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Infrequent faces bias social attention differently in manual and oculomotor measures

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Abstract

Although attention is thought to be spontaneously biased by social cues like faces and eyes, recent data have demonstrated that when extraneous content, context, and task factors are controlled, attentional biasing is abolished in manual responses while still occurring sparingly in oculomotor measures. Here, we investigated how social attentional biasing was affected by face novelty by measuring responses to frequently presented (i.e., those with lower novelty) and infrequently presented (i.e., those with higher novelty) face identities. Using a dot-probe task, participants viewed either the same face and house identity that was frequently presented on half of the trials or sixteen different face and house identities that were infrequently presented on the other half of the trials. A response target occurred with equal probability at the previous location of the eyes or mouth of the face or the top or bottom of the house. Experiment 1 measured manual responses to the target while participants maintained central fixation. Experiment 2 additionally measured participants' natural oculomotor behaviour when their eye movements were not restricted. Across both experiments, no evidence of social attentional biasing was found in manual data. However, in Experiment 2, there was a reliable oculomotor bias towards the eyes of infrequently presented upright faces. Together, these findings suggest that face novelty does not facilitate manual measures of social attention, but it appears to promote spontaneous oculomotor biasing towards the eyes of infrequently presented novel faces.

Keywords social attention · attentional biasing · faces · novelty

Introduction

Research has long-since determined that faces are functionally important within our daily lives (Bentin et al., 1996; Farroni et al., 2002; Yovel et al., 2003). Although a large number of studies have demonstrated this importance through findings of preferential and spontaneous attentional biasing towards faces and facial features like eyes (Bindemann et al., 2007; Birmingham et al., 2008; Cerf et al., 2009; Ro et al., 2001), recent studies have called the robustness of these social attentional biasing effects into question.

Specifically, multiple studies have now demonstrated that extraneous factors within the stimuli and the task may have played a key role in the previously reported attentional biasing effects. Pereira et al. (2019a) were among the first to demonstrate this. Using the dot-probe task, the authors presented participants with a face, house, and comparison neutral cues, followed by a target that appeared with equal probability at one of these cue locations. Unlike past work, stimulus content, visual context, and task factors were tightly controlled. To control stimulus content, the face and house

Public Significance: It is commonly thought that faces and facial features bias attention because of their social value. Recent work has challenged this notion, showing instead that effects similar to social attentional biasing may be elicited by factors not related to the social value of faces, i.e., luminance, configuration, attractiveness, background context, and/or task requirements. The present work further reveals that the novelty of face identity impacts social attentional biasing in oculomotor but not manual measures. As such, this work highlights the need for more comprehensive studies on the factors that underlie social attention and those that determine the perceived 'social' value of faces.

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cues were equated in size, distance from central fixation, global luminance, featural configuration, and perceived attractiveness, while the response target appeared against a uniform gray background to control for possible local contrast between the target and the cues. To control visual context, a single face and house cue pair was used to restrict stimulus novelty, while the cues were presented without extraneous information, such as the hair and body information for the face and scene setting information for the house. Finally, to control for task factors, the cue and the target were never spatially or semantically related, the response keys and response type were orthogonal to one another, and the same task was used for both covert and overt measures of attentional biasing, which measured reaction time to targets when eye movements were restricted and proportion of saccades towards any of the cue locations when eye movements were not restricted, respectively. Surprisingly, the results revealed no evidence of attentional biasing towards targets pre-cued by faces in manual responses, and a numerically small but statistically reliable attentional bias towards the eyes of the face in oculomotor responses. Importantly, once extraneous factors were reintroduced into the study design, robust attentional biasing towards faces reemerged, unambiguously demonstrating the role of stimulus content, visual context, and task factors in social attentional biasing.

Follow-up studies from the same group have reported that this lack of social attentional bias was not due to the removal of information from stimulus content factors, like overall facial luminance or canonical featural configuration (Pereira et al., 2022). However, the authors did find that attentional biasing was increased when faces were perceived as highly attractive (Pereira et al., 2022) and when visual context factors provided typical contextual background information for face cues (Pereira et al., 2019b). These results dovetail with existing work demonstrating modulations in the magnitude of social attention by visual context factors like self-relevance and emotional valence (McCrackin et al., 2021; McCrackin & Itier, 2018, 2021) and task settings like instructions, interaction, and task demands (Burra et al., 2018; Hessels, 2020; Võ et al., 2012). For example, McCrackin and Itier (2018) demonstrated that faces containing positive or fearful expressions elicited enhanced attentional orienting during a gaze cuing task as compared to neutral faces, while Burra et al. (2018) showed that changing task instructions from social judgement to non-social discrimination eliminated preferential gaze processing for faces across behavioural and neural measures. Together, these converging findings suggest that social attention is influenced by extraneous content, context, and task factors. As such, uncovering which specific factors instantiate social attentional biasing is vital for understanding the determining features of social attention and the underlying mechanisms that contribute to the perceived social value of faces.

Face novelty remains a relatively unexplored factor in social attention biasing. Overall stimulus novelty, explored through the frequency or repetition of cues within a task, has been shown to affect attention, particularly when social information like faces is presented. Faces are processed both by visual brain areas that are fine-tuned for the processing of social information (Bentin et al., 1996; Haxby & Gobbini, 2012; Kanwisher & Yovel, 2006; Little et al., 2011; Nummenmaa & Calder, 2008; Puce et al., 1998), as well as extended neural networks associated with the processing of enhanced aspects of social perception, such as person perception and emotion recognition (Gobbini & Haxby, 2007). However, when the same face identities are frequently presented within a task, processing within face-specific regions has been found to decrease due to repetition of pictorial, configural, and identity information. This repetition in turn also reduces the novelty aspect of faces (Brunas et al., 1990; Clark et al., 1998; Heisz et al., 2006; Henson, 2016; Henson & Mouchlianitis, 2007; Key & Dykens, 2016; Winston et al., 2004; Yi et al., 2006). Although similar processing decreases relating to stimulus repetition have been found for frequently presented non-social information (Gosling et al., 2016; Henson, 2001; Henson et al., 2000; Schomaker & Meeter, 2012), this impact is particularly enhanced for faces at both early and late stages of processing due to the recruitment of broader networks for social perception (Miller et al., 2015; Park et al., 2010; Schweinberger et al., 1995; Schweinberger et al., 2004; Schweinberger & Neumann, 2016). For example, when faces are presented frequently, attentional processing appears to be guided by more general facial features, such as overall shape (Clutterbuck & Johnston, 2002; Fletcher et al., 2008; Megreya & Burton, 2006; Osborne & Stevenage, 2008; Visconti di Oleggio et al., 2017), compared to when faces are presented infrequently, in which case processing has been found to rely on internally specific features, such as eyes, nose, and mouth regions (Althoff & Cohen, 1999; Heisz & Shore, 2008; Stacey et al., 2005; Visconti di Oleggio et al., 2015).

