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A visual search advantage for illusory faces in objects

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Abstract
Face detection is a priority of both the human and primate visual system. However, occasionally we misperceive faces in inanimate objects — "face pareidolia". A key feature of these 'false positives' is that face perception occurs in the absence of visual features typical of real faces. Human faces are known to be located faster than objects in visual search. Here we used a visual search paradigm to test whether illusory faces share this advantage. Search times were faster for illusory faces than for matched objects amongst both matched (Experiment 1) and diverse (Experiment 2) distractors, however search times for real human faces were faster and more efficient than objects with or without an illusory face. Importantly, this result indicates that illusory faces are processed quickly enough by the human brain to confer a visual search advantage, suggesting the engagement of a broadly-tuned mechanism that facilitates rapid face detection in cluttered environments.

Keywords Face perception · Face detection · Pareidolia · Visual search · Illusory faces

Rapidly detecting, identifying, and recognizing faces is a fundamental way in which our visual system supports our social interactions. Faces are rapidly detected in complex visual scenes (Crouzet, Kirchner, & Thorpe, 2010) and in natural viewing behavior, eye-movements preferentially target faces (Arcaro, Schade, Vincent, Ponce, & Livingstone, 2017; Dahl, Logothetis, & Hoffman, 2007; Farroni et al., 2005; Goren, Sarty, & Wu, 1975; Gothard, Erickson, & Amaral, 2004; Rosa Salva, Farroni, Regolin, Vallortigara, & Johnson, 2011; Sugita, 2008; Taubert, Wardle, Flessert, Leopold, & Ungerleider, 2017). Evidence for a dedicated face-detection system emerges early in development; shortly after birth, both humans and nonhuman primates preferentially orient toward faces and face-like stimuli (Buiatti et al., 2019; Farroni et al., 2005; Goren et al., 1975; Sugita, 2008). Notably, face perception is impaired in several clinical populations, such as autism spectrum disorder, which is characterized by reduced social interaction (Pavlova et al., 2017; Pelphrey et al., 2002).

Although the human brain is specialized for both detecting and recognizing faces, we sometimes perceive illusory faces where there are none—for example, in inanimate objects. In the current study, we exploit this phenomenon known as “face pareidolia” to examine rapid face detection in a compelling case in which face perception occurs in the absence of their typical low-level visual features (e.g., skin color, face shape). Examples of illusory face perception (see Fig. 1a) illustrate that face-detection mechanisms tolerate a high degree of low-level feature variance. Viewing ordinary objects perceived to have face-like features evokes early activation of face-specific areas (Hadjikhani, Kveraga, Naik, & Ahlfors, 2009), and the perception of illusory faces can be decoded from face-selective cortex from patterns of fMRI BOLD activation (Wardle, Taubert, Teichmann, & Baker, 2020), suggesting that illusory face perception recruits face-detection mechanisms. Further, nonhuman primates also experience illusory faces (Taubert et al., 2017; Taubert et al., 2018), evidence that face pareidolia involves perceptual mechanisms shared across species.

Although recent MEG results have shown that illusory faces are rapidly processed by the human brain (Wardle et al., 2020), it is not clear whether this confers an observable behavioral advantage. Here we aimed to test this by examining visual search behavior for illusory faces. Consistent with our general preference for faces, it has repeatedly been shown that human faces have a visual search advantage (Cohen,

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Fig. 1 Example search targets from Experiments 1 and 2. **a** Examples of illusory faces in inanimate objects. **b** Matched targets were selected to be examples of the same object as the illusory faces, but without faces. Note that Experiments 1 and 2 featured unique sets of nonface targets matched to the illusory faces. **c** In Experiment 2, we additionally included a set of human face targets selected to have high variance across the variables of age, gender, race, facial expression, and viewpoint in order to match the variance in the illusory faces

Alvarez, Nakayama, & Konkle, 2017; Golan, Bentin, DeGutis, Robertson, & Harel, 2014; Hershler & Hochstein, 2005; Mayer, Vuong, & Thornton, 2015), in which images of human faces are located more rapidly (i.e., shorter reaction times), and more efficiently (i.e., less affected by additional distractors), than are nonface objects. This speed advantage persists even when faces appear in the far periphery (Boucart et al., 2016). The presence of faces also interferes with search for nonface objects, capturing attention even when faces are task irrelevant (Langton, Law, Burton, & Schweinberger, 2008). If illusory faces recruit similar face-detection mechanisms, we expect that visual search for objects containing illusory faces might also be faster than search for similar objects without a face. If there is a search advantage for finding objects with illusory faces, this would provide evidence for a broadly tuned face-detection template that is activated quickly by illusory facial features, suggesting that face pareidolia is a rapid process that shares mechanisms with real face detection.

Here, we used a classic visual search paradigm to reveal whether there is a search advantage for naturally occurring illusory faces (Fig. 2). The critical feature of our experimental design is the use of a set of illusory face examples (Fig. 1a) which we matched to similar objects that did not contain a face (Fig. 1b). This yoked stimulus design enables us to separate out the perception of a face from the visual features that typically distinguish real faces from other objects. In Experiment 1, participants located images of specific inanimate objects (e.g., cheese graters, electrical sockets) either featuring an illusory face, or not. The targets appeared amongst 16, 32, or 64 highly homogenous, category-matched distractors in an 8 × 8 grid display (Fig. 2b). In Experiment 2, we added human face targets for comparison and rearranged the search arrays into circular displays with only 4, 8, or 16 diverse distractors (Fig. 2c). The aim of this easier version of the task was to reveal subtle differences in search dynamics (which may be apparent in less cluttered displays), and to compare search efficiency for illusory faces to that for real faces. Since human faces cannot be matched to objects like the illusory face targets were in Experiment 1, in Experiment 2 we used heterogenous object distractors from other categories for all target types. If features of illusory faces recruit mechanisms for face detection, we expect inanimate objects containing illusory faces to be found more rapidly than similar inanimate objects without illusory faces.

