Better to Mistake Than to Miss: The Mechanisms and Applications of Face Visual Illusions

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Date: 2022-09-14T00:00:00+00:00

Abstract

The phenomenon of face pareidolia manifests as individuals perceiving non-existent faces from other objects. Elements of face pareidolia have been widely applied in art, advertising, and commercial products, serving to attract attention and promote consumption. Meanwhile, previous research employing various paradigms has discovered differences between patients and healthy individuals in the generation of face pareidolia, as well as the relationship between pareidolia and visual hallucinations. According to different visual processing pathways, relevant paradigms can be categorized into pareidolia detection paradigms and pareidolia recognition paradigms. The former focuses on rapid predictions based on extracted face-like features, while the latter emphasizes that subjective expectations guide individuals' extraction of object features; both ultimately influence subsequent cognitive judgments. Future research may commence from the mechanisms underlying face pareidolia, integrating both top-down and bottom-up processing pathways, to provide theoretical foundations for the generation mechanisms of face pareidolia and to broaden the application of this element in clinical diagnosis and commercial advertising.

Full Text

Preamble

Better to Misidentify Than to Miss: A Review of Occurrence Mechanisms and Applications of Face Pareidolia

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Abstract: In real life, people occasionally perceive objects as something non-existent, a phenomenon known as pareidolia. Elements of face pareidolia have been widely utilized in art, advertising, and design to attract attention and promote consumption. Meanwhile, previous studies employing various paradigms have revealed differences in face pareidolia production between patients and typical individuals, as well as links between pareidolia and visual hallucinations. Based on distinct visual processing pathways, relevant paradigms can be divided into pareidolia monitoring paradigms and pareidolia discrimination paradigms. The former emphasizes rapid prediction based on extracted face-like features, while the latter focuses on how subjective expectations guide individuals to extract object features. Both ultimately influence subsequent cognitive judgments. Future research should develop new paradigms to further explore the interaction between top-down and bottom-up mechanisms of face pareidolia.

Keywords: face pareidolia, face processing, occurrence mechanisms

1 Introduction

People sometimes perceive objects that do not actually exist, such as seeing monkey faces in orchid blossoms or faces in cloud formations. This erroneous visual perception—perceiving non-existent objects—is called pareidolia [1]. This misperception manifests as individuals assigning new meaning to meaningless stimuli [2]. During pareidolia, individuals typically misperceive animals, objects, or events that are not actually present. Among these, individuals most frequently misperceive objects as faces that do not exist, a phenomenon termed face pareidolia [1; 3; 4]. Objects that can induce face pareidolia are referred to as face-like objects.

The emergence of face pareidolia stems from both innate adaptation and environmental influences. On one hand, from an evolutionary perspective, the ability to perceive faces serves an adaptive function. To effectively avoid potential environmental threats, individuals tend to lower their perceptual threshold for face stimuli carrying social information, making them more likely to mistakenly process objects as faces [5; 6]. Additionally, recognizing faces and facial emotions facilitates predictive perception of subsequent threats and opportunities [4; 7]. Although this evolutionary adaptation may cause individuals to erroneously identify objects as faces, the cost of such errors is far lower than missing a real face. On the other hand, the brain does not passively receive bottom-up visual signals but also engages in predictive coding [8; 9]. When situated in a highly stable and predictable world, individuals can compare extracted perceptual information against experience and memory to generate predictions about what they see [10]. Researchers suggest that faces in social contexts may be endowed with important social functions, leading to high expectations for faces

[11]. Since individuals exist in social environments with high expectations for faces, face pareidolia emerges when top-down expectations become imbalanced with bottom-up visual signals [12].

Previous research has examined not only the relationship between face pareidolia and face processing but also its applications in clinical diagnosis and commercial advertising. Individuals experiencing pareidolia typically see objects that exist in reality [13], whereas patients experiencing visual hallucinations more often perceive meaningless patterns [4; 14]. Although pareidolia and visual hallucinations differ symptomatically, they remain physiologically correlated [15]. Consequently, researchers have proposed that pareidolia may serve as a subclinical manifestation of visual hallucinations [16; 17]. Beyond serving as a diagnostic criterion for hallucinations, pareidolia can also be used to study selective attention to faces in autism spectrum disorder. While individuals with autism show avoidance of faces, particularly eyes, when searching images [18; 19], studies have found that autistic children still experience face pareidolia, albeit at lower rates than typical children [4]. Similarly, research on autistic adults has shown that individuals with lower autism traits still exhibit physiological arousal in response to face-like object images [20]. Beyond clinical diagnosis and intervention, face pareidolia is frequently exploited as an element in advertising design [3]. Anthropomorphic product advertisements, such as print ads arranging food to resemble faces, attract greater consumer attention and promote purchasing behavior [21]. Moreover, studies have found that incorporating human faces or face-like elements increases brand recognition and advertising preference compared to general print advertisements [22].