Findings indicating reduced processing of frequently presented faces are consistent with the lack of social attentional biasing reported by Pereira et al. (2019a, 2019b, 2022), as the authors utilized a single face and house cue identity throughout the task. They are also consistent with investigations showing robust social attentional biasing for infrequently presented faces that used multiple different face-house cue pairs (Bindemann et al., 2005; Bindemann et al., 2007; Birmingham et al., 2008; Devue et al., 2012; Lavie et al., 2003; Ro et al., 2001). Therefore, it is possible that higher repetition rates for a single face identity may have contributed to the decreased magnitude of social attention biasing reported by Pereira et al. (2019a, 2019b, 2022), whereas lower repetition rates for facial identity may have contributed to the robustness of social attentional biasing effects reported by other researchers (Bindemann et al., 2007; Birmingham et al., 2008).

In the present study, we tested this possibility by contrasting the impact of stimulus novelty on social attentional biasing for infrequently and frequently presented face and corresponding house cue identities. To do so, we used the same task as Pereira et al. (2019a, 2019b, 2022), in which the presentation of a face-house cue pair was followed by the presentation of a target appearing at one of the previous locations of the eyes or mouth of the face or the top or bottom of the house. A single face-house pair acted as a frequent cue stimulus and was presented on half of trials, while multiple different face-house pairs acted as infrequent cue stimuli and were presented on the other half of trials. To isolate the effects of novelty, we systematically controlled for other known differences in perceptual and attentional processing of faces by accounting for *(i)* processing benefits for upright faces (Frank et al., 2009; Simion & Giorgio, 2015; Yin, 1969) by presenting face-house pairs in upright and inverted orientations; *(ii)* facilitated processing for faces perceived in the left visual field (Kanwisher et al., 1997; Kanwisher & Yovel, 2006; Puce et al., 1998; Rossion et al., 2003; Yovel et al., 2003) by having faces appear in either the left or right visual field (with the house appearing in the opposite visual field); and *(iii)* time course differences in attentional biasing by varying the presentation time between the face-house pair and the target (i.e., time between the onset of the cue and the onset of the target) across short and long intervals. All other stimulus content (i.e., size, distance from central fixation, global luminance, and perceived attractiveness), visual context (i.e., background contextual information), and task setting factors (i.e., target predictability, response key counterbalancing) also remained equated.

Experiment 1 measured manual responses while participants maintained central fixation. Experiment 2 additionally measured participants' natural oculomotor behaviour when performing this same task while their eye movements were not restricted. If reduced frequency of face presentation was responsible for social attentional biasing in previous work (Bindemann et al., 2007; Birmingham et al., 2008), we expected to find attentional biasing for infrequently presented face cues but not for frequently presented ones.

Experiment 1

Methods

Participants Thirty volunteers (24 women, 6 men; M_{age} = 20.2 years, SD_{age} = 1.0 years) with normal or corrected-to-normal vision participated. They were compensated with course credits. This sample size reflects an a priori power analysis (F test family, ANOVA: repeated measures; G*Power; Faul et al., 2007), which indicated that data from 6–38 participants were needed to detect effects ranging from .65–.15, respectively (as estimated from η_p^2 based on relevant prior studies investigating social attentional biasing effect of faces versus comparison stimuli; Bindemann & Burton, 2008; Bindemann et al., 2007; Langton et al., 2008; Ro et al., 2001), with corresponding power values from .95–.97. We considered this range of effects because estimated magnitudes of attentional biasing for faces from past research typically utilize a variety of face stimuli and do not directly overlap with the manipulations used in the current study. The closest overlap comes from Pereira et al. (2019a; Experiment 4), wherein a sample size of 20 participants was sufficient to detect effects for faces versus comparison stimuli of .44 (as estimated from η_p^2) and yielded post-hoc power of .96. Informed consent was obtained from all participants. All procedures were approved by the University Research Ethics board and the study was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

Apparatus Stimuli were presented on a 16" CRT monitor at a viewing distance of 60cm. Stimulus presentation was controlled by MATLAB's Psychophysics toolbox (Brainard, 1997).

Stimuli The fixation screen consisted of a fixation cross (1° x 1° of visual angle), positioned at the center of the screen, which was set against a uniform 60% gray background. The cue stimuli, as illustrated in Fig. 1a and b, consisted of grey-scale photographs of *(i)* male and female faces looking straight ahead with neutral expressions and the hairline removed, and *(ii)* houses with no contextual background. For the Frequent cue (Fig. 1a), a single female face identity was paired with a single house image identity. For the Infrequent cues (Fig. 1b), 8 different male and 8 different female face identities were individually paired with 16 different house images identities, resulting in 16 unique face-house cue combinations.

