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Beauty is Better Pursued: Effects of Attractiveness in Multiple-Face Tracking

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Dear Professor Tipper,

Thank you for your thoughtful comments. We have now carefully revised our manuscript according to your new suggestions.

1. Following your advice, we have performed separate analyses for male and female participants. This showed significant main effects of attractiveness and face gender for female participants. There was also an interaction between the two variables. However, no effects were found for male participants. The pattern of results is consistent with your prediction. The new analyses have been added to the result section. We have also discussed this gender effect further in General Discussion. We agree that if Schacht et al (2008) did use fewer females, it could have been a cause for discrepant findings. We have checked this and found that they used 13 female and 5 male participants. Perhaps as they suggest, "the effects of attractiveness are strongly task dependent."

2. We have qualified our general conclusion that attractiveness is automatically computed and high level processes feedback into earlier tracking. We have cautioned that the attractive effects may only be true of female participants because of the findings in Experiment 3 (previously Experiment 2). We have also mentioned the similarity between the gender effect in our study and the effect in Bayliss et al. We have qualified the broad statements in the abstract as well.

3. We agree that more data from male participants for all other experiments would have been ideal. However, due to our limited resources, we have found this to be quite difficult to accomplish. We have therefore followed your second solution to re-write and restructure the paper. We hope the potential sex difference will spark future research.

Following your instruction, we have highlighted the changes we made in the manuscript by using the track changes mode in MS Word.

Sincerely yours,
Chang Hong Liu and Wenfeng Chen

Running Head: ATTRACTIVENESS AFFECTS MULTIPLE-FACE TRACKING

Beauty is Better Pursued:

Effects of Attractiveness in Multiple-Face Tracking

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Abstract

Using the multiple-object tracking paradigm, this study examines how spontaneous appraisal for facial beauty affects distributed attention to multiple faces in dynamic displays. Observers tracked attractive faces more effectively relative to unattractive faces in this task. Tracking performance was only affected by target attractiveness, suggesting an absence of appraisal for distractor attractiveness. Attractive male faces also produced stronger binding of face identity and location for female participants. Together, the results suggest that facial attractiveness was appraised during tracking even though this was task irrelevant. Contrary to the theory that multiple-object tracking is driven by encapsulated low-level vision, our results show that the content of target representation is not only penetrable by social cognition but also modulates the course of tracking operations.

Beauty is Better Pursued:

Effects of Attractiveness in Multiple-Face Tracking

It is well known that human observers pay greater attention to faces than to non-face objects (e.g., Ro, Russell, & Lavie, 2001). Moreover, some face stimuli attract more attention than others. Apart from certain facial expressions such as fear and anger (Palermo & Rhodes, 2007), attractive faces also trigger greater attention (Sui & Liu, 2009). Popular culture often suggests that a mere glance of a face elicits spontaneous appraisal of attractiveness. Humans may be predisposed to direct attention to attractive faces because of their biological and social significance. There is well-established evidence that even newborn babies look at attractive faces longer (e.g., Geldart, Maurer, & Carney, 1999; Langlois et al., 1987; Samuels et al., 1994; Slater et al., 1998). Adults also tend to spend more time looking at beautiful faces (Aharon et al., 2001; Kranz & Ishai, 2006), which are known to activate dopaminergic regions in the brain that are strongly linked to the reward system (Kampe, Frith, Dolan, & Frith, 2001).

Appraisal of facial beauty appears to depend on how well a face resembles the average in a population (Langlois & Roggman, 1990). Although symmetry also plays a role in facial beauty (e.g., Grammer & Thornhill, 1994), there is evidence that it is less important than averageness (Rhodes, Sumich, & Byatt, 1999; also see Rhodes, 2006, for an extensive review). Hence attentional capture by attractive faces may rely on preattentive computation of averageness in face stimuli.