In summary, current investigations into the mechanisms underlying face pareidolia remain insufficient and lack consistent conclusions. This review sequentially examines relevant research paradigms, occurrence mechanisms, and applications of face pareidolia in clinical diagnosis and commercial domains, laying a foundation for subsequent improvements to pareidolia paradigms and exploration of the neural mechanisms of face processing.

2 Research Paradigms for Pareidolia

Pareidolia is defined as a phenomenon where external stimuli trigger perception of a specific object [1]. Due to varying paradigms employed in current face pareidolia research, the resulting pareidolia experiences differ across studies. Based on differences in materials and methodologies, paradigms used in previous studies of hallucination symptoms in neurological and psychiatric patients can be categorized into reality monitoring paradigms [23] and reality discrimination paradigms [12; 24]. The former simulates automatic hallucination generation in patients, while the latter induces hallucinations through instructions under perceptually ambiguous conditions. Drawing on this classification framework for hallucination paradigms, this paper discusses face pareidolia generation from two paradigms: pareidolia monitoring paradigms and pareidolia discrimination paradigms. The former features presentation of object images containing face elements, while the latter uses only noise images to induce pareidolia. Similarly, Rahman and Boxtel named their tasks based on material type as the embedded face task and Mooney face task. Other research has similarly categorized tests into scene pareidolia tests and noise pareidolia tests based on material type [25].

2.1 Pareidolia Monitoring Paradigm

Similar to face pareidolia experienced in daily life, participants in pareidolia monitoring paradigms view face-like object images and experience face pareidolia. In typical visual face experiments, researchers present different types of face stimuli and require participants to respond based on specific criteria. Beyond reaction time and accuracy, researchers also record additional metrics such as saccade proportion [26], N170 component amplitude in ERP [27], or activation in occipitotemporal and prefrontal regions in fMRI [28]. Similarly, face pareidolia studies build upon face stimuli by adding face-like object images and sometimes pure object images as controls [27; 29]. This section organizes the literature around three aspects: material selection, parameter settings, and dependent variable acquisition.

First, studies vary in their collection of face and face-like object images. Face images may be computer-generated [30] or collected from real faces [16; 29]. Face-like object images can be sourced from the internet (e.g., https://www.flickr.com/groups/facesinplaces/pool/) or relevant books [27; 29; 31; 32; 33], or resemble portraits composed of various objects painted by Giuseppe Arcimboldo (1527-1593). Additionally, researchers can generate face-like object images through custom composition based on task difficulty and requirements [34], as shown in Figure 1b [Figure 1: see original paper].

Figure 1 Images from daily life that can induce face pareidolia: a) natural landscapes, b) composed food arrangements, c) car front grilles, d) pareidolia-inducing artworks (most images from https://www.flickr.com/groups/facesinplaces/pool/)

Second, image presentation methods vary based on experimental requirements. Typically, face-like object images are presented individually. For example, when investigating whether hallucination symptoms in Parkinson' s disease patients share neural mechanisms with pareidolia, researchers had patients view animal and plant images sequentially, asking them to indicate locations where they perceived non-existent objects [17]. Another study presented schizophrenic patients and typical individuals with faces composed of fruits and vegetables, asking whether they saw faces in the fruit arrangements [34]. In cognitive neuroscience experiments, pareidolia monitoring paradigms also vary in materials, generally presenting single face-like object images while recording electrophysiological changes [27; 28]. Beyond single-image presentation, face, pareidolia, and matched object images can be presented in pairs to compare preferences based on viewing duration. For instance, simultaneously presenting butterflies with and without eye-like spots allows participants to make decisions about preference and conservation attitudes toward the two images [31]. Alternatively, presenting upright and inverted face-like object images simultaneously enables analysis of viewing time to determine pareidolia occurrence [35], with longer attention to upright face-like object images indicating pareidolia induction and greater attention capture.