Each face-house pair was equated for size (4.2° x 6°) and distance from central fixation (6.3°). To match images for global luminance, average gray scale luminance (ranging from 0-1) was computed using the MATLAB SHINE toolbox (Willenbockel et al., 2010) and equated within each face-house cue pair. Any remaining luminance differences within each face-house cue pair (calculated as the average luminance of the face minus the average luminance of the house) did not differ from zero [one-sample t-test, $t(15)=1.45$, $p=.17$, $d=.36$]. To match for perceived attractiveness, thirty-five new naïve participants were independently asked to rate all images of face and house cues using a Likert scale ranging from 1- *Very Unattractive* to

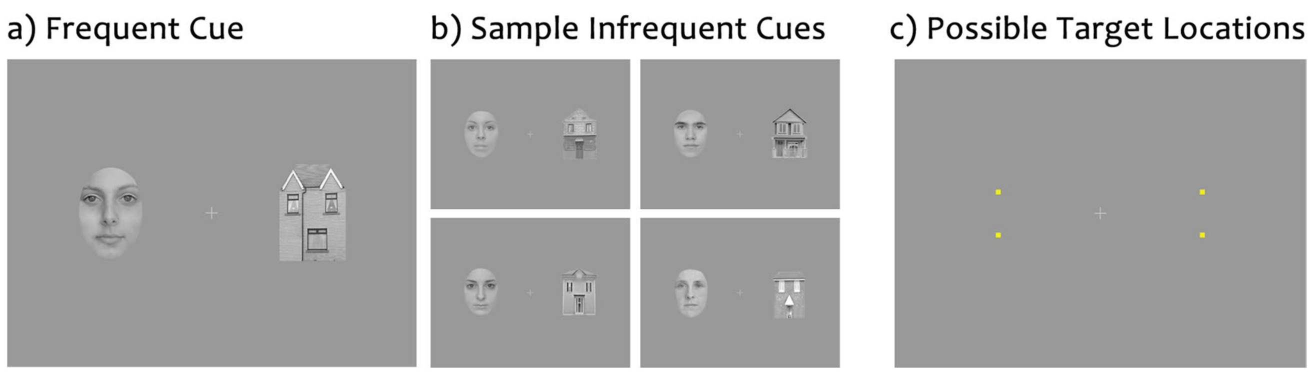

Fig. 1 The cue screen depicting upright cues with the face in the left visual field for (**a**) Frequent and (**b**) Infrequent cue conditions. (**c**) The target screen depicting all possible target locations (square target shown). The depicted face image for the Frequent cue represents an example stimulus and was not used in the present study

10- *Very Attractive*. The face and house cue images used for each pair received equivalent attractiveness ratings [all *p*s>.21, d_zs<.37], with differences within the pairs (calculated as the average attractiveness of the face minus the average attractiveness of the house) not differing from zero [one-sample t-test, $t(15)=.17$, $p=.87$, $d=.04$]. The frequent face-house cue pair used was the same as the cue pair image from Pereira et al. (2019a, 2019b, 2022) studies. The infrequent face images were sourced from the Glasgow Unfamiliar Face Database (Burton et al., 2010) and the infrequent house images were sourced from online resources. The target screen consisted of a yellow circle or square (0.3° x 0.3° each), positioned 7.2° away from the fixation cross (Fig. 1c).

Design The target discrimination task was a repeated measures design with six factors: *Cue frequency* (frequent, infrequent), *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Target location* (eyes, mouth, top house, bottom house), *Target identity* (circle, square), and *Cue-target interval* (i.e., the time between the onset of the cue and the onset of the target; 250, 360, 560, 1000ms). All factor combinations were intermixed, equiprobable, and presented equally often throughout the task.

Cue frequency varied between frequent and infrequent face-house pairs. For the Frequent cue pair, as illustrated in Fig. 1a, the same face identity was paired with the same image of a house. This same cue pair was presented on half of all trials (i.e., 384 times). For the Infrequent cue pairs, illustrated in Fig. 1b, 16 different face images (8 male and 8 female) were paired with 16 different house images, resulting in 16 unique face-house pairs. These cue pairs were presented on the other half of all trials, with each face-house cue pair presented 24 times throughout the study. This number of repetitions for the Infrequent face-house cue pairs is on par with past work. For example, there were 15 repetitions for each face cue in Langton et al. (2008) study, 16 repetitions for each face cue in Theeuwes and Van der Stigchel (2006) study, 24 repetitions for each face cue in Ro et al. (2001) study, and 45 repetitions for each face cue in Devue et al. (2012) study.

Cue orientation varied between upright and inverted images (i.e., the face-house cue pair could be presented as both cues upright or both cues inverted). This factor was included to examine whether any attentional effects were specific to faces in an upright orientation given the general processing and behavioural advantages for upright faces (Frank et al., 2009; Simion & Giorgio, 2015; Yin, 1969).

Face position varied between the left and right visual fields, with the house image occurring in the opposite visual field. This factor was included to examine whether facilitative effects for faces existed given the lateralized processing benefits found when faces are presented in the left visual field (Kanwisher et al., 1997; Kanwisher & Yovel, 2006; Pereira et al., 2019a; Puce et al., 1998; Rossion et al., 2003; Yovel et al., 2003).

Target location varied the spatial position of the target, which could occur at either the previous location of the eyes or mouth of the face or the top or bottom of the house, as illustrated in Fig. 1c. This manipulation was included to capture performance differences between targets occurring at the general location of the face and the specific location of the eyes versus the house.

Target identity varied between a yellow circle and a yellow square to measure both response time and response accuracy.

Finally, *Cue-target interval* varied between 250, 360, 560, and 1000ms to assess any differences in the time course of attentional biasing (Bindemann et al., 2007; Pereira et al., 2019a, 2019b, 2022).

Cue frequency, cue orientation, and face position were spatially uninformative about target location and target identity, such that each target was equally likely to occur at any of the possible target locations following any possible cue combination. Conditions were presented in a randomized order. Thus, participants had no incentive to attend to any cue.

Procedure A dot-probe task (MacLeod et al., 1986), which closely mirrored past work (Bindemann et al., 2007; Pereira et al., 2019a, 2019b, 2022), was used. After an initial fixation display of 600ms, either a frequent or infrequent face-house cue pair was shown for 250ms. After 0, 110, 310, or 750ms (constituting 250, 360, 560, and 1000ms cue-target intervals, respectively), a target was presented at the previous location of the eyes, mouth, top house, or bottom house, and remained visible until participants responded or 1500ms had elapsed. Participants were instructed to withhold their eye movements and to identify the target by pressing the 'b' or 'h' keys on the keyboard quickly and accurately. Target identity-key response was counterbalanced between participants.

Prior to the start of the task, participants were informed about the task sequence, that the target was equally likely to be a circle or a square, that the target could appear in any of the possible target locations, and that there was no spatial relationship between the cue content, cue orientation, cue placement, target location, or target shape. Participants completed 768 trials divided equally across four testing blocks, with ten practice trials run at the start. Manual Response Time (RT) was measured from target onset.

