Empirical research supports the existence of a psychological link between the color red and attraction. When red appears on the face, apparel, or in the background of a target, that person is rated by members of the opposite sex as more attractive than opposite-sex faces presented with other color cues (Buechner, Maier, Lichtenfeld, & Elliot, 2015; Elliot & Niesta, 2008; Elliot et al., 2010; Elliot, Tracy, Pazda, & Beall, 2013; Guéguen, 2012a; Jung, Kim, & Han, 2011; Lin, 2014; Pazda, Elliot, & Greitemeyer, 2012, 2014; Roberts, Owen, & Havlicek, 2010; cf. Elliot & Maier, 2013; Hesslinger, Goldbach, & Carbon, 2015; Lynn, Giebelhausen, Garcia, Li, & Patumanon, 2013; Seibt, 2015; see also Francis, 2013). Red cues also promote approach-oriented behaviors towards opposite-sex targets (Guéguen, 2012b, 2012c; Guéguen & Jacob, 2013, 2014; Meier, D’Agostino, Elliot, Maier, & Wilkowski, 2012; Niesta Kayser, Elliot, & Feltman, 2010; cf. Lynn et al., 2013). The nature of same-sex red-attraction effects is unclear due to mixed patterns of results (Buechner et al., 2015; Elliot & Niesta, 2008; Elliot et al., 2010; Roberts et al., 2010; Lin, 2014; Lynn et al., 2013; Seibt, 2015).

The red-attraction effect is moderated by several factors, including targets’ age, attractiveness, and sexually dimorphic cues as well as females’ fertility when rating males (Prokop, Pazda, & Elliot, 2015; Schwarz & Singer, 2013; Wen, Zuo, Wu, Sun, & Liu, 2014; Young, 2015). Such moderating factors are sensible from the viewpoint of color-in-context theory, which holds that red-attraction effects are grounded at least in part in evolutionary signaling (i.e., red as a cue of fertility and health) (Elliot & Maier, 2012, 2014). Mediation analyses support this signaling premise (Pazda, Thorstenson, Elliot, & Perrett, 2016).

Previous studies demonstrating boosts in attraction and approach behavior as a function of red cues have varied from highly controlled experiments where colors are closely matched on low-level properties (e.g., via manipulation in graphics software; Elliot & Niesta, 2008; Elliot et al., 2010; Pazda et al., 2012, 2014) to more ecologically valid but less stringently controlled color manipulations (e.g., the color of shirt worn by hitch-hikers or women in a bar; Guéguen, 2012b; Guéguen & Jacob, 2014). What previous research had in common until recently is that the examination of red-attraction effects occurred by concurrently presenting a color with a target during attractiveness ratings. Recently, red-attraction effects have been shown to generalize to cases where redness is primed by reading color-word primes in text descriptions prior to making ratings (Pazda & Elliot, 2016). None of these paradigms have been able to test two explanations: whether exposure to red cues increases ratings of attractiveness generally, or whether red cues need to be paired with a target in order to impact attractiveness ratings. To tease apart these explanations, what is necessary is a case...
where participants see red accompanying a target, and a case where participants see red before rating a target.

Using a large sample, we explored this heretofore unasked question. Specifically, we tested whether red-
attraction effects can be accounted for simply by recent exposure to red and/or whether red-attraction effects require pairing of color with a target (see Kuhbandner, Spitzer, Lichtenfeld, & Pekrun, 2015 for color-memory effects). We deployed a two-phase design. Faces were first paired with either red or blue (which served as a chromatic control), and then color-paired faces as well as novel faces were rated for attractiveness in the absence of color cues. Higher attractiveness of novel faces after exposure to red compared to a chromatic control condition would support the first account. Higher attractiveness of color-paired than novel faces in the red compared to chromatic control condition would support the second.