Finally, required response types and stimulus presentation durations vary based on experimental requirements. Some studies simply have participants view face-like object images, requiring button presses under specific conditions (e.g., when images are tilted or have borders) to ensure attention [29; 36]. However, most pareidolia monitoring paradigms require button-press responses to images. Behavioral studies primarily focus on reaction time—the interval between face-like object image presentation and pareidolia report [16; 26; 37]. Beyond button-press reaction time, some studies analyzing first-fixation duration and total fixation duration have compared preferences for face-like object images between autistic and typical children when presented with upright and inverted images [35]. Additionally, reported results can be categorized based on actual image properties, such as defining pareidolia occurrence rate as the proportion of trials where participants reported seeing faces among all pareidolia-inducing stimuli [14]. Presentation duration also depends on response type and data acquisition method. For subjective reports (e.g., verbal indication of pareidolia with specific location or quadrant), presentation may be unlimited [31; 34] or long (e.g., 60 seconds) [14]. For eye-tracking data, presentation times are relatively shorter [26; 35]. Similarly, EEG or fMRI experiments adjust presentation duration based on requirements, with some setting image duration within 3000 ms or even 300 ms to capture specific EEG components [27; 36] or activated brain regions [29], though durations over 10 seconds also occur [28].

2.2 Pareidolia Discrimination Paradigm

Face pareidolia arises from both rapid automatic processing and top-down expectations. Unlike pareidolia monitoring paradigms that use face-like object images, pareidolia discrimination paradigms induce top-down superstitious beliefs [38] or predictive codes [11] through instructions, causing participants to experience face pareidolia in pure noise images. This section organizes the literature around three aspects: material selection, experimental procedure, and dependent variable acquisition.

First, this paradigm uses noise images as materials. The characteristic feature is that individuals identify faces in noise images that contain no actual faces. Previous studies using pareidolia discrimination paradigms have been relatively consistent, including practice and test phases [39; 40]. Participants are instructed to press a button when they identify a face in noise images. During practice, noise-masked faces are included at various levels (e.g., 25%, 50%, 75% noise-masked faces and 100% pure noise) [39]. For noise masking, most studies use Gaussian blur [38; 39; 41; 42], though some employ alternative methods such as superimposing Gaussian noise points of different radii, creating more irregular patterns than uniform-radius noise [1]. Other approaches include fragment-based masking [43; 44; 45], $1/f^3$ frequency processing [14], and fractal noise [46], as shown in Figure 2 [Figure 2: see original paper].

Figure 2 Comparison of different pure noise images: a) blurred images; b) Gaussian noise; c) fractal noise

Second, the procedure is more complex than in monitoring paradigms. At the practice phase onset, participants are informed that half the trials will present face images and half will present pure noise. In the first practice block, faces appear without noise masking, but subsequent blocks introduce 25% noise-masked faces. This progression continues, making face identification increasingly difficult. Although instructions state that noise-masked faces will appear, the final practice block presents only pure noise. Studies vary in noise proportions during practice (e.g., 10%, 30%, 60%, 100% [39] or 10%, 50%, 75%, 100% [42]), but the core element is inducing face-related predictive codes and increasing perceived task difficulty. During the test phase, participants are again told that half the trials contain noise-masked faces, when in reality all trials present only pure noise. If participants report seeing a face during any test trial—erroneously processing noise as a face—this is defined as face pareidolia.

Participants experience pareidolia in this paradigm primarily due to predictive codes generated by instructions and practice. Instruction emphasis centers on the probability of face images during testing (50%) [38], though some simply inform participants that faces will appear [41]. Without explicit information about face presence in the test phase, the proportion of face reports decreases significantly [39]. Behavioral data includes the proportion of trials where participants report seeing faces [39; 41]. Some studies apply signal detection theory to obtain sensitivity and response bias measures [43]. Additionally, many studies cluster-analyze noise images judged as faces versus those not judged as faces to compare cluster locations with typical facial feature positions. Researchers have found that pure noise images identified as faces contain clustered points at locations similar to eyes and mouths, suggesting that subjective expectations may specifically process bottom-up visual signals to produce pareidolia [1; 38; 46].

