterality.

Face-specific distortions implicate face-specific mechanisms

Despite the intensive research on visual recognition in the occipitotemporal cortex, the organization of visual recognition mechanisms remains unclear. The leading accounts can be divided into three families. The modular account is motivated by neurological dissociations between different categories of stimuli, as well as by early fMRI studies that found regions with strong responses to categories such as faces (Kanwisher et al., 1997; Puce et al., 1996), bodies (Downing et al., 2001), places (Aguirre et al., 1998; Epstein & Kanwisher, 1998), and words (Puce et al., 1996). These results supported the view that these category-selective areas are specialized modules dedicated to a preferred object category (Conway, 2018; Kanwisher, 2017). This modular view has been buttressed by studies in which disruption of category-specific areas produced category-specific effects (Dilks et al., 2013; Gaillard et al., 2006; Jonas & Rossion, 2021; Pitcher et al., 2009) as well as intracranial recordings from category-selective areas that revealed highly selective responses (Gaillard et al., 2006; Hagen et al., 2020; Hirshorn et al., 2016).

Distributed theories propose that visual recognition instead depends on the pattern of responses across occipitotemporal cortex. According to this view, the patterns of activation seen for different stimuli, including the peaks of activation observed in putative category-selective areas, reflect general principles that structure this region of cortex. One dimension that may be an organizing principle is real-world object size (Konkle & Caramazza, 2013; Konkle & Oliva, 2012). Responses to variation in real-world object size show a gradient pattern across the occipitotemporal cortex, with small objects driving strong responses in central regions of the medial-lateral axis and larger objects producing greater activation in more peripheral regions. A second dimension may be animacy (Kriegeskorte et al., 2008; Sha et al., 2015). Studies suggest a gradient running from objects perceived as highly animate (e.g., humans, other primates) in lateral regions to inanimate objects in medial regions (Konkle & Caramazza, 2013; Kriegeskorte et al., 2008; Long et al., 2018). Finally, based on fMRI and single-unit recording in macaques, it was proposed that the animate-inanimate gradient, along with a spikiness-stubbiness dimension (i.e., roughly corresponding to the ratio between height and width), can account for the organization of visual recognition (Bao et al., 2020). A third possibility that combines these views is that visual recognition has a hybrid architecture, with category-selective modules that preferentially process specific categories and more general-purpose regions with dimensional gradients (Bao et al., 2020; Op de Beeck et al., 2008).

Much of the most revealing evidence about the organization of visual object recognition has come from dissociations in studies involving neuropsychological participants, transcranial magnetic stimulation (TMS), and intracranial stimulation. While these findings have provided some of the best evidence for category-specific mechanisms, the studies have always involved only a modest number of object categories due to practical constraints. A resulting concern is that work assessing visual recognition has not sampled object space comprehensively enough to provide a decisive distinction between category-specific and dimensional accounts. Testing individuals with high-level visual distortions, however, offers a rapid means to assess relationships across many sectors of object space.

Category	# of photos	A.S. Distortions	Aurora Distortions
Faces	100	100	100
Objects (500 x 2)	1000	0	0
Body Parts (10 x 2)	20	0	0
Animal Faces (10 x 2)	20	0	4
Doll Faces	10	0	10
Symbolic Faces	10	0	8
Total	**1160**		

Figure 5: THINGS PMO images and results. Top: Examples of photos. Bottom Table: Distortions reported by A.S. and Aurora by category.

Among the 51 cases in our PMO review (Herald et al., 2023), 39 reported distortions that affected only faces. Face-selective PMO provides some of the most compelling evidence for face specificity, as such cases experience distortions on most or on every face they encounter for years, while not seeing distortions on any non-face objects. In cases who perceive distortions for other objects, the distortions are often limited to only a few categories, with hands and arms being reported most often (Blom et al., 2020; Grüsser & Landis, 1991; Hécaen et al., 1957; Mehta et al., 2017; Mooney et al., 1965). However, the specificity of PMO needs to be tested rigorously by presenting large sets of non-face stimuli to participants. To evaluate the scope of distortions in participants with PMO, we selected 1,160 photographs drawn primarily from the THINGS image set (Hebart et al., 2019). The set consisted of 100 photos of faces - to confirm that a participant was experiencing face distortions during the testing period – as well as 1000 photos of objects, and an additional 60 photos of other categories of special interest (body parts, animal faces, doll faces). To increase the chances of observing object distortions, we selected objects that generated the strongest response in an artificial neural network-based encoding model that estimates the response of the right fusiform face area to images (Contier et al., 2022; Murty et al., 2020).