However, little is known about how facial attractiveness affects attentional mechanisms. This issue may be addressed through the existing attention paradigms. For example, Maner, Gailliot, and DeWall (2007) employed a dot-probe paradigm to assess the effect of attractiveness on disengaging attention. Consistent with their hypothesis, their observers were slower at disengaging attention from attractive female faces relative to average-looking female or male faces. In another study, Maner, Gailliot, Rouby, and Miller (2007) used the same method and found that participants fixated on highly attractive faces within the first half second and took longer to stop looking at them when asked to shift their attention away. In a different approach, Sui and Liu (2009) investigated whether appraisal for attractiveness occurs when spatial attention has already been directed elsewhere. They employed a spatial cuing task, where participants were asked to judge the orientation of a cued target presented to the left or right visual field while ignoring a task-irrelevant face image flashed in the opposite field. They found that the presence of attractive faces significantly lengthened task performance. This suggests that facial beauty can automatically compete with an ongoing task for attention, although this does not necessarily mean that appraisal of facial beauty is a mandatory process (see Schacht, Werheid, & Sommer, 2008). The analysis of eye movements in Sui and Liu's study revealed that the effect of facial attractiveness was not due to foveal fixation on the target or face stimuli, hence there is a strong possibility that facial attractiveness can be detected outside the fovea. This has been confirmed by a recent investigation, where discrimination of facial beauty was measured at several eccentricities (Guo, Liu, & Roebuck, 2011).

Both dot-probe and cuing tasks require focused attention, where attention is directed to a single spatial location. However, attention in reality can be distributed to several different targets or spatial locations. For instance, a group activity requires attention to be paid to multiple individuals and locations. The main purpose of this research was to investigate the effect of facial attractiveness on distributed attention. Another motivation of this research comes from observation that spontaneous appraisal of attractiveness is rapid and transient (Schacht et al., 2008). It remains unclear whether such an appraisal only manifests in brief attentional shifts. Hence the second purpose of this study was to investigate whether a similar kind of automatic appraisal for facial attractiveness occurs continuously when sustained attention is distributed among faces in multiple locations.

Pylyshyn and Storm (1988) designed a multiple-object tracking paradigm (MOT) to study how human observers maintain attention on multiple objects across space and time. In recent years, the issue of content addressability in object tracking is hotly debated. This issue was first raised by Pylyshyn (2004) who found that observers were remarkably poor at identifying the features or identity of correctly tracked objects. This phenomenon demonstrates a poor binding of object features and location. Pylyshyn's explanation is that MOT is implemented by early or low-level vision, where the information about individual identity is encapsulated and inaccessible from higher level cognition. His theory assumes that early vision picks out a small number of objects while ignoring their visual properties. Because of this, object identity differentiated by visual properties is not coded or accessible from higher level cognitive processes even when the objects with those properties are attended. However, recent evidence has challenged this position by showing that tracking is content addressable (Horowitz et al., 2007).

This debate has an important implication for the present study. If the information content of tracked faces is not processed, tracking performance should not be affected by facial attractiveness. It is known that information about face identity (i.e., individuation of face stimuli by features and configurations) is not completely lost in tracking tasks (Ren, Chen, Liu, & Fu, 2009). If representations of the tracked faces are to some extent content addressable, there is a chance that other high-level information such as facial attractiveness is also available for processing. If processing of such information is spontaneous, this could in turn affect multiple face tracking. The experiments in this study were designed to test this hypothesis. The outcome should reveal the extent to which a high-level social cognition can penetrate and influence the low-level visual perception. Appraisal for facial beauty requires high-level vision, because a main criterion for beauty—averageness—cannot be determined solely from low-level visual features such as luminance, contrast, and size. Computing averageness requires identifying the landmarks of higher level facial features such as the eyes, the mouth, and the face shape. The operations for image normalization, alignment, and comparison with the average in the hypothetical multi-dimensional face space also require high-level vision. To ensure that our results were controlled for the low-level contribution, we carefully scaled all our tracking stimuli to the same size, luminance, and contrast.