We also tested the extent to which conscious awareness of the pairing of a face with red is associated with the red-attraction effect. The position adopted by color-in-context theory is that colors act as an "implicit affective cue" (Elliot & Maier, 2014, p. 109). That is, colors should exert their influence outside of awareness. Indeed, individuals explicitly rate color as the least influential factor in their decisions about attractiveness (Elliot & Niesta, 2008; Schwarz & Singer, 2013). As typically framed, this means that people are unaware that a color is influencing their decision, but when taken to its logical end it may be that individuals do not even need to be aware that a color is being linked to a target. We sought to investigate this "strong" version of the implicit affective cue hypothesis. This was achieved by measuring individual differences in ability to detect faces during color pairing (e.g., Cheesman & Merikle, 1984), and correlating this ability with the magnitude of the red-attraction effect for color-paired faces.

Across the three empirical questions examined, and in line with the overall trend in the literature, we expected that red cues would lead to higher attractiveness ratings than blue (Buechner et al., 2016; Elliot & Niesta, 2008, Elliot et al., 2010, 2013; Jung et al., 2011; Roberts et al., 2010; Wen et al., 2014), and that such effects would be most pronounced for males rating females rather than for same-sex judgments or females rating males.

Materials and Method

Participants

A flowchart of participant recruitment and exclusions appears in Figure 1. Data from 778 participants (468 females; $M_{\text{age}} = 19.23$, $SD_{\text{age}} = 2.43$, 11 participants did not report their age) were analyzed. Participants classified themselves as Caucasian only ($n = 347$), East Asian only ($n = 149$) South Asian only ($n = 80$) both East and South Asian ($n = 27$), Subcontinental Asian only ($n = 60$), Middle Eastern ($n = 21$), or mixed or ‘other’ ethnicity ($n = 76$); with 18 preferring not to answer.

Introductory psychology students participated in the experiment during tutorial classes in groups of 13–27 as part of a course project, with each participant at an individual computer. Sample size was determined based on the size of the cohort; data collection ceased once the entire cohort had the opportunity to participate in the experiment. Exclusion of non-heterosexual participants is in line with precedent set in past research on the red-attraction effect (Elliot & Niesta, 2008; Pazda et al., 2014, Prokop et al., 2015; Wen et al., 2014; Young, 2015).

Procedure

The protocol for this experiment was approved by the University of New South Wales Human Research Ethics Approval Panel C (Approval #1970). Materials and data are available at https://osf.io/qhn9t/. All participants provided informed consent for participation in the protocol via a mouse click after reading the information statement.

All participants completed the session on Dell U2311H 60Hz LCD monitors, which were reset to factory monitor settings prior to commencement of data collection. All tasks were presented using Inquisit Web Edition 3.0.6 (2011), which serves as a distribution platform such that files run locally on each machine. Hence, its use does not introduce added internet-based variability to or stability concerns for experiment deployment, given that all machines had identical specifications.

Color-face pairing phase. Participants viewed one of two sets of 10 faces (5 female, 5 male). The color-paired set for one half of participants comprised the novel set for the other half of participants; this was counterbalanced on a by-class basis. Face photographs were drawn from the neutral expression subset of the Warsaw Set of Emotional Facial Expression Pictures (Olszanowski et al., 2015) and were randomly allocated to one of the sets. All photos were of White individuals, aged 20–30, and were converted to grayscale. The 20 faces were a subset of the 30-person set, selected on the basis of moderate attractiveness as judged by the author team. The characteristics of these faces (i.e., White faces in grayscale with neutral expressions) are similar to stimuli used in the seminal work on the red-attraction effect (e.g., Elliot & Niesta, 2008).

Participants were assigned, based on tutorial class, to either the red or blue condition. Accordingly, color-paired faces were surrounded by either a fully saturated red (RGB 142,0,0) or, in the chromatic control condition, blue (RGB 0,0,255) border of approximately equal luminance as indicated by a color spectrometer on a subset of the monitors. As only one chromatic control was used, the effects must be interpreted as relative effects of red versus blue. We return to this point in the Discussion.