Experiment 1

In Experiment 1, we used a visual search paradigm as an index for the speed of processing for illusory faces in inanimate objects. Search targets were either objects containing illusory faces or similar matched objects that did not contain a face (see Fig. 1a, b). We carefully matched individual distractor sets with each search target, so all distractors were unique examples of objects in the same category as the target object. The goal of this matching was to reduce both low-level and conceptual variance between targets and distractors, which in turn enabled us to probe the effect face-like features had on search performance. Hence, participants searched for images of inanimate objects either containing an illusory face or similar category-matched objects without an illusory face (i.e., a nonface object) amongst highly homogenous distractors. Importantly, the same set of distractors was used for both target types, thus we could be sure that any observed differences were due to the target rather than the distractors.

Method

Participants Eighteen undergraduate students from Macquarie University took part in Experiment 1. All participants had normal or corrected-to-normal vision and were naïve with regard to the experimental hypotheses. All participants gave written consent prior to the start of the experiment and received course credit for participation. The study was approved by the Macquarie University Human Research Ethics committee.

Sample size and stopping rule Previous related studies report significant differences in search performance between human faces and nonface objects for $N = 10$ (Hershler & Hochstein, 2005; VanRullen, 2006). We presumed that any face advantage may be smaller for illusory face stimuli than for real faces, because compared with human faces, illusory face stimuli have much more homogenous visual features that are better matched to the object distractors, thus eliminating low-level visual cues which may partially drive the visual search advantage for human faces. Hence, we used a larger sample size of $N = 18$ in our within-subjects design, and we performed no preliminary analyses before collecting all 18 samples (Cumming, 2014).

Apparatus A Dell Optiplex 9010 running MATLAB (R2007b; 7.5) presented stimuli and recorded participant responses via custom-written scripts. Participants viewed stimuli on an LCD monitor (Samsung S27SA950) at a ~40 cm viewing distance. Participants responded with a custom-made low-latency (serial over USB) button box powered by an ATmega32U4 (5V/16MHz) microcontroller (see Fig. 2a). The experimental code used functions from Psychtoolbox (Version 3.0.14; Brainard, 1997; Kleiner et al., 2007; Pelli, 1997).

Stimuli We constructed a large stimulus set of images for targets and distractors in the visual search task. All images were full color photographs sourced from internet image searches. None of the stimuli were upsampled or watermarked images, and none contained illustrations. We avoided images with solid-color backgrounds (e.g., in stock/catalogue photography) wherever possible. All images were converted to PNG format before being cropped square and resized (images were resampled when resized). All stimuli used in Experiment 1 are available in our materials repository (see Open Practices Statement).

The illusory face stimuli were 26 examples of face pareidolia in everyday objects (e.g., electrical sockets, doors, vegetables). We specifically selected clear images depicting specific objects that could be appropriately category matched to distractors.

Each illusory face image was paired with a unique set of 65 category-matched images (without illusory faces). This allowed us to create a yoked set of nonface object targets; 26 category-matched targets were randomly chosen from each set of images (only after pilot experiments were complete). The remaining 64 items were used as distractors; each yoked target pair had a corresponding set of 64 unique object-matched distractors (64×26 categories = 1,664 total unique distractors).

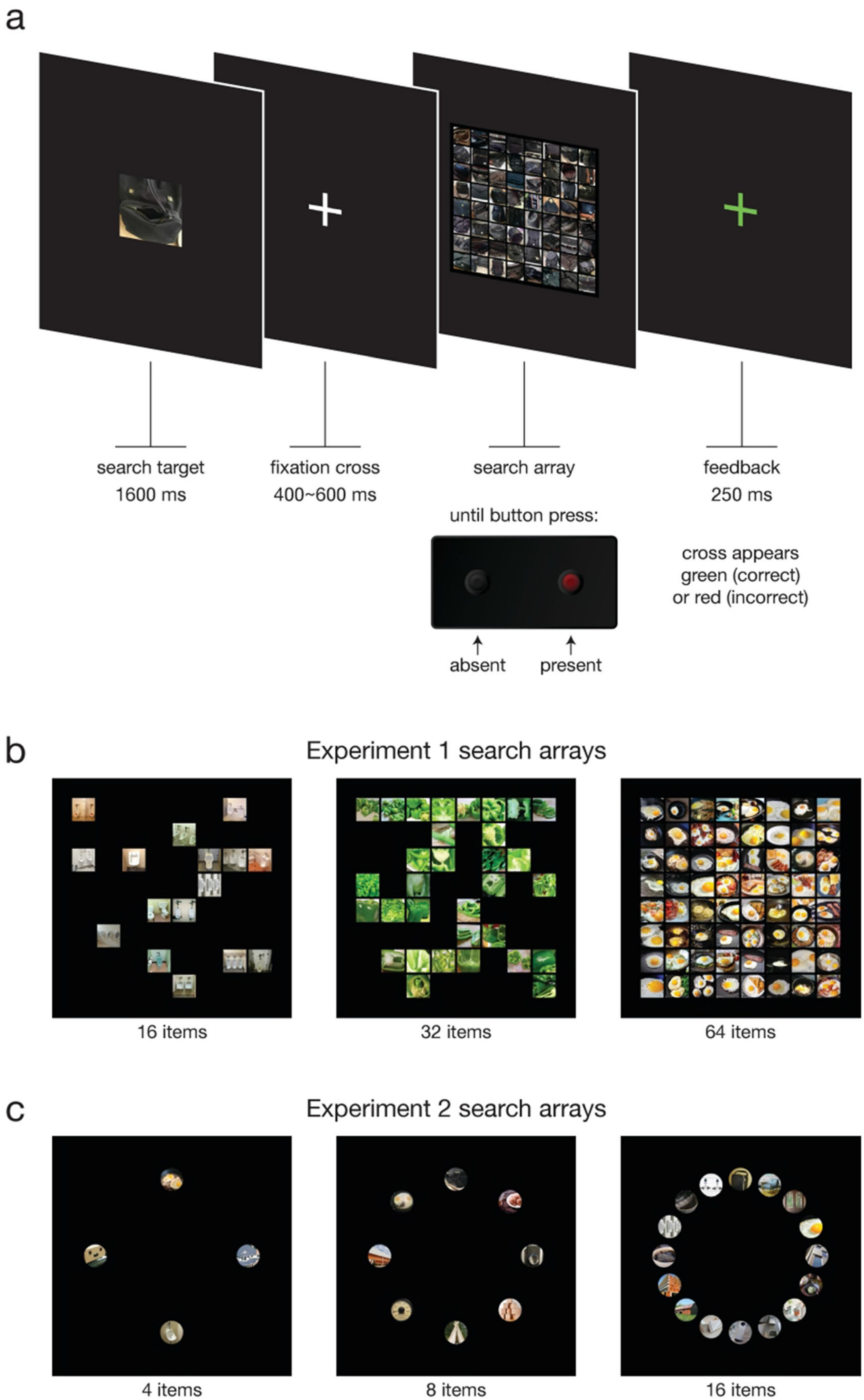
To manipulate the number of elements in the search array (set size), we presented 16, 32, or 64 images (Hershler & Hochstein, 2005; VanRullen, 2006) against a black background (see Fig. 2b). To control for viewing distance, the images appeared in random positions on an (invisible) 8×8 search grid, regardless of set size. Each element measured ~2° × 2° of visual angle. The entire search array measured ~17° × 17° of visual angle (including images and gap [~0.2°]).