Other high-level information accompanying appraisal of facial attractiveness could also contribute to multiple-face tracking performance. As Dion, Berscheid, and Walster (1972) showed in their seminal study, beautiful people are generally perceived to possess more positive attributes. They called this the "beauty-is-good" stereotype. Many studies have since produced evidence for this positive association between attractiveness and goodness (see Eagly, Ashmore, Makhijani, & Longo, 1991, and Langlois et al., 2000, for reviews). It is also referred to as the halo effect of attractiveness. This well established duality of beauty could predict a similar effect on tracking based on attractive and valence measures. Moreover, if the reward system is involved in perception of attractive faces (Kampe et al., 2001), arousal could also be responsible for any effect of attractiveness on tracking performance. To address these questions, we compared whether valence and arousal affect tracking performance in the same way as attractiveness.

Experiment 1

The main purpose of Experiment 1 was to investigate how target and distractor attractiveness may affect tracking performance differently. Given the prior finding that the target face identity is content addressable (Ren et al., 2009), we hypothesized that the target faces could be automatically appraised for their attractiveness. Attractive distractors, on the other hand, could impair tracking performance if they were also appraised for attractiveness.

Method

Participants. A total of 25 undergraduate students (19 females) from the University of Hull participated in this study. The age of the participants ranged from 18 to 28 years (*Mdn* = 19). All participants had normal or corrected-to-normal vision.

Stimuli. The face database was obtained from the University of St. Andrews. It contains 702 frontal-view Caucasian faces with no external features (hair and clothing). The size of the faces was normalized according to the face width. The resulting image measured 3.0 × 3.8 cm (2.8 × 3.6°) on screen. All images were scaled to the same mean luminance and root-mean-square contrast.

All faces in the database were rated by 19 raters (aged between 18 and 29 years, 12 females) for attractiveness on a 7-point scale. To contrast the effect of attractiveness, only the 149 most attractive and the 132 least attractive faces were used in this experiment. The mean ratings for the two groups of faces were 3.91 (3.96 for females, 3.72 for males. $SD = 0.39$) and 2.39 (2.35 for females, 2.46 for males. $SD = 0.38$), respectively. These were significantly different from each other ($p < .001$). Slightly more than half (58.3%) of the faces were females. Each attractive or unattractive face was only used once for each participant: 80 were randomly chosen from the pool of attractive faces, and another 80 were randomly chosen form the pool of unattractive faces.

We performed an additional norming study on the face stimuli to measure how attractiveness is related to valence and arousal. Twenty undergraduate students, aged between 18 and 33 years ($M = 21.1$, $SD = 4.4$), rated a total of 452 faces for valence and arousal. The image set consisted of the attractive and unattractive faces in this experiment as well as the additional 171 average faces used in Experiment 3. The faces were rated one at a time. The presentation order was random. To avoid response bias, the raters were not informed until the end of the experiment that the rating data would be used to study facial attractiveness. The details of our procedure were identical to that for the International Affective Picture System

(Lang, Bradley, & Cuthbert, 2008). A 9-point rating scale was used where 1 represented completely unhappy/calm, whereas 9 completely happy/excited respectively for the valence and arousal judgments. Table 1 shows the mean rating results for each face category. To determine whether valence and arousal ratings vary according to levels of attractiveness, we conducted separate analyses of variance (ANOVA) for the two variables. The main effect of valence was significant, F (1, 449) = 43.24, MSE = 19. 41, $p < .001$, *partial* $\eta^2 = .17$, where the valence for attractive faces was higher than for average-looking and unattractive faces (p < .001), and the valence for average-looking faces was higher than for unattractive faces (p < .001). On the other hand, the main effect of arousal was not significant, F (1, 449) = 1.49, MSE = .41, p = .23, *partial* $\eta^2 = .01$.

The tracking stimuli were displayed on a 21" monitor (SONY Trinitron, GDM-F520). A central square area with 22.8 × 22.8° of visual angle was designated for stimulus presentation. The background color of the display was gray. E-Prime (Version 1.2) was used to generate the dynamic tracking and still displays and to control the flow of the experiment.

Design. We employed a within-subject design. The independent variables were target attractiveness (attractive vs. unattractive) and distractor attractiveness (attractive vs. unattractive), and face gender (male vs. female). Following this design, the target faces, which were either all attractive or unattractive, were tracked among distractor faces, which were also either all attractive or unattractive.