Five PMO participants have now viewed the THINGS PMO image set (Kerns et al., 2025). Several participants, including Nagel, saw distortions in faces and a substantial number of objects. However, the image set was also viewed by two PMO cases who have never seen distortions for non-face objects in daily life, namely A.S. and Aurora (described above). A.S. and Aurora saw no distortions in the 1000 objects and 20 body parts they viewed (Figure 5), but did see distortions in all 100 human faces. Aurora also saw distortions in most photographs from the other face categories (e.g., dolls, animals). This procedure provides a far more thorough sampling of object space than previous studies of prosopagnosia (Barton et al., 2019; Busigny et al., 2010; Duchaine et al., 2006). A.S.'s and Aurora's results, combined with the face-specific nature of their day-to-day distortions, strongly indicate that face perception relies, at least in part, on face-specific mechanisms. In combination with Mr. C.K.'s well-documented case of severely disrupted object perception coupled with intact upright face perception (Moscovitch & Moscovitch, 2000; Moscovitch et al., 1997), their findings constitute a double dissociation that implicates the existence of specialized face perception systems.

The patterns found in participants with distortions for faces and other objects may also provide intriguing clues about the organization of visual recognition. For example, a 62-year-old right-handed woman suddenly began perceiving the right side of people's faces—including her own—and right hands as swollen and stretched (Grüsser & Landis, 1991). Magnetic resonance imaging revealed small infarcts on both sides of the splenium of the corpus callosum, with the larger lesion on the left extending into the parahippocampal gyrus. In both daily life and in formal testing, the patient's distortions were limited to faces and, for about two weeks, to hands. Selective association between faces and hands has been observed in other cases of PMO (Blom et al., 2020; Grüsser & Landis, 1991; Mehta et al., 2017; Mooney et al., 1965), suggesting a special relationship between face and hand perception. This may be due to separate but neighboring mechanisms, or to mechanisms that contribute to both face and hand perception but not to perception of other categories.

Summary

Prosopometamorphopsia is an extraordinary condition that has received little research attention (Blom et al., 2021) but holds promise as a means to advance our understanding of fundamental aspects of face perception and visual processing. PMO cases offer unique advantages for investigating theoretical questions. Results so far have revealed face-centered reference frames (Almeida et al., 2020) as well as the independent representation of face halves and the hemispheric organization of these representations (Herald et al., 2023). The remarkable face-specificity of distortions in cases like A.S. and Aurora constitutes powerful evidence for modular face-selective mechanisms. Other effects discussed only in passing here, such as dissociations between 2D vs 3D face processing (Mello et al., 2023), the influence of color on face appearance (Mello et al., 2024b), apparently normal face judgments despite intense face distortions (Fortner et al., under review), and the role of asymmetry in face distortions, indicate that future work may contribute to a wide range of issues. More generally, these investigations of face distortions demonstrate the enduring value of neuropsychological investigations by showing that careful single-case and case-series studies continue to shed light on cognitive and neural questions that are challenging to study with other approaches.

References

Aguirre, G. K., Zarahn, E., & D'Esposito, M. (1998). An area within human ventral cortex sensitive to "building" stimuli: Evidence and implications. *Neuron, 21,* 373–383.

Almeida, J., Freixo, A., Tábuas-Pereira, M., Herald, S. B., Valério, D., Schu, G., Duro, D., Cunha, G., Bukhari, Q., Duchaine, B., & Santana, I. (2020). Face-specific perceptual distortions reveal a view- and orientation-independent face template. *Current Biology, 30*(20), 4071–4077.e4.

Anbarasan, D., & Howard, J. (2012). Acute exacerbation of multiple sclerosis presenting with facial metamorphopsia and palinopsia. Multiple Sclerosis Journal, 19(3), 369–371.