Trials and procedure The visual search task comprised 312 trials, one for each combination of set size (three levels), target presence (two levels), target type (two levels), and object type (26 levels). Conditions were interleaved, and presented pseudorandomly, with the restriction that targets of the same object type (e.g., illusory face in fried eggs & nonface fried eggs) never occurred on consecutive trials. Trial order was randomized for each participant.

Participants were instructed to find a target image as quickly and as accurately as possible, and were unaware that some stimuli would contain face-like objects.

At the beginning of each trial, a target image appeared for 1,600 ms. Participants then fixated on a gray cross until the search array appeared (400~600 ms; random onset; see Fig. 2a). Participants were allowed free eye movements during visual search.

Participants indicated whether the target was present (red button; right hand) or absent (black button; left hand) using a custom-built serial button box. Following responses, a green


a
search target
1600 ms
fixation cross
400~600 ms
search array
until button press:
feedback
250 ms
cross appears
green (correct)
or red (incorrect)
absent
present
b
Experiment 1 search arrays
16 items
32 items
64 items
c
Experiment 2 search arrays
4 items
8 items
16 items

◀ **Fig. 2** Visual search paradigms. a Trial sequence for both Experiments 1 and 2 (example pictured from Experiment 1). Participants were instructed to report whether the target (shown at the start of a trial) was present or not as quickly and as accurately as possible, and were unaware that some stimuli would contain face-like objects. **b** In Experiment 1, participants searched for inanimate objects either featuring illusory faces, or without illusory faces. The distractors in each search array were nonface objects of the same type as the target. Importantly, the same set of distractors was used for both illusory face and nonface targets. **c** In Experiment 2, participants searched for inanimate objects featuring illusory faces, inanimate objects without illusory faces, and real faces. For all three target types, the distractors were different inanimate objects that did not match the target image category (i.e., if the target stimuli set featured houses, then the distractors featured a variety of objects that were not houses)

or red fixation cross appeared for correct and incorrect responses, respectively, and remained on screen (for 250 ms) to reorient participants' gaze to the center of the screen before the next trial, which began immediately afterwards (see Fig. 2a). Trials timed out after 15,000 ms if no response was given.

Before experimental trials, participants completed six practice trials (50% target present). Practice targets/distractors were all nonface objects and did not appear in experimental trials. Participants received five self-paced breaks at regular intervals during the experiment. Experimental sessions (including instructions, practice, and breaks) took ~35 minutes in total.

Results

Data preparation and transformation Before analysis, we removed response data for trials in which participants responded incorrectly (total 561 trials) or timed-out (total 8 trials). We included all remaining correct responses. We performed no further transformations of the data beyond those fully described in the present *results* section.

Reaction times for target-present trials To measure visual search speed, we compared mean reaction times for targets with and without illusory faces. Figure 3a shows mean (correct) reaction times for Experiment 1. Although we analyzed both target-present and target-absent trials for completeness, in order to compare the search efficiency of illusory face and object targets our main focus was on trials on which the target was present. For target-present trials, results were analyzed in a 2 × 3 repeated-measures analysis of variance (ANOVA; search target × set size). Target objects were found more rapidly overall when they contained illusory faces, $F(1, 17) = 67.89$, $p = 2.44\text{e-}07$). Increasing set size increased search times for both objects with and without illusory faces, $F(2, 34) = 61.43$, $p = 5.15\text{e-}12$. These main effects were not qualified by an interaction, $F(2, 34) = 2.44$, $p = .102$, demonstrating that illusory faces sped up search times overall, but did not change the relationship between search time and set size. Participants were not informed that any of the images would contain illusory faces, but were only instructed to search for images of everyday objects (a preview of the target appeared before each trial). Despite this, there was a remarkable advantage for illusory faces over matched objects that did not contain an illusory face. This advantage is consistent with previous reports that human faces are found more rapidly than other target objects (Cohen et al., 2017; Golan et al., 2014; Hershler & Hochstein, 2005; Mayer et al., 2015).