Results

First, we examined the data for errors. Trials with response anticipations (RTs < 100ms; 0.2% of all trials), response timeouts (RTs > 1000ms; 2.4%), and incorrect key presses (key press other than 'b' or 'h'; 0.2%) were removed from analyses. Overall, accuracy was high at 93%. All further analyses for manual response times were conducted on correct trials only.

Manual Response Time (RT) To directly probe the extent of social attentional biasing for infrequently versus frequently presented faces, mean correct RTs were first examined using a repeated measures ANOVA with the key factors of *Cue frequency* (frequent, infrequent) and *Target location* (eyes, mouth, top house, bottom house)[1]. Any violations of sphericity were adjusted using Greenhouse-Geiser corrections.

If no evidence of attentional biasing was found (i.e., if no effects or interactions between the two key factors were significant), Bayesian analyses were used to assess the relative strength of those findings (Dienes, 2011; Leppink et al., 2017)[2]. To do so, we used a two-tailed Gaussian prior distribution centered around a mean of 17.67ms and SD of 7.55ms, reflecting the magnitude of typical social attentional biasing reported in previous literature (Bindemann et al., 2007; Experiments 1a and 1b). While Bayes factor (BF_{10}) values are best interpreted on a scale rather than as a cut-off, a $BF_{10} < 0.33$ is typically taken as evidence supporting the null and a $BF_{10} > 3.00$ as evidence supporting the alternative hypothesis. If on the other hand, the ANOVA indicated evidence of attentional biasing, we then examined whether this biasing was qualified by the factors of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), and *Cue-target interval* (250, 360, 560, 1000ms) using a further omnibus ANOVA. Post-hoc comparisons were conducted using paired two-tailed t-tests, with multiple comparisons corrected using the Holm-Bonferroni procedure (Holm, 1979). All comparisons are shown with corresponding adjusted *p*-values (α_{FW} = .05; Ludbrook, 2000).

If novelty of face identity played a significant role in social biasing effects, we expected to find no attentional biasing for conditions wherein faces were frequently presented due to the reduction of face novelty in this condition. The opposite was expected for infrequently presented face identities. As depicted in Fig. 2, illustrating mean correct RTs as a function of cue frequency and target location, social attention biasing was not reliable for either frequently or infrequently presented cues.

That is, the ANOVA indicated no significant effects of *Cue frequency* [$F(1,29)=.01$, $p=.93$, $\eta_p^2<.01$], *Target location* [$F(3,87)=2.22$, $p=.09$, $\eta_p^2=.07$], or their interaction [$F(3,87)=.08$, $p=.97$, $\eta_p^2=.01$]. Bayesian analyses examining the difference between Upright Face versus House contrasts supported this conclusion, with a BF_{10} of .05 for Infrequent cues and .13 for Frequent cues. Thus, the results from manual data indicated no reliable social attentional biasing for either infrequently or frequently presented face cues.

Discussion

If previous robust social attentional biasing effects (Bindemann et al., 2007; Birmingham et al., 2008; Cerf et al., 2009; Ro et al., 2001) were due to increased face novelty brought about by infrequent presentation of multiple face identities,

[1] This simplified analysis plan is a modification of our a priori analyses based on reviewer feedback and is presented here to facilitate comprehension of data. For transparency and comparison, we present full a priori analyses within Supplementary Materials. The overall pattern of effects mirror one another.

[2] Bayes calculator: http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/bayes_factor.swf

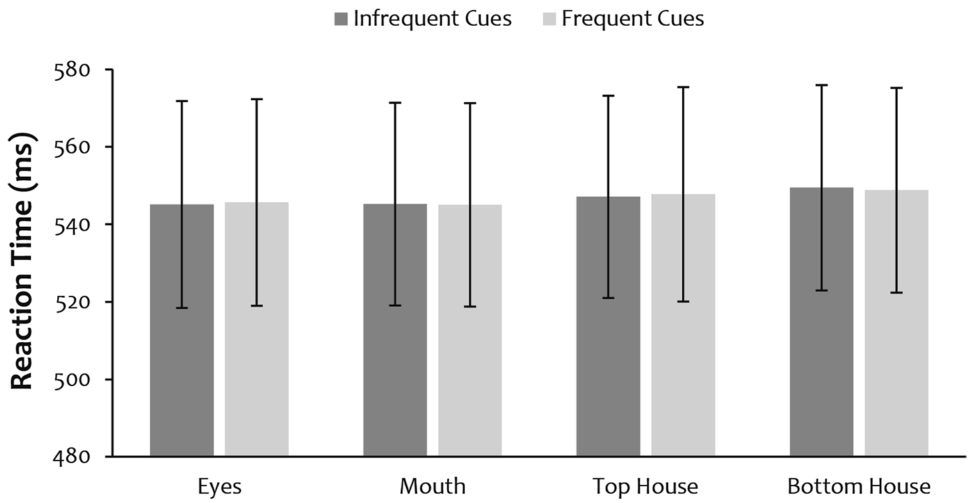

Fig. 2 Experiment 1 manual results. Mean correct RTs in ms as a function of Cue frequency and Target location. Error bars represent 95% CIs

we expected to find social biasing results for infrequently presented face cues. The results indicated no attentional biasing effects for targets occurring either at the location of the infrequently or frequently presented face cues. As such, these results are consistent with recent work showing no reliable attentional biasing by face cues (Pereira et al., 2019a, 2019b, 2022), and further suggests that face novelty, as reflected by the frequency of face identity presentation, does not preferentially bias manual attention towards faces and eyes in covert measures when eye movements are restricted. In Experiment 2, we examined the impact of face novelty on social attentional biasing when eye movements were freely allowed to occur while participants performed the same task.

Experiment 2

Previous work (Pereira et al., 2019a, 2019b, 2022) showed that when participants are not asked to maintain central fixation during the dot-probe task, a small but reliable bias to overtly look at the eyes of the face emerges. Here, we examined whether this oculomotor bias was modulated by face novelty. To do so, we kept the same procedure as in Experiment 1, but we did not provide participants with any instructions to maintain central fixation. A high-speed remote eye tracker was used to measure eye movements. Both manual RT for target responses and oculomotor behaviour during the cue period were measured.