The ten color-paired faces were presented in a random order, five times each such that there was no replacement of the ten faces until all had been displayed. Thus, this phase consisted of 50 color-pairing trials. In line with Bargh and Chartrand’s (2000) guidelines and prior research (Smith, Dijksterhuis, & Chaiken, 2008), each trial consisted of a black (RGB 0,0,0) fixation point on a gray screen (RGB 120,120,120), followed by a single-frame forward mask, and a single-frame presentation of a face, which was backward-masked for 60
frames using the same image as in the forward mask (see Figure 2). The masks consisted of Fast Fourier Transform phase-scrambled versions of the presented face. The colored background was present for the duration of the forward mask, face, and backward mask. A blank gray screen (RGB 120, 120, 120) appeared such that each trial lasted for a randomly-determined interval between 3 and 5 s.

On each trial, a fixation symbol preceded a forward- and backward-masked face. The border color of the face photo (and masks) was either red or blue according to condition on a between-subject basis.

Interspersed amongst the 50 color-pairing trials were five attention check trials in which the fixation symbol ‘+’ was replaced with ‘x’. This ‘x’ fixation was followed by a completely novel forward- and backward-masked face. Participants were instructed to monitor for and press the spacebar in response to ‘x’. Trials in which participants pressed the spacebar at any point before the next trial began (i.e., within 3–5 s) were coded as successful attention checks. Participants who failed all five trials were excluded from analysis (see Figure 1).

**Rating phase.** In the rating phase, participants rated the perceived attractiveness (“How attractive is this face?”) of 20 faces (i.e., ten color-paired, ten novel) on a scale from 1 (*not at all*) to 7 (*extremely*). This question was embedded amongst other questions not relevant to the investigation of the red-attraction effect (i.e., liking, familiarity). During the rating phase, all content was presented in grayscale. Four average perceived attractiveness scores were calculated for each participant: color-paired male faces, color-paired female faces, novel male faces, and novel female faces.

**Objective awareness.** Following the rating phase, the ability to detect and process color-paired faces was assessed by ten identification trials in which a color-pairing trial was repeated once for each face. After each
Identification trial, participants were asked to identify the presented face from an array of five faces (consisting of the target face and the other four faces in the same-sex color-paired set). A higher number of identifications indicated a lower threshold for objective awareness, and thus a greater likelihood of being objectively aware of the faces during the color-face pairing phase.

Results

The effect of prior color exposure
Analyses commenced with the fitting of a 2 (target sex: male, female; within-subjects) × 2 (color: red, blue; between-subjects) × 2 (participant sex: male, female; between-subjects) ANOVA on attractiveness ratings of novel faces. This model afforded a test of whether prior exposure to red influenced later attractiveness judgments of color-unpaired faces. Prior exposure to red in fact reduced the rated attractiveness of all rated targets relative to blue ($M_{\text{red}} = 4.02, SE_{\text{red}} = 0.06; M_{\text{blue}} = 4.24, SE_{\text{blue}} = 0.06$), $F(1, 774) = 8.27, p = .004, \eta^2_p = .011$. This “red-unattraction effect” (a term we employ to maintain the language used in this literature) was qualified by target sex, $F(1, 774) = 5.12, p = .024, \eta^2_p = .007$, which was further qualified by a marginally-significant interaction between participant sex and target sex, $F(1, 774) = 2.86, p = .091, \eta^2_p = .004$. Further analysis of this three-way interaction revealed that the red-unattraction effect was present in all trial types, $t(774) > 2.21, p < .028$, except for male participants rating female targets, $t(774) = -0.09, p = .928$.