Reaction times for target-absent trials For comparison with trials in which the target was present, mean reaction times for target-absent trials were analyzed in a separate 2 × 3 repeated-measures ANOVA (search target × set size). Similar to the effect found on target-present trials, participants were also faster to correctly report target absence when searching for targets containing illusory faces, $F(1, 17) = 19.91$, $p = .0003$. Increasing set size increased search times for both objects with and without illusory faces, $F(2, 34) = 45.39$, $p = 2.51\text{e-}10$. These main effects were not qualified by an interaction between search target and set size, $F(2, 34) = 0.66$, $p = .52$.

Slope parameters To measure search efficiency, we calculated individual parameter estimates from linear regression fitted to each participant's data across all (i.e., nonaveraged) trial reaction times (see Fig. 4). For all conditions, search slopes across participants were significantly greater than zero (target present: illusory face = 18 ms/item), $t(17) = 7.58$, $p\text{bonf} = 3.04\text{e-}06$, (nonface object = 25 ms/item), $t(17) = 7.77$, $p\text{bonf} = 2.17\text{e-}06$; (target absent: illusory face = 42 ms/item), $t(17) = 5.55$, $p\text{bonf} = 1.41\text{e-}04$, (nonface object = 51 ms/item), $t(17) = 7.78$, $p\text{bonf} = 2.15\text{e-}06$, indicating that, for all conditions, search time increased with additional distractors. Search slopes for illusory faces were shallower than slopes for nonface objects in target-present trials ($M\text{diff} = 7.0$, 95% CI [0.5, 13.5]), $t(17) = 2.26$, $p = .037$, $d = 0.58$. Overall, these results demonstrate that participants engaged in relatively inefficient visual search for objects with illusory faces: Here, we find search costs of ~18 ms/item for illusory faces, well above the ~6 ms/item found in other search conditions (Treisman & Souther, 1985). Hence, inanimate objects featuring illusory faces do not appear to "pop out" amongst highly homogenous matched objects, despite being found more quickly.

Experiment 2

The results of Experiment 1 demonstrated that illusory faces are found more rapidly in visual search compared with similar objects without a face. Since Experiment 1 did reveal a search

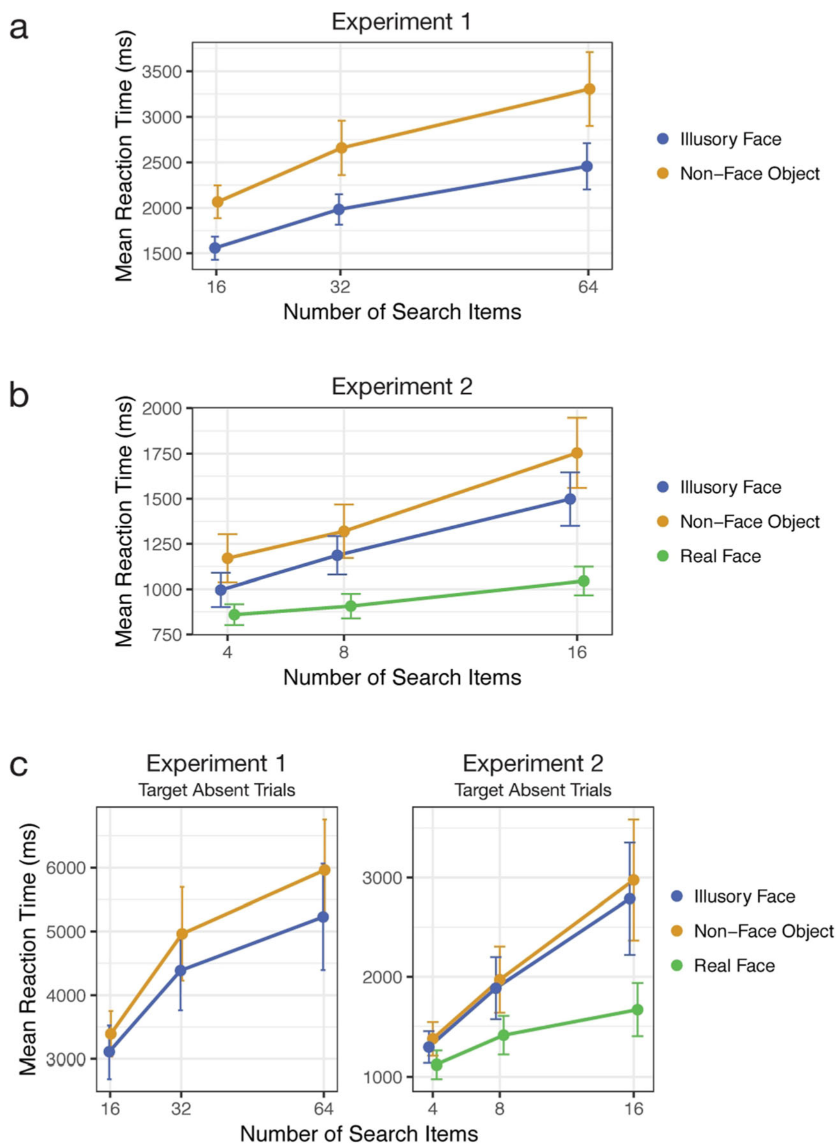


Fig. 3 Mean reaction times for correct responses to target-present trials in Experiments 1 (**a**) and 2 (**b**), and target-absent trials (**c**). Error bars are 95% confidence intervals. *Note.* Different scales for *x* and *y* axes between all panels

advantage for illusory faces, Experiment 2 was designed to follow up on the results of Experiment 1 in two ways. Firstly, by directly comparing search times for human faces versus illusory faces, and secondly, to determine the efficiency of search for illusory faces by quantifying search in easier arrays than the challenging carefully marched object arrays we used in Experiment 2.