Methods

Participants, Apparatus, Stimuli, Design, and Procedure Thirty additional new volunteers (23 women, 7 men; M_{age} = 20.7 years, SD_{age} = 1.2 years) participated. None took part in the previous experiment and all reported normal or corrected-to-normal vision.

All stimuli, design, and procedures were identical to Experiment 1, except that: *(a)* Participants' eye movements were tracked using a remote EyeLink 1000 eye tracker (SR Research; Mississauga, ON) recording with a sampling rate of 500Hz and a spatial resolution of .05°. Although viewing was binocular, only the right eye was tracked; *(b)* Prior to the start of the experiment, a nine-point calibration was performed, and spatial error was rechecked before every trial using a single-point calibration dot. Average spatial error was no greater than .5°, with maximum error not exceeding 1°; and *(c)* Participants were not given any instructions regarding maintaining central fixation to preserve their natural eye movements during the task.

Results

In Experiment 2, we analyzed both manual and oculomotor responses. Analysis procedures mirrored those from Experiment 1. Overall response accuracy was 96%, with response errors [anticipations (0.1%), timeouts (0.6%), and incorrect key presses (0.1%)] removed from manual data analyses.

Manual RT As in Experiment 1, mean correct RTs were first examined using a repeated measures ANOVA with *Cue frequency* (frequent, infrequent) and *Target location* (eyes, mouth, top house, bottom house). Fig. 3 illustrates mean correct RTs as a function of cue frequency and target location.

Fully replicating Experiment 1, no significant effects for *Cue frequency* [$F(1,29)=3.00$, $p=.09$, $\eta_p^2=.09$], *Target location* [$F(3,87)=2.33$, $p=.08$, $\eta_p^2=.07$], or their interaction

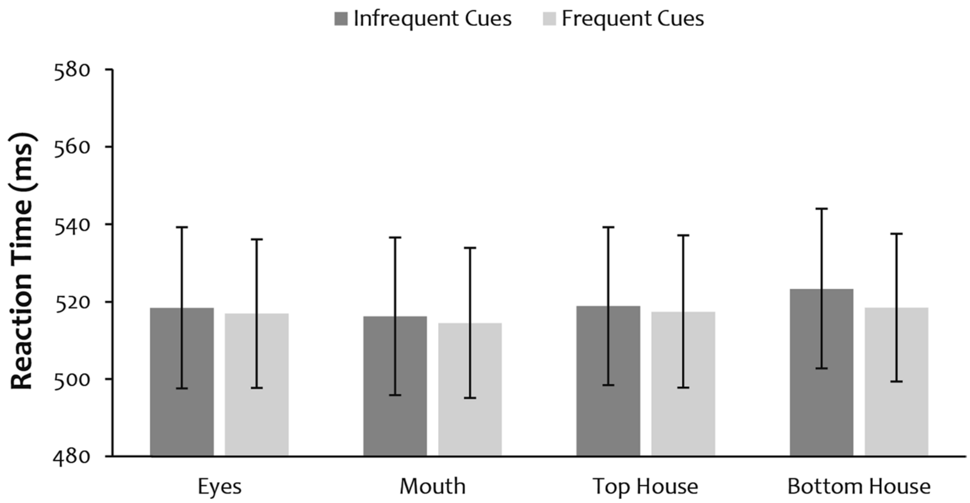

Fig. 3 Experiment 2 manual results. Mean correct RTs in ms as a function of Cue frequency and Target location. Error bars represent 95% CIs

[$F(3,87)=.45$, $p=.72$, $\eta_p^2=.02$] emerged. Bayesian analyses supported this finding for Upright Face versus House contrasts, returning BF_{10} of .08 for Infrequent cues and .16 for Frequent cues. Thus, once again the results from manual data indicated no attentional biasing towards either Infrequently or Frequently presented face-house pairs.

Eye Movements To assess if participants' eye movements were preferentially biased towards frequently or infrequently presented faces, we examined trials in which saccades were launched from the central fixation cross towards one of the cues during the 250ms cue presentation time. To analyze those trials, we first defined regions of interest (ROIs) around the cue display (i.e., eyes, mouth, top house, and bottom house), with each ROI spanning a 30° radial window. Then, for each participant, the number of first saccades, defined as eye movements with an amplitude of at least .5°, an acceleration threshold of 9,500°/s^2, and a velocity threshold of 30°/s, that were launched towards each ROI was determined by examining the direction of the saccade that launched from the central fixation cross towards one of the ROIs upon cue onset. Proportion of saccades towards each ROI for each participant was then calculated by tallying the number of trials containing saccades towards each ROI and then dividing this number by the total number of trials containing first saccades during the cue period.

On average, participants saccaded away from the fixation cross on 12% of all trials (Frequent = 5.6%, Infrequent = 5.9%). Of these saccaded trials, first saccades were launched towards an ROI on 96% of trials. Mean saccadic RT, defined as the time between the onset of the cue and the start of a saccade towards an ROI, was 214ms (Frequent = 214ms, Infrequent = 213ms). Mean saccadic speed, defined as the visual angle distance covered per second for the first saccade, was 175°/s (Frequent = 179°/s, Infrequent = 164°/s). Mean saccadic length, defined as the visual angle distance of the first saccade towards an ROI, was 7.0° (Frequent = 7.1°, Infrequent = 6.5°), suggesting that saccades reached the cue stimuli, which were centered 6.3° degrees of visual angle away from fixation.

Mirroring previous manual analyses, the proportion of first saccades was examined using a repeated measures ANOVA with *Cue frequency* (frequent, infrequent) and *ROI* (eyes, mouth, top house, bottom house). Fig. 4 illustrates the proportion of saccades as a function of cue frequency and ROI.

Unlike manual measures, and as shown in Fig. 4, the data indicated evidence of oculomotor biasing towards face cues. That is, there was a reliable main effect of *ROI* [Mauchly's test of sphericity, $\chi^2(5)=13.34$, $p=.02$; $F(2.24,65.06)=12.88$, $p<.001$, $\eta_p^2=.31$], indicating an overall greater proportion of saccades directed towards the Eyes compared to the Mouth and Bottom House regions [ts>3.83, ps<.003, d_zs>.70] and an overall greater proportion of saccades directed towards the Top House versus Mouth region [$t(29)=2.98$, $p=.023$, $d_z=.54$]. No differences were found between any other regions [all other ps>.07, d_zs<.44].