3 The Occurrence Process and Neural Mechanisms of Face Pareidolia

The cognitive neural mechanisms of face pareidolia involve visual signal transmission and erroneous face recognition. Visual perception and recognition encompass both upward transmission of primary visual signals to brain regions responsible for object identification and feedback of memory information to recognition areas for matching and judgment [8]. Studies have found low correlation between pareidolia rates in the two tasks, suggesting that results should be discussed separately [13]. In pareidolia monitoring paradigms, erroneous face judgments primarily stem from high similarity between external materials and facial features. In pareidolia discrimination paradigms, face expectations generate pareidolia, arising from either subjective consciousness or external environment [9]. Both paradigms can induce face pareidolia, but the former emphasizes extracting and processing face-like features from face-like object images to generate rapid but erroneous predictions that the object is a face. The latter focuses on longer processing where early predictions do not immediately lead to face awareness; instead, prior expectation signals promote reinterpretation of meaningless features, ultimately causing erroneous face identification in pure noise. Some researchers propose that monitoring paradigms induce genuine pareidolia, while discrimination paradigms involve face detection errors [45]. Given differences in materials and experimental purposes, the cognitive neural mechanisms underlying pareidolia may show both similarities and differences.

3.1 Automatic Generation of Face Pareidolia

According to Bar' s (2007) model of sensory prediction, face pareidolia follows a similar process. As shown in Figure 3a [Figure 3: see original paper], individuals first extract local features from face-like objects, then analogize these features with concepts stored in memory, associating physical and social attributes of the analogues during the process. Based on high feature overlap, predictions are generated, leading to rapid conclusions that face-like objects may be faces. Similar to daily pareidolia experiences, pareidolia monitoring paradigms present face-like object images directly, making pareidolia generation an automatic and rapid process [35].

Neural mechanisms for automatic pareidolia generation primarily involve the fusiform face area (FFA), which participates in analogical processing. Research suggests that when images are presented for 200–300 ms, individuals integrate low-level face-like features from face-like object images and activate face detection brain regions rather than reprocessing the images [29]. Neuroimaging studies using monitoring paradigms have also found that viewing face-like object images activates the FFA [29]. Another study using composite faces made from two different faces found that transcranial direct current stimulation to this region reduced false alarm rates for identifying composites as the same face, decreasing holistic perception of composite faces [47]. Additionally, Gulsum et al. (2018) found activation in both prefrontal cortex (PFC) and FFA during pareidolia trials. Researchers propose that in monitoring paradigms, the PFC participates in outputting top-down feedback signals while the FFA receives signals from both the PFC and occipital face area (OFA) [29], as shown in Figure 3b.

Furthermore, the wide variety of face-like object images creates substantial differences in low-level features. Some researchers propose that individuals may integrate partial low-level features resembling eyes and mouths into intermediate-level features, which are then transmitted upward to the FFA [13]. Proverbio and Galli (2016) found gender differences in face pareidolia, with female participants activating not only occipital and parietal regions but also the superior temporal sulcus (STS), cingulate gyrus, and orbitofrontal cortex (OFC)—areas involved in social and emotional information processing. These results suggest that pareidolia generation may involve not only shallow face perception but also deeper processing of social cues [13].

Figure 3 Cognitive neural mechanisms of automatic face pareidolia generation: a) Individuals extract local features from face-like objects and analogize them with concepts in memory, associating attributes of analogues during the process. Based on feature overlap, predictions are generated, leading to rapid conclusions that face-like objects may be faces; b) Neural mechanisms of rapid pareidolia generation. Note: prefrontal cortex (PFC), fusiform face area (FFA), occipital face area (OFA)

3.2 Subjectively Induced Face Pareidolia

In daily life, others may experience pareidolia first, and individuals then experience it under others' guidance. External subjective expectations can facilitate processing, analogizing, and subsequent predictions, ultimately producing face pareidolia. As shown in Figure 4a [Figure 4: see original paper], individuals extract local features from an object and analogize them with memory concepts. If feature overlap is low, they initially conclude the object is not a face. However, if overlap is moderate or subjective expectations suggest a face may exist, they continue analogizing, possibly lowering analogical criteria (e.g., judging face presence based only on local facial features) or increasing analogical attempts by re-extracting other features. After extended analogical prediction, they conclude the object may be a face. Similarly, in discrimination paradigms, participants receive no direct cues from others, but experimental instructions lead them to believe noise images containing faces will appear. The brain matches sensory signals with top-down expectations [10], and this pareidolia originates from previously generated expectation signals [39]. Similar to monitoring paradigms, studies have found positive activation in both OFA and FFA when participants report seeing faces in pure noise images [42].