We made three key changes to the method of Experiment 2 to make the search task easier compared with Experiment 2. These included reducing the set sizes of the search arrays by a factor of four, arranging all elements in a circle equidistant from fixation (see Fig. 2c), and finally by making the distractors less similar (visually and conceptually) to the target. Since we added human faces as a new target category in Experiment 2 which cannot be matched to objects as we did for the illusory face targets in Experiment 1, we used heterogenous object distractors from object categories other than the target for all target types. This had the added benefit of reducing the relative similarity between distractors and illusory face targets, contributing to making the task easier (see Fig. 5). Thus, in Experiment 2, search targets were either objects with illusory faces, matched objects without illusory faces, or real human faces. Distractors were objects of various categories different than that of the target, and were matched across all three target types, such that the only difference between conditions was the target identity.

Method

The method was identical to that of Experiment 1, except for the changes described below.

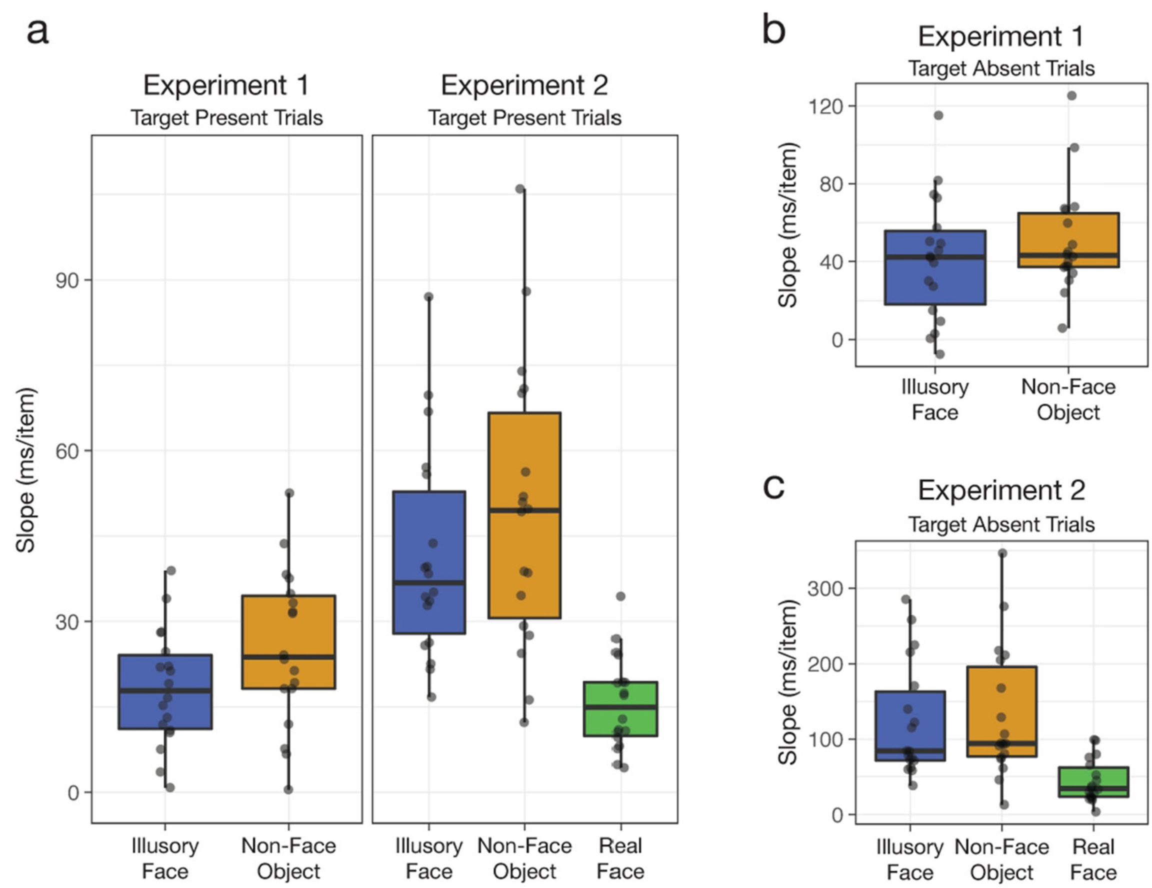


Fig. 4 Fitted slope parameters [ms/item] of search functions for target-present (**a**) and target-absent (**b, c**) trials. To measure search efficiency, we calculated individual slope parameter estimates from linear models fit to each participant's data across all trials

Participants A new sample of 18 undergraduate students from Macquarie University took part in Experiment 2. All participants had normal or corrected-to-normal vision and were naïve with regard to the experimental hypotheses. All participants gave written consent prior to the start of the experiment and received course credit for participation. The study was approved by the Macquarie University Human Research Ethics committee.

Stimuli, trials, and procedure Search targets were either illusory faces in objects, matched nonface objects, or real human faces. For object targets, we sampled 23 illusory faces and 23 matched objects from the Experiment 1 stimulus set. The matched targets (without illusory faces) were again randomly selected from respective sets of unique (nonface) examples from the same category, but excluded nonface targets used in Experiment 1. The real face stimuli were 23 images of human faces in natural scenes, which were selected to include a diverse range of examples across age, gender, race, facial expression, and head position.

Each target set (three images; illusory face, matched nonface object, and real face) was paired with a unique set of 28 distractors featuring ordinary inanimate objects without illusory faces. Each distractor matched one of the 23 object categories across the entire experiment; however, no distractor set included examples matching its respective (paired) target category on a given trial. Thus, for each distractor set, the 28 distractors were category diverse, but did not match the target image category (i.e., if the target stimuli set featured houses, then the distractors featured a variety of objects that were not houses). Hence, in Experiment 2, distractor sets were identical across the three target types, such that the only difference between conditions was the target identity. All stimuli used in Experiment 2 are available in our materials repository (see Open Practices Statement).

To manipulate the number of elements in the search array (set size), we presented 4, 8, or 16 images in a circular display against a black background (see Fig. 2c).