While no significant main effects emerged for *Cue frequency* [$F(1,29)=3.05$, $p=.09$, $\eta_p^2=.10$], there was a significant interaction between *Cue frequency* and *ROI* [Mauchly's test of sphericity, $\chi^2(5)=11.70$, $p=.04$; $F(2.35,68.14)=6.55$, $p=.001$, $\eta_p^2=.18$], demonstrating differential effects for infrequently versus frequently presented cues. For Infrequent cues, greater proportion of saccades were directed towards the Eyes versus all other regions [ts>3.04, ps<.02, d_zs>.55; all other ps>.07, d_zs<.44]. In contrast, for Frequent cues, there was a general oculomotor bias towards the upper regions of the cues, with greater proportion of saccades

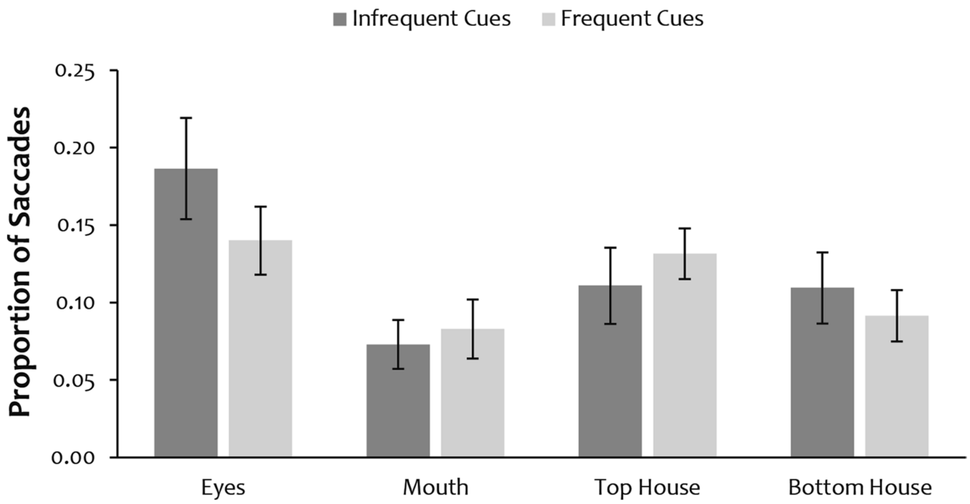

Fig. 4 Experiment 2 eye movement results. Mean proportion of breakaway saccades as a function of Cue frequency and ROI. Error bars represent 95% CIs

directed towards the Eyes and Top House versus the Mouth and Bottom House regions [*t*s>3.21, *p*s<.009, d_zs>.59]. No differences were found in proportion of saccades directed towards the Eyes versus the Top House [*t*(29)=.55, *p*=.99, d_z=.10] or towards the Mouth versus the Bottom House [*t*(29)=.62, *p*=.99, d_z=.11].

Thus, since the simplified analysis returned reliable effects and interactions between *Cue frequency* and *ROI*, we next examined proportion of first saccades in an omnibus repeated measures ANOVA as a function of *Cue orientation* (upright, inverted), *Face position* (left visual field, right visual field), *Cue frequency* (frequent, infrequent), and *ROI* (eyes, mouth, top house, bottom house). This analysis yielded two key significant interactions of interest.

The first was a three-way interaction between *Cue orientation*, *Cue frequency*, and *ROI* [*F*(3,87)=3.81, *p*=.013, η_p^2=.12], which indicated that attentional biasing effects were specific to Upright cues. That is, when Infrequent cues were Upright, there was a greater proportion of saccades directed towards the Eyes versus all other ROIs [*t*s>3.52, *p*s<.006, d_zs>.64] and a greater proportion of saccades directed towards the Top House versus the Mouth [*t*(29)=2.80, *p*=.027, d_z=.51; all other *p*s>.30, d_zs<.27]. When Frequent cues were Upright, a greater proportion of saccades were directed towards the Eyes and Top House versus the Mouth and Bottom House [*t*s>3.06, *p*s<.014, d_zs>.56; all other *p*s>.67, d_z<.18]. These effects are illustrated in Fig. 5. No reliable effects emerged when cues were Inverted [Infrequent cues, all *p*s>.10, d_zs<.46; Frequent cues, all *p*s>.99, d_zs<.25]. These effects were consistent with an overall two-way *Cue orientation* and *ROI* interaction [Mauchly's test of sphericity, χ^2(5)=29.82, *p*<.001; *F*(1.91,55.44)=7.78, *p*=.001, η_p^2=.21], which indicated that both cues had overall greater proportion of saccades directed towards the Eyes and Top House versus all other regions when Upright [*t*s>2.65, *p*s<.036, d_zs>.48; all other *p*=.53, d_z=.12; Inverted, all *p*s>.23, d_zs<.40].

The second interaction of interest was a two-way between *Face position* and *ROI* [Mauchly's test of sphericity, χ^2(5)=65.76, *p*<.001; *F*(1.30,37.60)=3.93, *p*=.045, η_p^2=.12], demonstrating differential saccadic effects for Eyes when faces were presented in the left versus right visual field, irrespective of stimulus novelty. That is, when faces were presented in the left visual field, there was an overall greater proportion of saccades directed towards the Eyes versus all other regions [*t*s>2.97, *p*s<.024, d_zs>.54; all other *p*s>.99, d_zs<.12], whereas when faces were presented in the right visual field, there was an overall lower proportion of saccades directed towards the Mouth versus all other regions [*t*s>2.83, *p*s<.033, d_zs>.52; all other *p*s>.09, d_zs<.41].

Consistent with the simplified analyses, the omnibus ANOVA also indicated a main effect of *ROI* [Mauchly's test of sphericity, χ^2(5)=13.34, *p*=.02; *F*(2.24,65.06)=12.88, *p*<.001, η_p^2=.31]. No other effects or interactions were significant [*F*s<3.05, *p*s>.09, η_p^2<.01].