Beyond OFA and FFA activation, discrimination paradigms also involve OFC activation to generate expectations. As shown in Figure 4b, researchers propose that detecting faces in pure noise may involve connections among OFC, OFA, and FFA—specifically, unidirectional connectivity from OFA to FFA and bidirectional connectivity between OFC and OFA [48]. Among these regions, OFC is involved in top-down subjective expectations, while OFA processes primary facial features, with this early processing facilitating subsequent face representation [49]. When subjective expectations arise, OFC transmits top-down feedback to OFA, promoting detection and extraction of facial features in noise. If face-like features are detected, OFA transmits visual signals upward to FFA for further face processing and also to OFC, further strengthening expectation signals from OFC to OFA through iterative reinforcement. When no facial features are detected, negative reinforcement between OFC and OFC weakens expectation signals.

Figure 4 Cognitive neural mechanisms of subjectively induced pareidolia: a) Individuals extract local features from noise images and analogize them. If feature overlap is low, they initially conclude no face exists. If overlap is moderate or subjective expectations suggest a face exists, they lower analogical criteria or re-extract features for further analogizing, ultimately concluding a face exists in the noise; b) Neural mechanisms of expectation-induced pareidolia generation. Note: orbitofrontal cortex (OFC), fusiform face area (FFA), occipital face area (OFA)

3.3 Analogizing, Associating, and Predicting During Pareidolia Generation

Regarding pareidolia mechanisms, scholars have proposed various perspectives based on different paradigms. Some suggest face pareidolia may stem from reduced sensitivity to face-object distinctions or lowered criteria for face classification [50]. Others, from a sensory prediction perspective [9], propose that pareidolia arises from three processes: analogizing, associating, and predicting [33]. Individuals first extract local features from face-like objects, analogize them with memory representations and associated attributes, and generate predictions based on high feature overlap. Reduced sensitivity to face-object distinctions manifests in feature extraction, while lowered classification criteria appear in the prediction process. Monitoring paradigm studies emphasize single sensory prediction processes—extracting face-like features from images and matching them with memory representations—thus focusing on the OFA involved in primary facial feature processing [29]. Conversely, discrimination paradigm studies emphasize expectation signals generated by instructions, focusing on top-down expectations facilitating detection of primary facial features in noise images [1; 48]. Although previous research has explored mechanisms of both pareidolia types separately, no paradigm has yet simultaneously investigated rapid and slow pareidolia processing. Future research could combine both tasks to further elucidate face pareidolia mechanisms.

3.4 Connections Between Face Pareidolia and Face Processing

Faces contain both physical attributes (eyes, nose) and social attributes (trustworthiness, attractiveness). The neural mechanisms of face processing involve two systems: a core system and an extended system [49; 51; 52]. The core system includes the occipital face area (OFA), fusiform face area (FFA), and posterior superior temporal sulcus (pSTS). FFA and pSTS handle deep face processing: FFA, especially in the right hemisphere, processes invariant aspects such as face identity [48; 53] and social attributes, even when perceiving objects rather than faces [54]; pSTS processes variant attributes like eye and lip movements. OFA is sensitive to local face properties, processing low-level features and transmitting information to FFA and pSTS. Face processing proceeds from primary attribute processing to identity recognition [55]. The extended system handles deeper social information processing, with the amygdala and insula processing facial emotion, the inferior frontal gyrus handling semantic analysis, and the orbitofrontal cortex processing attractiveness and sexuality [42; 49].

Individuals may perceive both physical and social attributes from face-like objects. As described above, face pareidolia involves perceiving face-like features, but individuals also perceive facial emotions [2; 56] and attribute personality traits to face-like objects [57; 58]. Therefore, researchers propose that individuals may perceive social attributes from face-like objects, generating attentional orientation [13; 59]. This orientation resembles that elicited by social cues, through which individuals infer others' attentional targets and intentions or mental states [60; 61; 62; 63]. Given that neuroimaging studies suggest face pareidolia involves deeper processing of social cues [13; 64], individuals may associate social attributes alongside physical attributes during analogical prediction, directing attention to face-like objects. Monitoring paradigm studies have found activation in both FFA (involved in social attribute processing) [28] and OFA (involved in primary processing) [29] when presenting face-like object images. Another study found that female participants, compared to males, more readily activated STS, cingulate gyrus, and OFC—regions involved in social and emotional information processing—when viewing face-like object images [27]. These findings further confirm that during pareidolia analogizing, individuals may attach social attributes to extracted local features, endowing face-like objects with facial social properties.

Numerous studies have explored connections between face pareidolia and face processing using both paradigms. In monitoring paradigms, materials are face-like objects, so pareidolia is generally assumed throughout the experiment. In discrimination paradigms, pareidolia is defined only when participants report seeing faces in noise images. Consequently, neuroimaging studies of face pareidolia more commonly employ monitoring paradigms, comparing brain activation changes when viewing face images, face-like object images, and ordinary object images [29; 40; 65]. Few studies have used discrimination paradigms to explore face and text pareidolia under expectation signals [1]. Although many studies have examined two distinct processing mechanisms of face pareidolia, few have integrated both paradigms to compare and explain pareidolia generation from both perspectives simultaneously.