The effect of color-face pairing
A 2 (target sex) × 2 (color) × 2 (participant sex) ANOVA on color-face pairing attractiveness scores (see Figure 3 caption) revealed a significant interaction between target sex and color, $F(1, 774) = 7.04, p = .008, \eta^2_p = .009$, that was not qualified by participant sex, $F(1, 774) = 1.03, p = .311, \eta^2_p = .001$ (Figure 3). Further analyses indicated that, whereas prior color-face pairing with red marginally increased attractiveness relative to blue for male targets, $F(1, 774) = 3.72, p = .054, \eta^2_p = .005$, prior color-face pairing with red significantly reduced attractiveness relative to blue for female targets, $F(1, 774) = 6.16, p = .013, \eta^2_p = .008$.

The impact of objective awareness
As the effects of color-face pairing on attractiveness were moderated by target sex, we examined the impact of objective awareness separately for each target sex using 2 (color) × 2 (participant sex) ANOVAs on color pairing scores with objective awareness as a continuous, moderating between-subjects variable. In these models, the critical effects are interactions involving both color and objective awareness.

For female targets, a main effect of objective awareness emerged, with higher objective awareness associated
with higher attractiveness ratings, $F(1, 770) = 10.84$, $p < .001$, $\eta_p^2 = .014$. An interaction between color and objective awareness (not further qualified) also emerged, $F(1, 770) = 8.25$, $p = .004$, $\eta_p^2 = .011$. Decomposition of this effect suggested that awareness was unrelated to ratings of blue-paired female targets, but was positively correlated with ratings of red-paired female targets. These results suggest that, with increasing objective awareness, the observed red-unattraction effect is reversed to a red-attraction effect (Figure 4, Panel A).

For male targets, objective awareness was associated with lower attractiveness ratings, $F(1, 770) = 11.88$, $p < .001$, $\eta_p^2 = .015$. The color by objective awareness interaction (not further qualified) also emerged, $F(1, 770) = 4.80$, $p = .029$, $\eta_p^2 = .006$. Again, awareness was unrelated to ratings of blue-paired targets, but in this case it was negatively correlated with ratings of red-paired male targets (Figure 4, Panel B).

**Discussion**

This experiment explored three novel phenomena regarding the nature of red-attraction effects: the effect of prior color exposure, the effect of color-face pairing on ratings made after a delay, and the impact of objective awareness of color-face pairing. Each of these represents a novel extension to the basic red-attraction effect reported elsewhere (Buechner et al., 2015; Elliot & Niesta, 2008; Elliot et al., 2010; 2013; Guéguen, 2012a; Jung et al., 2011; Lin, 2014; Pazda et al., 2012, 2014; Roberts et al., 2010; cf. Elliot & Maier, 2013; Hesslinger et al., 2015; Lynn et al., 2013; Seibt, 2015; see also Francis, 2013). One interpretation of the failure to find red-attraction effects (relative to blue) in the current research is that they challenge the robustness of red-attraction effects reported elsewhere. This, in our opinion, is a valid conclusion, though one we offer with caution given substantial divergence of methods. Moreover, the methodological differences were undertaken specifically to speak to three previously untested

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**Figure 3:** Average color-face pairing scores according to target sex. Color-face pairing scores represent the difference between average attractiveness ratings of color-paired faces and those of novel faces. A color-face pairing score of 0 indicates that color-paired faces were rated as equally attractive as novel faces, positive scores indicate relatively higher attractiveness of color-paired faces, and negative scores indicate relatively lower attractiveness of color-paired faces. Red bars represent average color-face pairing scores amongst participants who viewed red during the color-face pairing phase whereas blue bars represent average color-face pairing scores amongst participants who viewed blue during that phase. 95% confidence intervals (CIs) indicated that red-paired male targets were rated as significantly more attractive than novel male targets (CI: 0.01, 0.17), and that red-paired female targets were rated as significantly less attractive than novel female targets (CI: –0.18, –0.01). The 95% CIs for blue-paired male targets (–.10, .06) and blue-paired female targets (–.03, .15) indicated no difference in rated attractiveness of blue-paired and novel faces. Error bars represent ±1SE. Estimated marginal means are plotted.
aspects of the underlying processes that might give rise to red-attraction effects when observed. We consider each of these in turn below.