Discussion

In Experiment 2, we examined whether the frequency of face identity presentation influenced social attentional biasing in manual and oculomotor measures when eye movements were freely allowed to occur. Manual data once again indicated no response advantage for infrequently or frequently presented face identities, and Bayesian analyses supported these results. Oculomotor data on the other hand

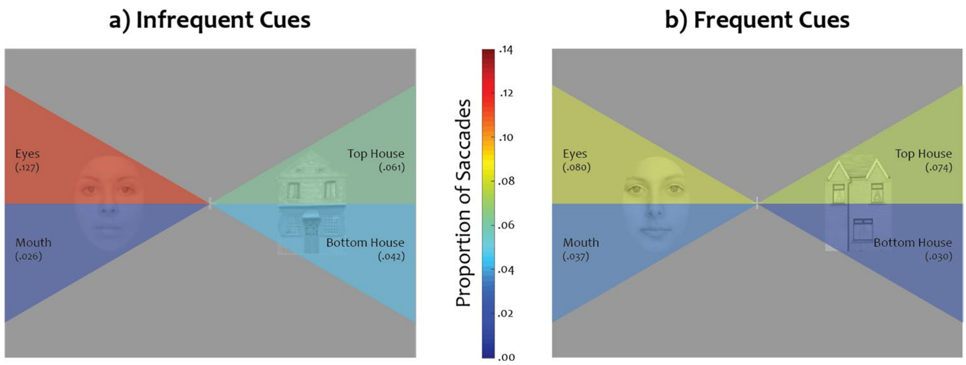

Fig. 5 Experiment 2 eye movement results. Mean proportion of breakaway saccades for Upright cues (collapsed across Face position) depicted within respective ROIs for (**a**) Infrequent and (**b**) Frequent cues

indicated that a greater proportion of saccades were directed towards infrequently presented faces, with the eyes of infrequent faces saccaded to more than other regions. This effect was specific to upright faces and occurred when faces were presented in the left visual field. The effect for frequently presented faces was less specific, such that more first saccades were launched towards the upper regions of both face and house cues, with the eyes and top house regions having greater proportions of saccades as compared to the mouth and bottom house regions, and no differences between the eyes and top house regions or between the mouth and bottom house regions. As such, the data from Experiment 2 show that infrequently presented face identities bias social attention in oculomotor responses.

General Discussion

The present study examined whether the frequency of face identity modulated social attentional biasing towards faces. Using the dot-probe paradigm, we presented participants with frequently repeating (i.e., the cue appeared often throughout the experiment) and infrequently repeating (i.e., different cues appeared seldom throughout the experiment) face and house identities, which were followed by a target that was presented at the previous location of the eyes or mouth of the face or the top or bottom of the house. Based on past work, frequent presentation of a single face identity has been associated with lower facial novelty (Heisz et al., 2006; Winston et al., 2004; Yi et al., 2006), while infrequent presentation of multiple face identities served to maintain face novelty. As in previous work (Pereira et al., 2019a, 2019b, 2022), other stimulus content (i.e., size, distance from central fixation, overall luminance, and perceived attractiveness), visual context (i.e., background information), and task factors (i.e., target predictability, response key counterbalancing) were controlled. In Experiment 1, we instructed participants to maintain central fixation and measured manual responses by examining the speed of target discrimination. In Experiment 2, we did not restrict eye movements, and in addition to manual responses to the target, we also assessed spontaneous first saccades during the cue period.

When measuring manual responses to the target, regardless of whether eye movements were restricted in Experiment 1 or were free to occur in Experiment 2, we found no reliable evidence for social attentional biasing towards infrequently or frequently presented face identities. That is, there were no differences in the speed of responses for targets occurring at the location of the infrequent or frequent face cue as compared to the house cue, and these responses did not vary as a function of cue orientation or face position. These findings were consistent across null hypothesis testing and Bayesian analyses. Thus, face novelty, regardless of the frequency of presentation and cue orientation / position, does not appear to influence social attentional biasing in manual data. These results are once again at odds with past work that has utilized similar presentations of several different faces and demonstrated robust social attention biasing towards faces (Ariga & Arihara, 2017; Bindemann et al., 2005; Bindemann et al., 2007; Devue et al., 2009; Lavie et al., 2003; Ro et al., 2001; Sato & Kawahara, 2015), suggesting that these past results may have been influenced by other factors, such as stimulus content, visual context, and/or task settings (Pereira et al., 2019a, 2019b, 2022).

In contrast, when eye movements were free to occur in Experiment 2, there was evidence for social attentional biasing. That is, first saccades were consistently biased towards the eyes of infrequently presented upright faces, with greater overall effects when faces were presented in the left visual field. This result replicates past work showing a general oculomotor preference for faces in an upright orientation (Rossion et al., 2003; Yin, 1969) and lateralized face processing in the right hemisphere of the brain (Kanwisher & Yovel, 2006; Puce et al., 1998; Yovel et al., 2003), and it is also consistent with previous research showing strong attentional biases towards novel stimuli (Burack & Enns, 1997; Fagan Iii & Haiken-Vasen, 1997; Johnston et al., 1990) and away from frequently repeated stimuli (Colombo & Mitchell, 1990). More recent work has demonstrated that frequent presentations of stimuli can lead to both short-term and long-term decrements in attentional effects (Turatto & Pascucci, 2016), suggesting that infrequently presented cues may be perceived as more alerting than frequently presented ones. Our findings support this work by showing that novel faces engaged the oculomotor system within 250ms of presentation time and led to saccadic modulations based on the frequency of cue presentation, with eye movements being spontaneously biased towards infrequently presented face identities (i.e., those with more novelty) as compared to frequently presented ones (i.e., those with less novelty).

An important aspect of the oculomotor effects for infrequently presented faces is that these findings occurred consistently and spontaneously despite specific task constraints. First, the effects were statistically reliable even though eye movements occurred on only a small subset of trials (i.e., 12% of all trials). Second, the effects were specific to infrequently presented faces, even though both frequently and infrequently presented face-house cue pairs resulted in a similar number of trials containing eye movements (i.e., Frequent = 5.6%, Infrequent = 5.9%). Third, oculomotor biasing for faces occurred even though the task contained both novel faces and novel houses. That is, even though both cues were novel within each cue pairing, eye movements were preferentially biased towards faces and eyes rather than the house. Together, this suggests that there is a unique aspect of novelty within faces that drives the attentional system to overtly focus on novel faces and their eyes, over and above other novel or frequently presented stimuli.