Procedure. Participants were tested individually. An adjustable headrest was used to fix the participant's viewing position, which was set 60 cm away from the computer monitor. The faces presented in each trial were of the same sex. They were randomly chosen for each trial from the pool of 281 faces. The chosen images were not repeated in the subsequent trials until all faces in the pool were used. The procedure for each trial of the experiments is illustrated in Figure 1A. Each trial was initiated by a key press. It began with 10 stationary black rectangles on the screen. The location of the rectangles was randomly assigned, with the constraint that none would occlude the others and the center-to-center distance was not less than twice of their size. Five of the rectangles would then start to blink twice for 2 *s*, signaling the target location. Following this, the rectangles changed abruptly into 10 faces, and started to move in random directions. The faces bounced off each other when the center-to-center distance was less than twice of their size. They avoided the edge of the display area when the center to edge distance was less than their size. Participants were asked to track the five moving targets. The velocity of the face images varied between 3.9 and 6.3 ° / *s* with a mean of 5.1° / *s*. All faces moving about the screen for 5 *s*. As soon as the motion stopped, all the faces were again occluded by black rectangles. The task was to pick out the five targets by clicking on the rectangles. Once being clicked, the rectangle was highlighted with a yellow border which could be switched on and off by clicking. Participants were forced to select 5 items and were allowed to guess. Once 5 items were selected, they clicked a “finish” button to start the next trial. The experiment lasted about 30 minutes.

A total of 80 experimental trials were run after 4 practice trials. Each of the eight conditions (2 target attractiveness × 2 distractor attractiveness × 2 face gender) had 10 trials. All 80 trials were mixed in random order in one block.

Results and Discussion

An alpha level of .05 was used for all statistical analyses in this report. Results of tracking accuracy are shown in Figure 2. The data were analyzed using repeated-measures ANOVA. There was a significant main effect of target attractiveness, F (1, 24) = 8.50, MSE = 18.52, $p < .01$, *partial* $\eta^2 = .26$, where attractive faces were tracked better than unattractive faces. However, there was no difference between results for attractive and unattractive distractors, F (1, 24) = 1.77, MSE = 27.74, $p = .20$, *partial* $\eta^2 = .07$. There was also a main effect of face gender, F (1, 24) = 7.47, MSE = 23.31, $p < .01$, *partial* $\eta^2 = .24$, where male faces were tracked better than female faces. However, face gender did not interact with other factors, *p*s > .57. None of the other two-way or three-way interactions was significant, *p*s > .15.

The experiment shows that tracking performance was affected by appraisal of facial attractiveness. This effect was only present for the target faces, while the influence of attractive distractors was negligible. Although male faces were tracked better than female faces, the effect was not modulated by attractiveness.

The effect of attractive faces on tracking performance could be due to varying levels of involuntary attention to task-irrelevant information. Some participants might be able to suppress or control attention to the task-irrelevant information better than others. If this is the case, it would be possible that those who were poor at the tracking task would show a stronger attractiveness effect, because they are poor at suppressing the attractiveness information. To test this prediction, we analyzed the correlation between the size of attractiveness effect and overall tracking performance. Consistent with this prediction, a negative correlation was found between the two, $r = -0.59$, $p < .001$. Figure 3A shows a scatter plot of this correlation.

Because the attractive faces had greater valence rating than unattractive faces in our norming study, we evaluated how the difference of valence contributed to the attractiveness effect in this experiment. This was done by an item-based analysis of covariance (ANCOVA), where facial attractiveness was treated as a random factor, and the valence a covariate. ANCOVA measures whether attractiveness had an effect on tracking performance after removing the covariate valence. Because only the target attractiveness had an effect on tracking performance, we only used target attractiveness in our ANCOVA as an independent factor. Hence the target faces were used as random sample, and corresponding valence for these faces as covariate. Results showed a significant main effect of target attractiveness, *F* (1,

278) = 3.57, *MSE* = .07, $p < .03$, *partial* $\eta^2 = .02$, where attractive targets were tracked better than unattractive targets. However, the covariate was not significant, F (1, 278) =.59, *MSE* =.001, $p = .44$, *partial* $\eta^2 = .002$, suggesting that the valence made no contribution to the attractiveness effect found in this experiment.