The visual search task comprised 414 trials, one for each combination of set size (three levels), target presence (two levels), target type (three levels), and target stimuli set (23 levels). Conditions were interleaved and presented in random order.

Participants received five self-paced breaks at regular intervals during the experiment. Experimental sessions (including instructions, practice, and breaks) took ~35 minutes.

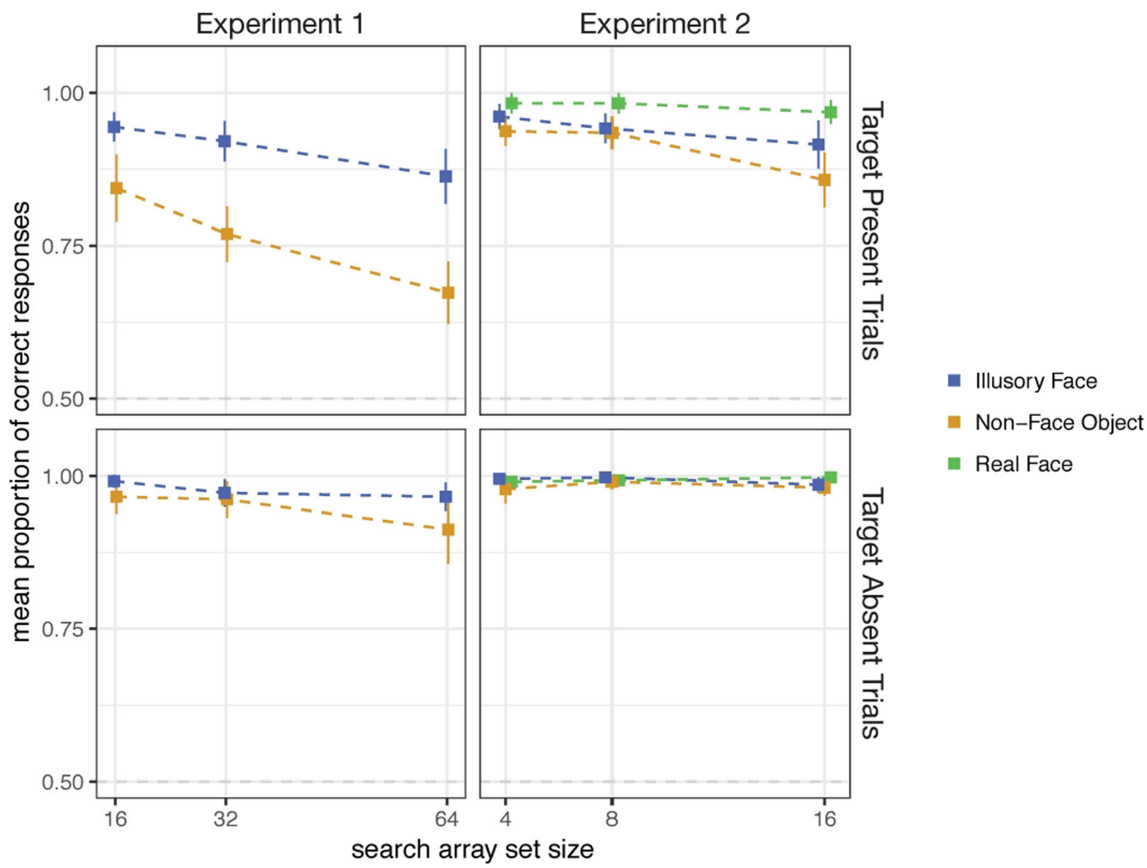


Fig. 5 Mean proportion of correct responses for both target-present (top panels) and target-absent (bottom panels) trials in both Experiments 1

Results

Data preparation and transformation Before analysis, we removed response data for trials in which participants responded incorrectly (total 252 trials). In Experiment 2, no participants timed-out on any trial. We included all remaining correct responses. We performed no further transformations of the data beyond those fully described here.

Reaction times for target-present trials As in Experiment 1, we compared mean reaction times for locating the three target categories: inanimate objects without illusory faces, inanimate objects with illusory faces, and real human faces. Figure 3b shows mean (correct) reaction times for Experiment 2. As in Experiment 1, although we analyzed both target-present and target-absent trials for completeness in order to evaluate the search efficiency of different types of targets (face, illusory face, object), our main focus was on trials on which the target was present. For target-present trials, results were analyzed in a 3 × 3 repeated-measures ANOVA (search target × set size). Overall, there was a main effect of search target on mean reaction times, $F(2, 34) = 98.97$, $p = 6.66\text{e-}15$, consistent with the search advantage for illusory faces from Experiment 1. Further, there was a main effect of set size on overall search times, $F(2, 34) = 104.6$, $p = 2.96\text{e-}15$. In addition to these main effects, there was a significant interaction between search target and set size, $F(4, 68) = 12.48$, $p = 1.14\text{e-}07$. Post hoc analyses for the main effect of search target showed that illusory faces were found more rapidly than nonface objects, p (FDR corrected) < .0001, and that real faces were found more rapidly than both nonface objects, p (FDR corrected) < .0001, and illusory faces, p (FDR corrected) < .0001.