Bala, A., Iwański, S., Żyłkowski, J., Jaworski, M., Seniów, J., & Marchel, A. (2015). Visual disorders, the prosopometamorphopsia and prosopagnosia type in the early days after the onset of brain hemorrhagic stroke: A case report. Neurocase, 21(3), 331–338.

Bao, P., She, L., McGill, M., & Tsao, D. Y. (2020). A map of object space in primate inferotemporal cortex. *Nature, 583*(7814), 103–108.

Barton, J. J. S., & Moritz, F. (2025). Foundations of prosopagnosia: The three classic Austro-German reports. *Cortex*, *193*, 1-15.

Barton, J. J., Albonico, A., Susilo, T., Duchaine, B., & Corrow, S. L. (2019). Object recognition in acquired and developmental prosopagnosia. *Cognitive Neuropsychology*, 1-31.

Behrmann, M., & Avidan, G. (2005). Congenital prosopagnosia: Face-blind from birth. *Trends in Cognitive Sciences, 9*(4), 180–187.

Bentin, S., Deouell, L. Y., & Soroker, N. (1999). Selective visual streaming in face recognition: Evidence from developmental prosopagnosia. *NeuroReport, 10*(4), 823.

Blom, J. D. (2020). *Alice in Wonderland Syndrome.* Cham, Switzerland: Springer Nature.

Blom, J. D., ter Meulen, B. C., Dool, J., & ffytche, D. H. (2021). A century of prosopometamorphopsia studies. *Cortex, 139,* 298–308.

Bodamer, J. (1947). Die Prosop-Agnosie (Die Agnosie des Physiognomieerkennens). *Archiv für Psychiatrie und Nervenkrankheiten, 179,* 6–53.

Bornstein, B. (1963). Prosopagnosia. In L. Halpern (Ed.), *Problems in dynamic neurology.* Hadassah Medical School.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77,* 305–327.

Brust, J. C. M., & Behrens, M. M. (1977). “Release hallucinations” as the major symptom of posterior cerebral artery occlusion: A report of two cases. Annals of Neurology, 2(5), 432–436.

Bukowski, H., Dricot, L., Hanseeuw, B., & Rossion, B. (2013). Cerebral lateralization of face-sensitive areas in left-handers: Only the FFA does not get it right. *Cortex, 49*(9), 2583–2589.

Busigny, T., Graf, M., Mayer, E., & Rossion, B. (2010). Acquired prosopagnosia as a face-specific disorder: Ruling out the general visual similarity account. *Neuropsychologia, 48*(7), 2051–2067.

Caramazza, A., & Hillis, A. E. (1990). Spatial representation of words in the brain implied by studies of a unilateral neglect patient. *Nature, 346*(6281), 267–269.

Chatterjee, G., & Nakayama, K. (2012). Normal facial age and gender perception in developmental prosopagnosia. *Cognitive Neuropsychology, 29*(5–6), 482–502.

Cho, J.-Y., Moon, S. Y., Hong, K.-S., Cho, Y.-J., Kim, S.-C., Hwang, S.-I., & Park, H. K. (2011). Teaching neuroimages: Unilateral prosopometamorphopsia as a dominant hemisphere-specific disconnection sign. *Neurology, 76*(22), e110.

Contier, O., Fujimori, S., Seeliger, K., Murty, N. A. R., & Hebart, M. (2022). Revealing interpretable object dimensions from a high-throughput model of the fusiform face area. *Journal of Vision, 23*(9), 5356–5356.

Conway, B. R. (2018). The organization and operation of inferior temporal cortex. *Annual Review of Vision Science, 4,* 381–402.

Dalrymple, K. A., Davies-Thompson, J., Oruc, I., Handy, T. C., Barton, J. J. S., & Duchaine, B. (2014). Spontaneous perceptual facial distortions correlate with ventral occipitotemporal activity. *Neuropsychologia, 59,* 179–191.

De Haan, E. H. (1999). A familial factor in the development of face recognition deficits. *Journal of Clinical and Experimental Neuropsychology, 21*(3), 312–315.

Deen, B., Blank, I., Waller, R., Chafee, M. V., & Kanwisher, N. (2024). A familiar face and person processing area in the human temporal pole. *Proceedings of the National Academy of Sciences, 121*(33), e2321346121.