Experiment 2

In Experiment 1, the target faces were either attractive or unattractive. When the targets had a similar level of attractiveness, attention might be more or less evenly distributed among the targets. However, if attractiveness varies considerably among targets, attention and consequently tracking performance for a given target could be affected by its attractiveness relative to other targets. To test this hypothesis, we varied level of target attractiveness in this experiment such that the targets consisted of attractive, average, and unattractive faces. We then compared the performance for these different types of targets.

Another issue concerning the use of all attractive or all unattractive targets was that attractive faces may be more visually similar to one another than unattractive faces. Yantis (1992) showed that similarity among targets improves tracking. Because of this, the tracking advantage for attractive targets may not reflect attractiveness directly, but rather through featural similarity. The design in the present experiment was able to eliminate this problem because an effect of attractiveness would no longer be due to greater similarity among the attractive targets.

Method

Participants. A different group of 61 undergraduate students (48 females and 13 males) from the University of Hull participated in this study. The age of the participants ranged from 17 to 34 years (*Mdn* = 20). All participants had normal or corrected-to-normal vision.

Stimuli. The attractive and unattractive face stimuli were the same as in Experiments 1 and 2. In addition, we also added average-looking faces. The mean ratings for the average-looking faces was 2.99 (*SD* = 0.11, *N* = 171). As in the previous experiments, each face category consisted of 80 faces randomly selected from the respective pool of stimuli for each participant. Each trial contained one attractive, one unattractive, and three average-looking target faces. The distractors in this experiment consisted of average-looking faces. Because 8 average faces were used in each trial and 80 trials in total, this requires a total of 640 average faces (80 × 8). Since there were 171 average faces available, each face was repeated about 4 times (640 ÷ 171 = 3.7).

Design. This was again a within-subject design. The independent variables were target attractiveness (attractive, average, and unattractive) and face gender. Because Experiment 1 showed no effect of distractor attractiveness, this variable was not included in this and the next experiments.

Procedure. This was identical to Experiment 1.

Results and Discussion

The tracking results are shown in Figure 4. The main effect of target attractiveness was significant, F (2, 120) = 4.96, MSE = 61.83, $p < .01$, *partial* $\eta^2 = .10$. No significant effect was found for face gender, F (1, 60) = 0.01, MSE = 93.25, $p = .98$, or interaction between face gender and target attractiveness, F (2, 120) = 0.90, MSE = 70.68, $p = .41$. Post hoc comparisons of means with Bonferroni correction revealed better tracking performance for attractive targets relative to average or unattractive targets *t*s (60) > 2.66, *p*s < .02. There was no difference between results for average and unattractive targets, t (60) = 0.11, $p = 1.00$. The results suggest that attractive faces were attended more favourably whereas unattractive and average-looking faces were not treated differently during tracking.

Consistent with Experiment 1, there was a significant negative correlation between participants' overall tracking performance and the size of the attractiveness effect, $r = -0.22$, $p < .04$. A scatter plot of this correlation is shown in Figure 3B.

Results of ANCOVA for Experiment 2 show that there was a significant main effect of target attractiveness, F (1, 448) = 7.37, MSE = .07, p < .01, *partial* η^2 = .03, where attractive faces were tracked better than average-looking and unattractive faces (ps < .01), and there was no difference between average-looking faces and unattractive faces (p = .51). The covariate, or valence of the faces, was also significantly related to the tracking performance, F (1, 448) = 9.90, MSE = .09, p < .01, *partial* η^2 = .02. This indicates that the valence of faces also contributed to the attractiveness effect in this experiment.

Experiment 3

The tracking task in Experiments 1 and 2 did not explicitly require binding of a target identity with its location. If target attractiveness is appraised, it is possible that the location of an attractive target is monitored more accurately relative to an unattractive target. To test this hypothesis, we employed a variant of the MOT paradigm, where one of the faces was randomly chosen from the targets and probed at the end of each trial. The task here was to specify the location of the probe face.