The results in Fig. 3b suggest that mean search times differed for the three different target types (human faces, illusory faces, objects) at all set sizes. To investigate whether these differences were statistically significant, we performed nine pairwise t tests for each target type pair at each set size, using FDR correction (see Table 1). The results of this analysis confirmed that mean reaction times differed significantly between all conditions at each set size. As in Experiment 1, illusory faces were found more rapidly than nonface objects were at every set size. This confirms that the search advantage for illusory faces that we found in Experiment 1 with homogeneous object distractors also occurs when illusory face targets are presented amongst highly heterogeneous object distractors. However, although there was a search advantage for finding illusory face targets compared with object targets,

Table 1 Experiment 2: Pairwise comparisons of mean reaction times for target-present trials

Set size	Comparison	Mean difference	95% CI		$t(17)$	p (FDR corrected)	Cohen's d
			Lower	Upper			
4	nonface vs. illusory face	175	90	260	4.33	.0006	0.75
	vs. real face	311	214	408	6.79	<.0001	1.51
	illusory face vs. real face	136	73	199	4.56	.0004	0.87
8	nonface vs. illusory face	133	44	222	3.16	.0058	0.51
	vs. real face	413	305	521	8.08	<.0001	1.78
	illusory face vs. real face	280	211	349	8.59	<.0001	1.57
16	nonface vs. illusory face	255	120	391	3.98	.0011	0.73
	vs. real face	709	556	861	9.82	<.0001	2.38
	illusory face vs. real face	453	345	561	8.86	<.0001	1.90

Note. This table contains corrected post hoc analyses of data in Fig. 3b

the results of Experiment 2 revealed that human faces were still found faster than both illusory faces and objects without a face. Thus, while there is a robust search advantage for both illusory and real faces, the advantage is greater in magnitude for real faces.

Reaction times for target-absent trials For comparison, we also analyzed trials on which the target was absent. Mean reaction times for target-absent trials were analyzed in a separate 3 × 3 repeated-measures ANOVA (search target × set size). Similar to the effect found on target-present trials, there was a main effect of search target, $F(2, 34) = 56.84$, $p = 1.43e\text{-}11$, on mean reaction time. Further, there was a main effect of set size on overall search times, $F(2, 34) = 50.03$, $p = 7.42e\text{-}11$. These effects were qualified by an interaction between search target and set size, $F(4, 68) = 15.32$, $p = 5.58e\text{-}09$. Additionally, we performed nine pairwise t tests for each target type pair at each set size, using FDR correction (see Table 2). The pairwise comparisons did not reveal significant differences between illusory faces and nonfaces for any set size; however, both differ significantly from real faces for all set sizes. Together, the results in Fig. 3b and Table 2 suggest, first, that participants were quicker to confirm the absence of a genuine human face than the absence of an inanimate object (with or without an illusory face), and second, that increasing the set size had less of an effect on search times for real faces than for inanimate objects with or without illusory faces (i.e., when confirming target absence, participants were most efficient for real human faces).

Slope parameters To compare search efficiency between search target types, we calculated individual slope parameter estimates from regressions fit to each participant's data across all (i.e., nonaveraged) trial reaction times (see Fig. 4). For all conditions, mean search slopes were significantly greater than zero (target present: illusory face = 41 ms/item), $t(17) = 9.33$, $p$bonf = 2.56e-07, (nonface object = 49 ms/item), $t(17) = 8.36$, $p$bonf = 1.19e-06, (real face = 16 ms/item), $t(17) = 8.07$, $p$bonf = 1.95e-06; (target absent: illusory face = 123 ms/item), $t(17) = 6.88$, $p$bonf = 1.60e-05, (nonface object = 132 ms/item), $t(17) = 6.43$, $p$bonf = 3.70e-05, (real face = 44 ms/item), $t(17) = 6.60$, $p$bonf = 2.70e-05. Pairwise t tests (FDR corrected) showed that real faces had a shallower slope than both illusory faces (Mdiff = 25.8, 95% CI [16.8, 34.8]), $t(17) = 6.04$, $p = .00004$, $d = 1.77$, and nonface objects (Mdiff = 33.7, 95% CI [20.7, 46.7]), $t(17) = 5.45$, $p = .00006$, $d = 1.81$, for target-present trials. However, search slopes for target-present trials did not differ between illusory faces and nonface objects ($M_{\text{diff}} = 7.9$, 95% CI [−5.3, 21.1]), $t(17) = 1.26$, $p = .22$, $d = 0.36$. Together with the ANOVA results above, these results suggest that real face targets not only were more rapidly located but were also less affected by additional distractors than inanimate objects were (with or without illusory faces). In contrast to real faces, illusory faces were not found more efficiently than nonface objects, despite being located more rapidly overall.

Discussion

Our key finding is that inanimate objects featuring illusory faces are located more rapidly than similar objects without illusory faces in visual search. This search advantage was found when illusory faces appeared amongst highly homogenous arrays of object-matched distractors that were both visually and semantically similar to the target (Experiment 1) and also amongst highly heterogeneous arrays of diverse object distractors (Experiment 2). Importantly, this result indicates that illusory faces are processed quickly enough by the human

Table 2 Experiment 2: Pairwise comparisons of mean reaction times for target-absent trials

Set size	Comparison	Mean difference	95% CI		$t(17)$	p (FDR corrected)	Cohen's d
			Lower	Upper			
4	nonface vs. illusory face	84	−23	190	1.65	.1313 (*ns*)	0.25
	vs. real face	257	149	365	5.01	.0002	0.82
	illusory face vs. real face	173	111	235	5.88	.0001	0.57
8	nonface vs. illusory face	86	−49	221	1.34	.1979 (*ns*)	0.13
	vs. real face	560	331	790	5.15	.0002	1.02
	illusory face vs. real face	475	273	676	4.97	.0002	0.90
16	nonface vs. illusory face	189	−15	393	1.96	.0864 (*ns*)	0.16
	vs. real face	1,308	888	1727	6.58	<.0001	1.38
	illusory face vs. real face	1,119	726	1512	6.01	.0001	1.25

Note. This table contains corrected post hoc analyses of data in Fig. 3c

brain to confer a visual search advantage, suggesting the engagement of a rapid face-detection mechanism.