Dilks, D. D., Julian, J. B., Paunov, A. M., & Kanwisher, N. (2013). The occipital place area is causally and selectively involved in scene perception. *Journal of Neuroscience, 33*(4), 1331–1336.

Downing, P. E., Jiang, Y., Shuman, M., & Kanwisher, N. (2001). A cortical area selective for visual processing of the human body. *Science, 293,* 2470–2473.

Driver, J., & Halligan, P. W. (1991). Can visual neglect operate in object-centered co-ordinates? An affirmative single-case study. *Cognitive Neuropsychology, 8*(6), 475–496.

Duchaine, B. (2000). Developmental prosopagnosia with normal configural processing. *NeuroReport, 11*(1), 79–83.

Duchaine, B. C., Yovel, G., Butterworth, E. J., & Nakayama, K. (2006). Prosopagnosia as an impairment to face-specific mechanisms: Elimination of the alternative hypotheses in a developmental case. *Cognitive Neuropsychology, 23*(5), 714–747.

Ebata, S., Ogawa, M., Tanaka, Y., Mizuno, Y., & Yoshida, M. (1991). Apparent reduction in the size of one side of the face associated with a small retrosplenial haemorrhage. Journal of Neurology, Neurosurgery & Psychiatry, 54(1), 68–70.

Eng, Z. H. D., Yick, Y. Y., Guo, Y., Xu, H., Reiner, M., Cham, T. J., & Chen, S. H. A. (2017). 3D faces are recognized more accurately and faster than 2D faces, but with similar inversion effects. *Vision Research, 138,* 78–85.

Epstein, R., & Kanwisher, N. (1998). A cortical representation of the local visual environment. *Nature, 392,* 598–601.

Fortner, S., Mello, A., Stehr, D., Kodiweera, C., Jun, H., Bujarski, K., Wager, T., & Duchaine, B. (under review). The first comprehensive case study of early-emerging prosopometamorphopsia.

Funatsu, N., Hayakawa, M., Tokuda, N., & Toyoda, K. (2017). Transient prosopometamorphopsia restricted to the left eye caused by ischemia at the right splenium of the corpus callosum. Internal Medicine, 56(21), 2933–2935.

Furl, N., Garrido, L., Dolan, R., Driver, J., & Duchaine, B. (2011). Fusiform gyrus face selectivity reflects facial recognition ability. *Journal of Cognitive Neuroscience, 23*(7), 1723–1740.

Gaillard, R., Naccache, L., Pinel, P., Clemenceau, S., Volle, E., Hasboun, D., Clémenceau, S., & Dehaene, S. (2006). Direct intracranial, fMRI, and lesion evidence for the causal role of left inferotemporal cortex in reading. Neuron, 50, 191–204.

Ganssauge, M., Papageorgiou, E., & Schiefer, U. (2012). Facial dysmorphopsia: A notable variant of the “thin man” phenomenon? Graefe’s Archive for Clinical and Experimental Ophthalmology, 250(10), 1491–1497.

Garrido, L., Duchaine, B., & DeGutis, J. (2018). Association vs dissociation and setting appropriate criteria for object agnosia. Cognitive Neuropsychology, 35, 55–58.

Gauthier, I., Tarr, M. J., Moylan, J., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). The fusiform “face area” is part of a network that processes faces at the individual level. Journal of Cognitive Neuroscience, 12(3), 495–504.

Grill-Spector, K., & Weiner, K. S. (2014). The functional architecture of the ventral temporal cortex and its role in categorization. Nature Reviews Neuroscience, 15(8), 536–548.

Grüsser, O. J., & Landis, T. (1991). Faces lost: Prosopagnosia. In M. J. Farah & G. Ratcliff (Eds.), Visual agnosias and other disturbances of visual perception and cognition (Vision and Visual Dysfunction, Vol. 12, pp. 259–286). Macmillan.

Hagen, S., Jacques, C., Maillard, L., Colnat-Coulbois, S., Rossion, B., & Jonas, J. (2020). Spatially dissociated intracerebral maps for face- and house-selective activity in the human ventral occipito-temporal cortex. Cerebral Cortex, 30, 4026–4043.