First, viewing red prior to rating the attractiveness of novel faces reduced attractiveness ratings compared to viewing blue, suggesting a red-unattraction effect. The fact that color cues had any effect at all on later attractiveness ratings suggests that color cues operate at a heuristic level, and do not depend on a concurrent color-target pairing. This heuristic may, however, rely on the color cue being mediated by memory. One way of reconciling red-attraction effects observed using concurrent presentation

Figure 4: Color-face pairing scores as moderated by objective awareness of color-face pairing. An * denotes a significant correlation ($p < .05$) between objective awareness and the effect of color-face pairing on attractiveness for participants who saw the noted color. Raw color-pairing scores and objective awareness scores are plotted.
of color and target and red-unattraction effects observed in the present study with a delay between color exposure and target presentation and rating is to interpret the red-unattraction effect as evidence of contrast priming. This interpretation is facilitated by the use of sequential priming in the present task, as a sequence of attractive prime followed by a target being rated on attractiveness regularly leads to the prime lowering perceived attractiveness of the target (Kenrick & Gutierres, 1980; Wedell, Parducci, & Geiselman, 1987). Here, a chromatic background temporally preceded the faces that elicited the red-unattraction effect during rating. If redness is in-and-of itself, more attractive than blueness, then the conditions under which sequential contrast priming occurs would be met. However, we note that a contrast priming interpretation was developed in the face of the findings rather than a priori, and falls short of fully accounting for the mixed patterns of attractiveness ratings for those faces previously paired with a color.

Second, pairing faces with a color also influenced attractiveness ratings of those same faces at a delay, though the direction of this influence varied as a function of target sex. Specifically, a red-unattraction effect emerged for female targets and a marginally-significant red-attraction effect emerged for male targets. Given the delay, these findings suggest that information gleaned from color cues is stored with the mental representation of a target and is available for later retrieval. As a consequence, color-attraction effects are not likely a product of implicit response biases resulting from concurrent target presentation and rating temporarily lowering the criterion of attractiveness. Rather, color may create a within-target attractiveness benchmark. When female targets previously paired with red are later rated without the red border, they are rated as less attractive. In a real world context, this suggests that wearing red to increase attractiveness may be a one-shot strategy for females, constrained to the point in time when red is worn. When the red hue is removed, attractiveness is reduced in a way that does not occur for male targets. Once again, we wish to acknowledge that this benchmark possibility is speculative, and one that remains to be tested explicitly using experimental paradigms.

Third, awareness of faces during color pairing played an important role in the effects of color on attractiveness ratings. At low levels of awareness, the red-attraction effect for male targets and red-unattraction effect for female targets were present. However, as objective awareness increased, these patterns were reversed. This would seem to indicate that the observed results are largely contingent on participants lacking access to simultaneous explicit information about the pairing of color and target. Indeed, work in other domains has shown that whether a prime has an assimilative or contrast effect on judgments is determined by awareness (Lobardi, Higgins, Bargh, 1987; Strack, Schwarz, Bless, Kübler & Wänke, 1993). Our findings suggest that the strong version of the implicit cue notion articulated in the introduction does not hold. Rather, red cues require some degree of explicit processing to produce the red-attraction effect. Importantly, conditions of high awareness under which we observed the red-attraction effect for female targets are consistent with the conditions under which the red-attraction effect has been observed (i.e., long, uncontrolled viewing times; Elliot & Niesta, 2008; Elliot et al., 2013; Lin, 2014; Pazda et al., 2012, 2014; Roberts et al., 2010). Even the shortest presentation times used in prior research (i.e., 150 ms; Young, 2015) are still well above thresholds of conscious processing.