Method

Participants. A different group of 50 undergraduate students (25 females and 25 males) from the University of Hull participated in this study. The age of the participants ranged from 18 to 35 years (*Mdn* = 20). All participants had normal or corrected-to-normal vision.

Stimuli. These were the same as Experiment 1.

Design. This was again a within-subject design. The independent variables were attractiveness, face gender, and participant gender. Although not originally planned, potential participant gender difference was included in our analysis because the number of participants in each gender group was fully balanced.

Procedure. The procedure of this experiment was identical to Experiment 1 except that at the end of each trial one of the faces was randomly chosen from the targets and probed (see

Figure 1B). The participant was required to specify the specific location of the probe face by clicking on one of the occluded faces with a mouse. The occluder of the chosen face was then removed to reveal the answer after the mouse click. This feedback was used to engage the participants. Because this task was harder than the standard task, the number of faces in each trial was reduced to 8, with the number of target faces reduced to 4. The task began with four practice trials followed by 40 experimental trials (10 trials × 4 conditions).

Results and Discussion

The locations of attractive targets were identified better than unattractive targets, F (1, 48) = 4.70, MSE = 241.50, $p < .04$, *partial* $\eta^2 = .11$. Neither face gender nor participant gender produced a significant main effect, Fs (1, 48) = 1.08 and 0.001, ps = .30 and .98, respectively. However, this was qualified by a significant two-way interaction between participant gender and attractiveness, F (1, 48) = 9.97, MSE = 241.50, $p < .01$, *partial* $\eta^2 = .17$, as well as a marginally significant interaction between participant gender and face gender, F (1, 48) = 3.80, MSE = 204.27, $p = .057$, *partial* $\eta^2 = .07$. The three-way interaction also approached the level of significance, F (1, 48) = 2.78, MSE = 168.51, $p = .10$, *partial* $\eta^2 = .06$. The two-way interaction between face gender and attractiveness was not significant, (1, 48) = 1.63, $p = .21$, *partial* $\eta^2 = .03$. The interaction effects are illustrated in Figure 4.

To investigate the interaction effects, we conducted separate ANOVAs for the two participant genders. Results for the female participants showed a significant main effects of attractiveness, F (1, 24) = 14.73, MSE = 246.00, $p < .001$, *partial* $\eta^2 = .38$, and face gender, F (1, 24) = 4.45, MSE = 478.39, $p < .05$, *partial* $\eta^2 = .16$. There was also a significant interaction between attractiveness and face gender, F (1, 24) = 7.55, MSE = 96.54, $p < .01$, *partial* $\eta^2 = .24$. Further analyses of the interaction via pairwise comparisons of means revealed that female participants identified the spatial locations for attractive male targets more accurately than for unattractive male targets, t (24) = 4.73, $p < .001$. In contrast, the locations for these attractive and unattractive male targets were identified equally well by male participants, t (24) = -0.51, p = .61. In contrast to the results for female participants, ANOVA did not find any main effects of face gender and attractiveness, or the interaction between the two for the male participants, Fs (1, 24) < 0.42, ps > .53.

Consistent with Experiments 1 and 2, the performance was again negatively correlated with the size of attractiveness effect, r = -0.29, p < .03. Figure 3C shows a scatter plot of this correlation.

To determine whether valence has also contributed to tracking performance, we performed an ANCOVA on the data following the same statistical procedure as Experiment 1. Results showed a significant main effect of target attractiveness, F (1, 278) = 3.22, MSE =.78, p < .04, *partial* η^2 = .02, where attractive faces were tracked better than unattractive faces. The valence, as a covariate, did not significantly affect the tracking performance, F (1, 278) =.39, MSE =.09, p = .53, *partial* η^2 < .001.

The data in this experiment suggest that an attractive target was more likely to create a stronger identity-location binding in female participants for attractive male targets. The difference between identity-location binding for attractive and unattractive female targets was not significant. Consistent with Experiment 1, valence did not contribute to the binding advantage of attractive targets.