Hebart, M. N., Dickter, A. H., Kidder, A., Kwok, W. Y., Corriveau, A., Van Wicklin, C., & Baker, C. I. (2019). THINGS: A database of 1,854 object concepts and more than 26,000 naturalistic object images. PLoS ONE, 14(10), e0223792.

Hécaen, H., Angelergues, R., Bernhardt, C., & Chiarelli, J. (1957). Essai de distinction des modalités cliniques de l’agnosie des physionomies. Revue Neurologique (Paris), 96(2), 125–144.

Heo, K., Cho, Y. J., Lee, S.-K., Park, S. A., Kim, K.-S., & Lee, B. I. (2004). Single-photon emission computed tomography in a patient with ictal metamorphopsia. Seizure, 13(4), 250–253.

Herald, S. B., Almeida, J., & Duchaine, B. (2023). Face distortions in prosopometamorphopsia provide new insights into the organization of face perception. Neuropsychologia, 182, 108517.

Heutink, J., Brouwer, W. H., Kums, E., Young, A., & Bouma, A. (2012). When family looks strange and strangers look normal: A case of impaired face perception and recognition after stroke. Neurocase, 18(1), 39–49.

Hillis, A. E., & Caramazza, A. (1995). A framework for interpreting distinct patterns of hemispatial neglect. Neurocase, 1(3), 189–207.

Hirshorn, E. A., Li, Y., Ward, M. J., Richardson, R. M., Fiez, J. A., & Ghuman, A. S. (2016). Decoding and disrupting left midfusiform gyrus activity during word reading. Proceedings of the National Academy of Sciences, 113(29), 8162–8167.

Hishizawa, M., Tachibana, N., & Hamano, T. (2015). [A case of left hemifacial metamorphopsia by a right retrosplenial infarction]. Rinsho Shinkeigaku, 55, 87–90.

Hoff, H., & Pötzl, O. (1937). Über eine optisch-agnostische Störung des „Physiognomie-Gedächtnisses“ (Beziehungen zur Rückbildung einer Wortblindheit). Zeitschrift für die gesamte Neurologie und Psychiatrie, 159, 367–395.

Hwang, J. Y., Ha, S. W., Cho, E. K., Han, J. H., Lee, S. H., Lee, S. Y., & Kim, D. E. (2012). A case of prosopometamorphopsia restricted to the nose and mouth with right medial temporo-occipital lobe infarction that included the fusiform face area. Journal of Clinical Neurology, 8(4), 311–314.

Imai, N., Nohira, O., Miyata, K., Okabe, T., & Hamaguchi, K. (1995). A case of metamorphopsia caused by a very localized spotty infarct. Rinsho Shinkeigaku (Clinical Neurology), 35(3), 302–305.

Jiahui, G., Yang, H., & Duchaine, B. (2018). Developmental prosopagnosics have widespread selectivity reductions across category-selective visual cortex. Proceedings of the National Academy of Sciences, 115, E6418–E6427.

Jiang, Y., Sasikumar, S., & Jin, A. Y. (2017). View-dependent prosopometamorphopsia after stroke. Canadian Journal of Neurological Sciences, 44, 613–614.

Jonas, J., & Rossion, B. (2021). Intracerebral electrical stimulation to understand the neural basis of human face identity recognition. European Journal of Neuroscience, 54(1), 4197–4211.

Jonas, J., Brissart, H., Hossu, G., Colnat-Coulbois, S., Vignal, J.-P., Rossion, B., & Maillard, L. (2018). A face identity hallucination (palinopsia) generated by intracerebral stimulation of the face-selective right lateral fusiform cortex. Cortex, 99, 296–310.

Jonas, J., Descoins, M., Koessler, L., Colnat-Coulbois, S., Sauvée, M., Guye, M., Vignal, J.-P., Vespignani, H., Rossion, B., & Maillard, L. (2012). Focal electrical intracerebral stimulation of a face-sensitive area causes transient prosopagnosia. Neuroscience, 222, 281–288.

Jonas, J., Rossion, B., Brissart, H., Frismand, S., Jacques, C., Hossu, G., Colnat-Coulbois, S., Vespignani, H., Vignal, J.-P., & Maillard, L. (2015). Beyond the core face-processing network: Intracerebral stimulation of a face-selective area in the right anterior fusiform gyrus elicits transient prosopagnosia. Cortex, 72, 140–155.