4 Research Value of Face Pareidolia

Face pareidolia is not accidental; exploring its generation holds significant research value. As discussed, occurrence mechanisms differ by generation method but fundamentally involve analogizing, associating, and predicting processes related to face processing. Given that face-like objects and real faces share similar processing mechanisms [56], pareidolia research can illuminate how individuals extract features when processing face-like objects, providing reference for investigating face processing mechanisms [13]. Furthermore, face pareidolia involves both "face" and "pareidolia" dimensions, and some patients exhibit symptoms of face recognition difficulties or visual perception errors [15; 66], making pareidolia a potential clinical manifestation. Finally, investigating attention-capture mechanisms of face-like objects can provide theoretical foundations for pareidolia mechanisms and establish bases for commercial applications [21; 22].

4.1 Autism Spectrum Disorder and Face Pareidolia

Autism Spectrum Disorder (ASD) is a developmental disorder characterized by deficits in social interaction and communication [67]. Individuals with ASD show different attention to social stimuli than healthy adults, focusing more on non-social regions lacking social cues and less on regions containing social information [68; 69], such as avoiding eye gaze when viewing faces [18; 19]. Atypical face processing in ASD may stem from differences in the social brain network comprising the amygdala and STS, showing reduced functional connectivity between regions compared to typical individuals [70]. Social brain network functions overlap with ASD symptoms, including difficulty inferring emotions or intentions, recognizing facial expressions, and lacking attentional orientation to social cues [54; 71]. A meta-analysis found that individuals with ASD showed reduced activation in left fusiform gyrus during face processing tasks, with impaired occipital regions involved in primary face processing potentially causing atypical face processing [72].

Given these differences, research has examined whether individuals with ASD process face-like objects differently. Monitoring paradigm studies found that autistic children showed weaker face detection for face-like object images and had difficulty generating pareidolia compared to typical peers [4]. Another study presented children with ten food-composed images that became increasingly face-like, asking them to judge face presence to explore differences between autistic and typical children [73]. They found that autistic children had higher thresholds for identifying food-composed images as faces, indicating poorer face modulation ability. These results suggest autistic children experience greater difficulty generating pareidolia. However, other research has investigated whether autistic individuals can generate pareidolia at all. One monitoring paradigm study presented upright and inverted face-like object images simultaneously to children while collecting eye-tracking data, finding that autistic children had later first fixations on upright face-like object images than typical peers, though both groups attended more to upright than inverted images [35]. Another study using monitoring paradigms and shape judgment tasks found that both autistic and typical children showed significantly increased N170 amplitude—involved in face structural processing—when viewing face-like objects compared to ordinary objects. However, typical children showed significantly increased N170 amplitude during pareidolia monitoring compared to shape judgment tasks, while autistic children showed no significant difference between tasks [74]. These results indicate that autistic children can experience pareidolia but do so less readily than typical children.

Differences between autistic and typical individuals in pareidolia generation may stem from analogizing and associating processes. Compared to typical children, autistic children lack threshold perception and orienting monitoring for faces, preventing rapid extraction of face-like local features for analogizing. Additionally, weaker activation in face-processing brain regions may prevent analogical predictions based on association. Although generating pareidolia is difficult for autistic individuals, this does not mean they cannot do so. Higher autism levels may promote stronger search desires for social cues [75], and they may eventually generate pareidolia through continuous feature extraction [68]. Moreover, autistic individuals' face insensitivity manifests as social synchronization deficits —lacking attentional guidance toward social cues [66]. As previously discussed, face-like objects also possess attention-guiding functions and can serve as social cues for behavioral intervention. Given that autistic individuals show greater acceptance of pareidolia [20], future social attention research could use mixed face-like object and real face images rather than faces alone to gradually acclimate patients to social cues. Additionally, training autistic children with human faces for social attention has improved expression recognition abilities that generalize to other contexts [76]. If similar intervention effects can be achieved using more acceptable face-like object images instead of real faces, researchers and clinicians could apply face-like object images in behavioral therapies to improve face information processing in autism.