A natural question that follows from the current set of findings is whether similar effects for face novelty could be found in other forms of social attention, such as social attentional orienting. Often, attentional orienting by faces is studied using gaze cuing tasks, wherein participants are presented with a central social cue (e.g., schematic or photographed face) that gazes at either the left or right visual field, followed by a target that appears at either the gazed-at or not gazed-at location. Prior work has found that even when participants are informed that the direction of eye gaze is irrelevant to the task, responses are faster and more accurate for targets that occur at gazed-at locations (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). Given that our findings show that the eyes of infrequently presented faces bias attention, it would be intuitive to expect that face novelty may also result in subsequent greater gaze cuing effects. However interestingly, past work has shown the opposite, such that increased face familiarity was associated with greater gaze cuing effects (Deaner et al., 2007). This is observed from a young age as well (Barry-Anwar et al., 2017; Del Bianco et al., 2019; Hoehl et al., 2012), with studies suggesting that these familiarity effects may reflect social factors that convey similarity or trustworthiness (Dalmaso et al., 2016; Hungr & Hunt, 2012; Strachan & Tipper, 2017). Indeed, prior work has found that faces that are personally familiar recruit theory of mind regions (i.e., medial prefrontal cortex, temporoparietal junction) more strongly than novel faces due to the strong association between personally familiar representations and social knowledge (Cloutier et al., 2011; Gobbini et al., 2004; Gobbini & Haxby, 2007). Future work is needed to understand how face familiarity may differentially affect different facets of social attention, namely attentional biasing by faces and attentional orienting in response to specific facial cues like eye gaze.

More broadly, an important aspect of the present results also concerns the relationship between manual and oculomotor results. That is, for manual RT in both Experiments 1 and 2, there were no social attentional biasing effects; however, for oculomotor data in Experiment 2, there was evidence of social attentional biasing towards infrequently presented faces and eyes. This dissociation across response modalities raises at least two points for discussion.

One, it suggests that facial novelty may exert early effects on attentional processes that result in immediate engagement of eye movements towards faces without extended effects on manual measures. Note though, that because eye movements only occurred on a small subset of trials in Experiment 2, one possibility is that the ability to make eye movements during tasks may be an important factor in revealing manual effects that are representative of social attentional biasing by novelty. Given the low proportions of eye movements within the current study, it was not possible to conduct more complex analyses on whether trials containing eye movements towards faces and eyes may have also contained manual effects for targets appearing in these locations, or even whether saccadic RT, length, and speed were different across cue regions. As such, further studies can utilize a similar study design while making eye movements relevant to the task to examine whether face novelty can result in both short-term oculomotor and long-term manual performance effects, and the degree to which these effects are related.

Two, the differential results across manual and oculomotor measures have the potential to lend further insight into how these two measures link with covert and overt social attention, as recent results have repeatedly found that social attentional measures dissociate depending on whether eye movements are restricted or allowed, i.e., across covert and overt measures, respectively (Bonmassar et al., 2019; Gobel et al., 2015; Kuhn et al., 2016; Kuhn & Teszka, 2018; Laidlaw et al., 2011; Laidlaw et al., 2016; Laidlaw & Kingstone, 2017; Latinus et al., 2015; Risko et al., 2016; Scott et al., 2018). It is important to note here that the present manipulation does not fully overlap with typical constructs of covert and overt attention. Specifically, Experiment 1 did not provide a pure measure of covert attention since participants were only verbally instructed to maintain fixation without fixation monitoring. Similarly, Experiment 2 did not provide a typical measure of overt attention because eye movements were not task-relevant, as in typical oculomotor tasks. However, despite these differences, there is evidence to suggest concordance between present and past work. For covert attention, past attentional work has confirmed that verbal instructions result in excellent compliance with central fixation (Friesen et al., 2004; Posner, 1980; Riege et al., 2020), and prior studies similarly demonstrate overlapping effects when verbally instructing restrictions on eye movements versus when controlling for eye movements using an eye tracker (Pereira et al., 2019a). Similarly, for overt attention, although eye movements were not relevant to the task, their occurrence within the short period of cue presentation time indicates that oculomotor biasing occurred in a spontaneous and unconstrained manner. As such, the present manipulations provided correspondingly consistent effects to past work and lend parallel evidence of dissociations in manual and oculomotor measures of social attention biasing.

The dissociations between covert and overt social attention shown here and in past work lead to further questions about the links between attention and eye movement with regards to social information. Prior research on the relationship between attentional systems and eye movement control shows that in contrast to classic work, which theorized that eye movement preparation drives subsequent covert attentional shifts (Klein, 2004; Rizzolatti et al., 1987; Shepherd et al., 1986), the two processes relate in the opposite direction of influence, with covert attentional shifts driving subsequent eye movements to attended locations (Bundesen, 1990; Deubel & Schneider, 1996). As such, attentional systems and eye movement control often move together but can diverge and operate independently (Hunt et al., 2019; Smith & Schenk, 2012). Together with previous studies (Pereira et al., 2019a, 2019b, 2022), our current results further support the notion that when social stimuli are used to engage attention, attentional and eye movement systems can be engaged together or independently based on their utility and task purpose (Kuhn et al., 2016; Laidlaw et al., 2011; Risko et al., 2016). Further work investigating the links between manual and oculomotor measures of social attention and their links with covert and overt modes of attentional engagement will be beneficial in uncovering the role and functionality of social attention both in the laboratory and in real world settings.

In sum, the present study demonstrated that social attentional biasing is affected by infrequent presentations of faces only when participants are allowed to make eye movements. As such, these results indicate that face novelty plays a role in social attentional biasing and highlights the need for further comprehensive studies on the factors that determine the co-occurrence of social attentional biasing in manual and oculomotor measures.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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Open Practices Statement The data and materials for all experiments can be found on the Open Science Framework, https://osf.io/3kyd4/. None of the experiments were preregistered.