General Discussion

Results in these experiments suggest a facilitative effect of facial attractiveness in multiple-face tracking. Experiment 1 showed a better tracking performance when attractive faces were assigned as targets. Experiment 2 showed that attractive targets were more likely to be tracked successfully when they were mixed with unattractive or average looking targets. Finally, Experiment 3 found that attractive targets could induce a stronger binding of face identity and location.

Given that attractive faces may be more visually similar to one another than unattractive faces and that Yantis (1992) showed that similarity among targets improves tracking, one may argue that the tracking advantage for attractive targets may not reflect attractiveness directly, but rather through featural similarity. The replicated attractiveness advantage of Experiment 2 has eliminated this equivocal problem. Furthermore, attractive targets and attractive distractors were likely to be more similar than unattractive targets and unattractive distractors in Experiments 1 and 3. This may make tracking more difficult (Makovski & Jiang, 2009) and predict an opposite unattractiveness advantage. From this point, the tracking advantage for attractive targets is less likely to reflect featural similarity of attractive faces.

Facial beauty would not produce an effect on these tracking tasks if facial features and their holistic information were not processed during the process of tracking. Therefore, given the pattern of our results, the representations of the target items must be content addressable. There is already evidence that face or object identities are processed in multiple target tracking (Horowitz et al., 2007; Oksama & Hyönä, 2008; Ren et al., 2009). The present study shows further that facial attractiveness is also processed during tracking. As the results in Experiment 1 indicate, attractiveness appeared to be assessed only for the target items, because distractors had negligible effects on tracking performance. This finding is consistent with the observation that only target identity is processed in multiple-object or multiple-face tracking (Pylyshyn, 2006; Ren et al., 2009).

Contrary to the suggestion that multiple object tracking is purely driven by low-level vision, of which higher level cognitive processes are unable to penetrate, tracking performance appeared to be modulated by the information content of target items. Content addressability may depend on whether the information is important to the observer and whether the observer is predisposed to process the type of information. Like face identity, attractive faces may automatically engage the attention system. The appraisal for attractiveness in our experiments was spontaneous because it was task irrelevant. Although the effects of such automatic appraisal in this and other studies (e.g., Sui & Liu, 2009) can be quite small, they are consistent and replicable. A small effect in these studies may suggest that task-irrelevant processing can be largely suppressed by the central control. The present study revealed that a participant's tracking performance was negatively correlated with the size of attractiveness effect. This suggests that some individuals may have weaker central control than others: Those who were not as good at tracking showed a larger attractiveness effect because they might not have as much central control and were more easily distracted by the irrelevant information.[1]

Perhaps due to the extent of the central control, not all evidence to date shows that appraisal of attractiveness is spontaneous or mandatory. Schacht, Werheid, and Sommer (2008) found that attractiveness appraisal depended on whether facial attractiveness was task relevant (e.g., beauty rating). This led them to conclude that attractiveness appraisal requires voluntary attention to the attractiveness dimension. The findings of our study show that facial attractiveness can be appraised even when it is not task relevant. Our analyses of the correlation between the effect of attractiveness and tracking performance in the three experiments provide preliminary evidence that participants with higher tracking performance tend to produce a smaller attractiveness effect. This may be due to these participants' better central control to suppress task-irrelevant appraisal of facial attractiveness. Task irrelevant processing of facial beauty has been reported in brain research. Chatterjee, Thomas, Smith and Aguirre (2009) found that the ventral occipital region remained responsive to facial beauty when the task of their participants was to judge facial identity rather than to attend explicitly to attractiveness. They proposed that this region, which includes the fusiform gyrus, the lateral occipital cortex and medially adjacent regions, is activated automatically by beauty and may serve as a neural trigger for pervasive effects of attractiveness in social interactions (see also Kampe et al., 2001). Undoubtedly, the exact level of control that the central executive can have over automatic processing of certain task-irrelevant stimuli will require systematic future research.