This experiment possesses a number of strengths, including a large sample that enabled detection of effects smaller than typically reported in this literature, answering a recent call for large-sample studies on color effects (Elliot, 2015). Moreover, because we deployed a design that included cross-sex and same-sex ratings (see also Lynn et al., 2013, Roberts et al., 2010, Wen et al., 2014), the varying sex effects we observed cannot be attributed to cross-study differences in sample or design, as might explain past mixed findings across studies (e.g., Buechner et al., 2015; Elliot & Maier, 2013; Elliot & Niesta, 2008; Elliot et al., 2010, 2013; Hesslinger et al., 2015; Lin, 2014; Pazda et al., 2012, 2014; Seibt, 2015). While the source of these varying sex effects is as yet unknown, the deployed paradigm will be useful in exploring the underlying moderators and mechanisms of color-attraction effects, including sex.

The effort to obtain a large sample required a sacrifice with regard to tight control of color properties (e.g., monitor-to-monitor variance, time-of-day lighting differences). While control of such properties is ideal from an experimental control perspective, we would argue that there is benefit in establishing the nature of color-attraction effects in the face of slight contextual variability, in that it increases ecological validity. We note that several prior studies have also examined red-attraction effects in variable contexts, including those with only exposure to linguistic rather than chromatic cues (Pazda & Elliot, 2016). As such, the effect is unlikely to be constrained to strict chromatic parameters, but rather the subjective experience of chromatic cues as red. However, if color cues were manipulated in a more controlled environment such that only the hue parameter changed, we expect that larger effects would likely be observed if the effect is attributable to redness.

Uncovering what appear to be contrast effects also highlights the need to more formally test the underlying mechanisms of red-attraction effects when they arise. We speculate that the red-unattraction effects observed here are indicative of contrast, but convincing demonstration of this would necessitate showing the red-attraction effects and contrast effects in the same experiment and on the same stimuli. This could be achieved through the use of two rating phases: one in which ratings are made at delay, as in the present study, and one in which ratings are made at the time of color-target pairing, as has typically been deployed in past research. Such a design, however, would need to rule out the possibility that making one explicit rating might impact the second.
Two other limitations should be noted. We did not assess colorblindness, though the likely result of the inclusion of any colorblind participants is increased error variance. Further, the findings reported here are relative effects of red compared to blue. Admittedly, the use multiple colors would enable more robust conclusions. However, it should be emphasized that the major differentiator of the two colors used was their hue, not their saturation or luminance. Further, as articulated by Buechner and colleagues (2015), blue is a fitting comparison color for red due to both being popular colors for which individuals have positive associations. While our study is consistent with the common use of a single color against which red is compared within a particular study examining red-attraction effects (Buechner et al., 2015; Elliot & Niesta, 2008; Elliot & Maier, 2013; Elliot et al., 2010, 2013; Hesslinger et al., 2015; Pazda et al., 2012; Seibt, 2015; Prokop et al., 2015; Schwarz & Singer, 2013; Young, 2015), it would be valuable for further research to utilize other colors in the novel paradigm deployed here.

This experiment represents the first attempt to answer heretofore unexplored questions regarding the nature of red-attraction effects. We disentangled the effect of prior exposure to color from the effect of pairing a target with a color. We also established that, to the extent that participants were aware of the face paired with color, the observed patterns for female targets converged more strongly with prior work (i.e., red-attraction effects). The nuanced findings we uncovered highlight the importance of investigating color effects using sophisticated paradigms. While one valid conclusion is that these results challenge the robustness of the red-attraction effect, we offer interpretations that highlight the particularities of underlying mechanisms that may give rise to the effect or indeed disrupt the effect.

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Competing Interests
The authors have no competing interests to declare.

Author Contributions
Contributed to conception and design: LAW, TPS, TJW
Contributed to acquisition of data: TPS, TJW
Contributed to analysis and interpretation of data: LAW, TPS
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