4.2 Pareidolia and Visual Hallucinations

Perceiving non-existent objects in visual perception is not unique to pareidolia; visual hallucinations exhibit similar manifestations. Visual hallucinations involve seeing non-existent flickering lights or geometric patterns [77]. Many neurological disorders, including dementia with Lewy bodies, Parkinson' s disease, Alzheimer' s disease, and psychiatric conditions like schizophrenia, include visual hallucinations among their symptoms [78; 79]. Patients experience both visual hallucinations and pareidolia, with varying prevalence rates across these disorders [80]. Early research proposed that visual hallucinations and pareidolia represent common clinical manifestations of neurological and psychiatric diseases [15]. Subsequent studies have suggested that pareidolia may serve as a subclinical manifestation of visual hallucinations [14; 16; 17]. Therefore, investigating behavioral and physiological differences between patients with hallucination symptoms and typical individuals when viewing pareidolia images can better explain pareidolia mechanisms and provide references for hallucination mechanisms [12].

Beyond hallucinations, neurological and psychiatric patients also differ from healthy adults in pareidolia. Parkinson' s disease patients show impaired facial expression recognition and visual identification deficits [16], with hallucination symptoms further affecting quality of life [78]. A monitoring paradigm study found that non-demented Parkinson' s patients experienced pareidolia more readily than healthy controls [17]. Further analysis revealed that pareidolia report frequency correlated with hypometabolism in bilateral temporal, parietal, and occipital cortices, while hallucination scores (Neuropsychiatric Inventory, NPI) correlated with left parietal hypometabolism. Based on these findings, researchers proposed that left posterior parietal cortex dysfunction may represent a common neural mechanism for pareidolia and hallucinations in Parkinson's disease. Another discrimination paradigm study found increased frontal activation when Parkinson' s patients experienced pareidolia [44], suggesting abnormal top-down modulation during visual processing that prevents ignoring meaningless stimuli. Additionally, dementia with Lewy bodies patients frequently experience visual hallucinations. One study had typical individuals and Lewy body dementia patients with and without hallucinations perform a discrimination paradigm, finding that hallucinating patients may compensate for perceptual deficits by lowering face perception criteria, making them more susceptible to pareidolia [43]. Similar to Parkinson' s patients, schizophrenia patients show deficits in face and facial emotion recognition due to impaired facial feature processing [81; 82]. A monitoring paradigm study found that schizophrenia patients experienced face pareidolia more readily than healthy controls, showing weaker face recognition ability at the behavioral level [34].

Given similarities between pareidolia and hallucinations, face-like object images can serve as assessment tools for clinical diagnosis of neurological and psychiatric disorders. Since numerous studies suggest pareidolia and hallucinations are not independent [14; 16; 17], pareidolia tasks could be considered predictive indicators of hallucinations. Mamiya et al. (2016) found moderate correlation between false alarm rates in monitoring paradigms and hallucination scores, suggesting that monitoring paradigm false alarm rates could serve as hallucination indicators for assessing Lewy body dementia patients. O' Brien et al. (2020) also noted that pareidolia experiences could be applied to clinical diagnosis of hallucinations, potentially enabling development of more effective and reliable assessment tools for Lewy body dementia. Additionally, research has proposed using monitoring paradigms to predict which sleep disorder patients may develop Lewy body dementia [83].

4.3 Commercial Applications of Face Pareidolia

Face pareidolia is widely applied in commercial domains, primarily characterized by visual anthropomorphism. Anthropomorphism—attributing human characteristics to non-living entities—is commonly used in paintings, architecture, and daily products [84]. As shown in Figure 1a, natural or artificial rock landscapes can trigger pareidolia, allowing individuals to perceive emotions like happiness or fear from architecture incorporating pareidolia elements [2]. Additionally, as shown in Figure 1d, Spanish painter Salvador Dalí (1904–1989) frequently created portraits composed of various fruits and vegetables, employing numerous pareidolia elements to blur boundaries between reality and illusion and provide unique artistic experiences [85]. Individuals sometimes automatically perceive faces in these architectural works and paintings, while some require subjective induction or specific viewing angles. Although commercial applications of pareidolia manifest as anthropomorphism, anthropomorphism is not equivalent to pareidolia. For instance, cartoon animals in paintings are given human features by artists, but whether this qualifies as pareidolia remains unexamined.