Jonas, J., Rossion, B., Krieg, J., Koessler, L., Colnat-Coulbois, S., Vespignani, H., Jacques, C., Vignal, J.-P., Brissart, H., & Maillard, L. (2014). Intracerebral electrical stimulation of a face-selective area in the right inferior occipital cortex impairs individual face discrimination. NeuroImage, 99, 487–497.

Jung, B.-K., Kim, K.-H., Lee, H.-C., Lee, J.-T., Hwang, Y.-H., & Kim, Y.-W. (2018). Prosopometamorphopsia in acute ischemic stroke. Journal of the Korean Neurological Association, 36, 40–42.

Kamikubo, T., Abo, M., & Yatsuzuka, H. (2008). [Case of long-term metamorphopsia caused by multiple cerebral infarction]. Brain and Nerve, 60(6), 671–675.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. Journal of Neuroscience, 17, 4302–4311.

Kemp, S., Young, A. W., Szulecka, K., & de Pauw, K. W. (2003). A case of paraprosopia and its treatment. Cognitive Neuropsychiatry, 8(1), 43–56.

Kerns, S., Mello, A., & Duchaine, B. (2025). Two cases of prosopometamorphopsia whose distortions are face-specific in daily life and in testing with 510 object categories. Journal of Vision, 25(9), 2911.

Kidder, A., & Duchaine, B. (2023). Mouth-specific distortions: Evidence from prosopometamorphopsia for independent representations of individual facial features. Journal of Vision, 23(9), 5006.

Kim, R., Jun, J.-S., Baek, S.-H., Yun, C.-H., & Park, S.-H. (2016). Postictal prosopometamorphopsia after focal status epilepticus due to cavernous hemangioma in the right occipital lobe. Journal of Clinical Neurology, 12(3), 371–374.

Konkle, T., & Caramazza, A. (2013). Tripartite organization of the ventral stream by animacy and object size. Journal of Neuroscience, 33(25), 10235–10242.

Konkle, T., & Oliva, A. (2012). A real-world size organization of object responses in occipito-temporal cortex. Neuron, 74(6), 1114–1124.

Kriegeskorte, N., Mur, M., Ruff, D. A., Kiani, R., Bodurka, J., Esteky, H., Tanaka, K., & Logothetis, N. K. (2008). Matching categorical object representations in inferior temporal cortex of man and monkey. Neuron, 60(6), 1126–1141.

Landi, S. M., & Freiwald, W. A. (2017). Two areas for familiar face recognition in the primate brain. Science, 357, 591–595.

Landi, S. M., Viswanathan, P., Serene, S., & Freiwald, W. A. (2021). A fast link between face perception and memory in the temporal pole. Science, 373(6554), 581–585.

Lee, C.-M. (2015). Splenial corpus callosum infarction presenting with unilateral prosopometamorphopsia: A case report. Dementia and Neurocognitive Disorders, 14(2), 94–96.

Liu, H., Laeng, B., & Czajkowski, N. O. (2020). Does stereopsis improve face identification? A study using a virtual reality display with integrated eye-tracking and pupillometry. Acta Psychologica, 210, 103142.

McConachie, H. R. (1976). Developmental prosopagnosia: A single case report. Cortex, 12(1), 76–82.

Mehta, U. M., Kumar, C. N., Venkatasubramanian, G., & Thirthalli, J. (2017). Multimodal sensory distortions in postpartum exacerbation of schizophrenia. Clinical Schizophrenia & Related Psychoses, 10(4), 222–224.

Mello, A., Garside, D., Stehr, D., Bujarski, K., Conway, B., & Duchaine, B. (2024b). Color robustly affects the intensity of facial distortions in two cases of prosopometamorphopsia. Journal of Vision, 24(10), 659.

Mello, A., Kodiweera, C., Stehr, D., Bujarski, K., & Duchaine, B. (2025). Visual perceptual distortions reveal an object-centered reference frame for faces and a stimulus-centered reference frame for hands. Journal of Vision, 25(9), 2804.

Mello, A., Stehr, D., Bujarski, K., & Duchaine, B. (2024a). Visualising facial distortions in prosopometamorphopsia. The Lancet, 403(10432), 1176.