Previous research has established a search advantage for human faces in a number of contexts (Cohen et al., 2017; Golan et al., 2014; Hershler & Hochstein, 2005; Langton et al., 2008; Mayer et al., 2015). The current study demonstrates a similar visual search advantage for naturally occurring illusory faces. The key manipulation (made possible by using illusory faces) here is the presence of face-like features in the absence of the typical low-level visual features that define real faces. These face-like features are exceptional in that they create a conflict between the experience of a face, and the knowledge that an object is inanimate. Despite this, search for illusory faces, like real faces, is rapid. This shared pattern of results suggests that mechanisms supporting rapid detection of faces are sensitive to the visually diverse "face-like" features exemplified in cases of illusory face perception. This is consistent with the idea that illusory face perception is the result of a broadly tuned face-detection mechanism that is shared with other primate species (Taubert et al., 2017; Taubert et al., 2018), and with recent neuroimaging results showing that illusory faces are rapidly processed by the human brain (Wardle et al., 2020). Notably, although there is a search advantage for illusory faces, it is not as pronounced as that for human faces. This is likely because human faces differ on many visual dimensions from objects (e.g., color, shape), which provides low-level visual information about the location of a human face target (VanRullen, 2005). The significance of the finding that illusory faces also have a search advantage even if smaller in magnitude is that it demonstrates that the search advantage for faces is likely not entirely reducible to these low-level visual differences between faces and other visual categories such as objects. Instead, our results support the idea that faces have visual primacy and this is exhibited by a robust visual search advantage.

Our findings are also consistent with the view that rapid face processing involves higher level visual properties, such as the configuration and orientation of subfeatures. This appeal to "holistic" face processing may explain why inverted face stimuli are found less rapidly than upright faces (Goold & Meng, 2016), and similarly, why visual search for nonface objects is longer when an upright face is present in the search array—but unaffected by the presence of an inverted face (Langton et al., 2008). However, others have reported minimal differences between search for upright and inverted faces and argue that it is unclear to what degree a search advantage for faces could be driven by holistic face-specific features, rather than by other low-level features characteristic of faces (e.g., shape, skin color; Nothdurft, 1993; VanRullen, 2006; cf. Hershler & Hochstein, 2006). Compared with real human faces, illusory faces have increased variance of low-level visual features and thus exemplify particular high-level structures of face representations. If rapid face detection relied solely on low-level image features, we would not expect to find the pattern of results in Experiments 1 and 2. The present results suggest that the visual system can rapidly extract face-like features in illusory faces, even when low-level image features are highly variant. This mechanism may hence rely on broadly-tuned feature representations, which are highly sensitive to diverse face-like features. An obvious cost of this feature sensitivity is a greater likelihood of false positives (e.g., when orienting toward nonfaces in an environment). However, this sensitivity may facilitate advantageous rapid detection and orientation toward faces in the environment, and thus be a worthwhile trade-off, given that the cost of occasional erroneous face detection is unlikely to be high.

The results for target-absent trials point to the relevance of search context. In Experiment 1, we found that reaction times were faster for illusory faces than objects not only on target-present trials but also on trials in which the target was absent.

However, in Experiment 2, there was no difference in reaction times for illusory face and object targets on target-absent trials. This discrepancy is likely due to differences in search context between the two experiments, and a difference in the behavioral mechanism for confirming the presence versus the absence of a target. The reason we found a difference between illusory faces and object targets on absent trials in Experiment 1 but not Experiment 2 is likely because the decision to respond with "target absent" requires the observer to set the end point for search, unlike target-present trials in which there is a natural end point to the trial when the observer finds the target (see Fig. 5). It is possible that the relative search "end point" for illusory face and object targets on absent trials differed between the search contexts in Experiments 1 and 2 as a result of their methodological differences. For example, in Experiment 2, distractor set sizes were smaller, distractors were heterogeneous instead of homogenous (i.e., from different categories than the target), and human faces were added as a third target type. Given that the target is not present on these trials, absent trials are less informative about the mechanisms of face detection; however, these differences between the experiments highlight the importance of context in visual search.

We replicated the finding of a search advantage for illusory faces in objects over similar object targets without a face when the distractor items were both highly homogenous (Experiment 1) and heterogeneous (Experiment 2). In Experiment 1, all targets were matched to their distractors (both visually and semantically by the type of object), and hence illusory faces differed from distractors in only a single dimension (i.e., face-likeness). In Experiment 1, distractor objects differed from target objects, and hence illusory and nonface objects both differed from distractors in their object-specific visual properties. Given the highly heterogeneous search arrays in Experiment 2, participants could have used a shared strategy for both illusory and nonface objects by attending to object-specific features. In such a case, the presence of face-like features in objects should confer a minimal, if not absent, behavioral advantage over nonface objects. However, we found that this search advantage, although less pronounced, was still present in Experiment 2. It is also notable that in Experiment 2 the human face targets were the least similar target category (both visually and conceptually) to the object distractors, which has a known effect on search efficiency (Wolfe & Friedman-Hill, 1992). This may explain why we did not find faster reaction times for illusory faces on trials when the target was absent in Experiment 2. Taken together, the present results demonstrate that even when numerous low-level features are available to guide visual search, our visual system will exploit the presence of face-like features to augment search behavior. This points to the primacy of faces as an important visual category and is consistent with recent MEG results showing that the face-like response to illusory faces is as rapid as to human faces, but rapidly transforms into an object-based representation as this "mistake" of face processing is resolved (Wardle et al., 2020).

Conclusion

Rapid face detection is an important feature of both the human and primate visual system and is a clear illustration of how perceptual mechanisms may be tuned to support our social behaviors. Our results indicate that the human brain processes illusory faces quickly enough to confer a visual search advantage, suggesting that rapid face-detection mechanisms are sensitive to the visually diverse "face-like" features in illusory faces. This is consistent with the idea that illusory face perception is the result of a broadly tuned face-detection mechanism that is shared with other primate species (Taubert et al., 2017; Taubert et al., 2018). The finding that illusory faces are processed quickly enough to confer a behavioral advantage in a speeded task illustrates their utility in understanding the mechanisms underlying one of our most important social behaviors.

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