More research has focused on how pareidolia guides attention in user perception and experience. Beyond architecture and paintings, businesses apply pareidolia elements in product design to attract viewer attention. Early research proposed that visual anthropomorphism could be used in various commercial contexts—including industrial manufacturing, food, and fashion—to guide consumer purchasing and usage [21]. Incorporating pareidolia elements makes products more comprehensible, better reflecting functional attributes or utilitarian value, thereby enhancing visual effects, brand recognition, and public acceptance across commercial scenarios [22]. Based on this, advertisers and designers assign specific characteristics to products based on facial morphology and expressions to attract attention [3; 84]. As shown in Figure 1c, car front grilles feature anthropomorphic designs that make them resemble faces. Research suggests that humans recognize car exteriors similarly to faces, attributing personality traits [57]. Participants crossed roads earlier when facing cars with "threatening" front grilles (large size, rigid contours) compared to "friendly" ones (small size, soft contours, large round headlights). Another study found that cars with enlarged headlights elicited more positive emotional responses, with "baby schema" features (small size, large round headlights) rated as cuter than ordinary cars [58]. Beyond automobiles, other products incorporating pareidolia elements also attract more attention, such as cookies printed with human faces [86]. Eye-tracking studies of supermarket product layouts found that cereal boxes with cartoon characters and faces attracted more customer attention than faceless boxes [87]. Additionally, pareidolia in advertising increases ad attention and acceptance, with pareidolia ads attracting consumer attention preferences and promoting purchase intentions [88]. One study compared pareidolia and non-pareidolia advertisements, finding significantly longer attention duration and higher ad acceptance for pareidolia ads [22].

In summary, pareidolia—especially face pareidolia—has been applied in commercial and artistic domains. Individual factors such as gender and personality traits also affect pareidolia generation [50], and future research could investigate whether commercial applications differ across consumer groups. Based on pareidolia mechanisms, increasing the proportion of face-like features in products may enhance analogizing and associating stages, strengthening attention-guiding effects. Additionally, future research could examine connections among face-like objects, anthropomorphic cartoon patterns, and real faces in attention capture.

5 Summary and Future Directions

Pareidolia generation is not accidental but results from combined innate adaptation and environmental influences, with face pareidolia being predominant. Research on face pareidolia encompasses face processing, sensory prediction models, social attention, and machine learning. This review introduced two paradigms for studying face pareidolia—monitoring and discrimination paradigms—and discussed occurrence processes, neural mechanisms, and applications in clinical diagnosis and commerce. Future research could explore the following aspects:

5.1 Improvements to Pareidolia Paradigms

Pareidolia generation can be either rapid or slow. Current paradigms include monitoring paradigms presenting face-like object images directly [14; 17; 34] and discrimination paradigms inducing belief in face presence through instructions, causing false face reports in pure noise images [1; 39; 40]. Some researchers propose that the two paradigms differ, with monitoring paradigms generating purer pareidolia and discrimination paradigms producing more detection errors [45].

As parameters for both paradigms were detailed above, paradigm variations may affect pareidolia generation. In monitoring paradigms, material selection differs across populations. Compared to healthy adults, materials for children, elderly individuals, or psychiatric patients are relatively simpler with fewer parameter variations [34; 73]. Additionally, face-like objects themselves guide attention [5; 13], so future research should carefully select materials to avoid social attribute-induced attentional biases that could affect behavioral responses. In discrimination paradigms, given different noise image types across studies [41; 43; 46], future research should examine whether different noise image selections differentially affect pareidolia generation.

5.2 Expanding and Deepening Pareidolia Research in Commercial Applications

Future research could deepen understanding of pareidolia and anthropomorphism in commercial applications through several approaches. First, although numerous studies indicate that products with pareidolia elements attract consumer attention [3; 84; 88], few have mechanistically explained differences between pareidolia-inducing and ordinary products, and few empirical pareidolia studies have been translated to real-world environments. Second, pareidolia is not equivalent to anthropomorphism; differences exist. For example, perfume bottles shaped like female silhouettes [84] constitute anthropomorphism rather than face pareidolia. Research suggests that face-like objects and real faces share mechanisms for expression perception [56], so face-like objects, anthropomorphic objects, and real faces may share face-processing mechanisms. Future research could combine pareidolia with anthropomorphism to examine how they attract attention in behavioral experiments and whether these effects transfer to real-world decision-making contexts. Finally, although anthropomorphism or pareidolia applications attract consumer attention to specific products, they do not guarantee improved product efficiency [84]. The relationship between product pareidolia/anthropomorphism degree and usage efficiency warrants investigation to determine whether both can be enhanced simultaneously. Additionally, commercial applications may vary across consumer groups such as children and women.

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Note: Figure translations are in progress. See original paper for figures.