Mello, A., Stehr, D., Bujarski, K., Störmer, V., & Duchaine, B. (2023). Strong modulation of face distortions in prosopometamorphopsia by color. Journal of Vision, 23(9), 5715.

Milner, A. D., & Goodale, M. A. (2006). The visual brain in action (2nd ed.). Oxford University Press.

Miwa, H., & Kondo, T. (2007). Metamorphopsia restricted to the right side of the face associated with a right temporal lobe lesion. Journal of Neurology, 254(12), 1765–1767.

Mooney, A. J., Carey, P., Ryan, M., & Bofin, P. (1965). Parasagittal parieto-occipital meningioma with visual hallucinations. American Journal of Ophthalmology, 59, 197–205.

Moscovitch, M., & Moscovitch, D. A. (2000). Super face-inversion effects for isolated internal or external features, and for fractured faces. Cognitive Neuropsychology, 17(1), 201–219.

Moscovitch, M., Winocur, G., & Behrmann, M. (1997). What is special about face recognition? Nineteen experiments on a person with visual object agnosia and dyslexia but normal face recognition. Journal of Cognitive Neuroscience, 9(5), 555–604.

Mundel, T., Milton, J. G., Dimitrov, A., Wilson, H. W., Pelizzari, C., Uftring, S., Torres, I., Erickson, R. K., Spire, J.-P., & Towle, V. L. (2003). Transient inability to distinguish between faces: Electrophysiologic studies. Journal of Clinical Neurophysiology, 20(2), 102.

Murty, N. A. R. M., Bashivan, P., Abate, A., DiCarlo, J. J., & Kanwisher, N. G. (2020). Computational models of category-selective brain regions enable high-throughput tests of selectivity. Nature Communications, 12(1), 5540.

Nagaishi, A., Narita, T., Gondo, Y., Nakane, S., Fukudome, T., & Matsuo, H. (2015). [Left-sided metamorphopsia of the face and simple objects caused by an infarction at the right side of the splenium of the corpus callosum]. Rinsho Shinkeigaku, 55, 465–471.

Nijboer, T. C. W., Ruis, C., Worp, H. B., & de Haan, E. H. F. (2008). The role of Funktionswandel in metamorphopsia. Journal of Neuropsychology, 2(1), 287–300.

Nunn, J. A., Postma, P., & Pearson, R. (2001). Developmental prosopagnosia: Should it be taken at face value? Neurocase, 7(1), 15–27.

Ogawa, K., Akimoto, T., Takahashi, K., Hara, M., Morita, A., Kamei, S., Nakajima, H., Fujishiro, M., Suzuki, Y., Soma, M., Shikata, E., Futamura, A., & Kawamura, M. (2020). A case of prosopometamorphopsia caused by infarction of the splenium of the corpus callosum and major forceps. Neurocase, 26(5), 264–269.

Op de Beeck, H. P., Haushofer, J., & Kanwisher, N. (2008). Interpreting fMRI data: Maps, modules and dimensions. Nature Reviews Neuroscience, 9(2), 123–135.

Parvizi, J., Jacques, C., Foster, B. L., Withoft, N., Rangarajan, V., Weiner, K. S., & Grill-Spector, K. (2012). Electrical stimulation of human fusiform face-selective regions distorts face perception. Journal of Neuroscience, 32(43), 14915–14920.

Phua, C. S., Bhaskar, S., & Calic, Z. (2019). Hemiprosopometamorphopsia: A case of impaired facial perception restricted to the eye. SN Comprehensive Clinical Medicine, 1(11), 931–933.

Pitcher, D., Charles, L., Devlin, J. T., Walsh, V., & Duchaine, B. (2009). Triple dissociation of faces, bodies, and objects in extrastriate cortex. Current Biology, 19(4), 319–324.

Puce, A., Allison, T., Asgari, M., Gore, J. C., & McCarthy, G. (1996). Differential sensitivity of human visual cortex to faces, letterstrings, and textures: A functional magnetic resonance imaging study. Journal of Neuroscience, 16, 5205–5215.

Rangarajan, V., & Parvizi, J. (2016). Functional asymmetry between the left and right human fusiform gyrus explored through electrical brain stimulation. Neuropsychologia, 83, 29–36.

Rossion, B., Jacques, C., & Jonas, J. (2024). The anterior fusiform gyrus: The ghost in the cortical face machine. Neuroscience & Biobehavioral Reviews, 158, 105535.

Safran, A. B., Achard, O., Duret, F., & Landis, T. (1999). The “thin man” phenomenon: A sign of cortical plasticity following inferior homonymous paracentral scotomas. British Journal of Ophthalmology, 83(2), 137–142.

Saito, Y., Matsunaga, A., Yamamura, O., Ikawa, M., Hamano, T., & Yoneda, M. (2014). A case of left hemi-facial metamorphopsia induced by infarction of the right side of the splenium of the corpus callosum. Rinsho Shinkeigaku (Clinical Neurology), 54(8), 637–642.

Schalk, G., Kapeller, C., Guger, C., Ogawa, H., Hiroshima, S., Lafer-Sousa, R., Saygin, Z. M., Kamada, K., & Kanwisher, N. (2017). Facephenes and rainbows: Causal evidence for functional and anatomical specificity of face and color processing in the human brain. Proceedings of the National Academy of Sciences, 114(46), 12285–12290.

Schroeder, C., Schneider-Gold, C., Behrendt, V., Grüter, T., Lukas, C., Gold, R., & Krogias, C. (2017). Unilateral right prosopometamorphopsia with positive “half-face-covering” test after small occipitotemporal stroke. Journal of the Neurological Sciences, 379, 247–248.

Schrouff, J., Raccah, O., Baek, S., Rangarajan, V., Salehi, S., Mourão-Miranda, J., Helili, Z., Daitch, A. L., & Parvizi, J. (2020). Fast temporal dynamics and causal relevance of face processing in the human temporal cortex. Nature Communications, 11(1), 656.

Seron, X., Mataigne, F., Coyette, F., Rectem, D., Bruyer, R., & Laterre, E. C. (1995). A case of metamorphopsia restricted to faces and different familiar objects. Revue Neurologique, 151(12), 691–698.

Sha, L., Haxby, J. V., Abdi, H., Guntupalli, J. S., Oosterhof, N. N., Halchenko, Y. O., & Connolly, A. C. (2015). The animacy continuum in the human ventral vision pathway. Journal of Cognitive Neuroscience, 27(4), 665–678.

Stehr, D. A., Zhang, Y., Patgiri, A., Kidder, A., Kay, K., & Duchaine, B. (accepted). Developmental prosopagnosics have normal spatial integration in posterior ventral face-selective regions. eLife.

Tokida, H., & Tagawa, K. (2014). A case of metamorphopsia and micropsia of physiognomy caused by cerebral infarction in the right retrosplenial region. Higher Brain Function Research, 34(2), 260–263.

Trojano, L., Conson, M., Salzano, S., Manzo, V., & Grossi, D. (2009). Unilateral left prosopometamorphopsia: A neuropsychological case study. Neuropsychologia, 47(3), 942–948.

Vallar, G., Burani, C., & Arduino, L. S. (2010). Neglect dyslexia: A review of the neuropsychological literature. Experimental Brain Research, 206(2), 219–235.

Whiteley, A., & Warrington, E. K. (1977). Prosopagnosia: A clinical, psychological, and anatomical study of three patients. Journal of Neurology, Neurosurgery & Psychiatry, 40, 395–403.

Wigan, A. L. (1844). A new view of insanity: The duality of the mind proved by the structure, functions, and diseases of the brain, and by the phenomena of mental derangement, and shewn to be essential to moral responsibility. Longman, Brown, Green, and Longmans.

Wilbrand, H. (1892). Ein Fall von Seelenblindheit und Hemianopsie mit Sectionsbefund. Deutsche Zeitschrift für Nervenheilkunde, 2, 361–387.

Yakar, F., Eroglu, U., Peker, E., Armagan, E., Comert, A., & Ugur, H. C. (2018). Structure of corona radiata and tapetum fibers in ventricular surgery: A neuroanatomical study. Journal of Clinical Neuroscience, 57, 143–148.

Young, A. W., & Burton, A. M. (2018). Are we face experts? Trends in Cognitive Sciences, 22(2), 100–110.