The present study also provides preliminary evidence that target tracking is spontaneously affected by gender detection. Experiment 1 showed that male faces were tracked better than female faces. This could be due to a gender bias as participants in this experiment were mainly comprised of females. When we tested equal number of male and female participants in Experiment 3, results showed that female participants tracked the location of an attractive male face more accurately relative to an unattractive male face. However, it is unclear why the same effect was not found for female faces. The gender effect found in Experiment 3 may be similar to Bayliss et al (2005), who found that averted eyes of a face or nonpredictive arrows produce a stronger reflexive shift of attention in females than in males. Given that the participants in our Experiments 1 and 2 were predominantly females, the results in these experiments could be largely driven by certain aspects of gender difference. The role of gender difference in attentive tracking is therefore an important area for future investigation.

Consistent with prior research, attractive face stimuli in this study were also rated more positively on the valence dimension. Although valence did not contribute to the tracking advantage of attractive faces when the tracked faces had similar attractiveness (Experiments 1 and 3), it did contribute to the tracking performance when the target faces consisted of a full range of attractiveness (Experiment 2). Thus, the lack of valence effect in Experiments 1 and 3 may be due to the much smaller range of this variable associated with the attractive targets. Positive valence is a central trait of facial beauty. It is therefore not surprising that it produced a similar effect to attractiveness on distributed attention. It should be noted, however, that the differences in valence ratings of attractive and non-attractive faces were quite small. No significant difference was found in arousal ratings of attractive and non-attractive faces. These rating data may suggest a moderate link between facial attractiveness and valence, whereas the link between facial attractiveness and arousal is negligible.

Although it is difficult to separate attractiveness from positive valence due to the very nature of beauty, it is possible to study whether valence in other types of stimuli produces a similar effect on multiple object tracking. A similar conclusion can be made about the relationship between attractiveness and averageness. It would not be possible to separate attractiveness from averageness because averageness is a defining feature of attractiveness. However, it is possible to study whether averageness in non-face stimuli also produces a similar advantage in a multiple object tracking task. There is little evidence that averageness in other kinds of stimuli also attracts attention although it is highly likely that beautiful things in general attract more attention. Unlike faces, the relationship between averageness and other types of beautiful things remains to be seen. In face research, this relationship is established through image morphing techniques. However, it is often difficult to use the same method that requires well-defined corresponding features to build an average for other categories of things such as beautiful sunsets, because obvious correspondence in such images is often absent.

The attentional bias for attractive faces found in this study suggests that multiple object tracking is modulated by underlying biological significance of the tracked targets. It may reflect biological interests of the observer. The preference for attractive faces may be deeply rooted in evolution (Langlois et al., 2000; Rhodes, 2006). Prior research has demonstrated an automatic reaction to facial beauty in focalized attention. The present study shows a similar response to beauty in distributed attention. Because multiple object tracking depends on attentional resources in the working memory (Oksama & Hyona, 2004), our results may suggest higher working memory capacity and greater attentional resources for attractive faces.

Author Notes

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Footnote

[1]We thank Dr. Trafton Drew for suggesting this idea.

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Table 1

Mean ratings of valence and arousal. Values in parentheses represent standard deviation.

Attractiveness	*Valence*	*Arousal*
Attractive	5.08 (0.65)	4.03 (0.48)
Average	4.68 (0.62)	3.94 (0.52)
Unattractive	4.33 (0.74)	3.99 (0.56)

Figure Captions

Figure 1. Illustration of the procedure used in the study. A. Procedure used in Experiments 1 and 2. B. Procedure used in Experiment 3.

Figure 2. Tracking accuracy in Experiment 1 as a function of target and distractor attractiveness. A. Results of male faces. B. Results of female faces. Error bars represent standard errors.

Figure 3. Scatter plots for the correlation between the size of attractiveness effect and tracking performance.

Figure 4. Tracking accuracy in Experiment 2 as a function of target attractiveness and face gender. Error bars represent standard errors.

Figure 5. Tracking accuracy in Experiment 3 as a function of target attractiveness and face gender. A. Results of male faces. B. Results of female faces. Error bars represent standard errors.

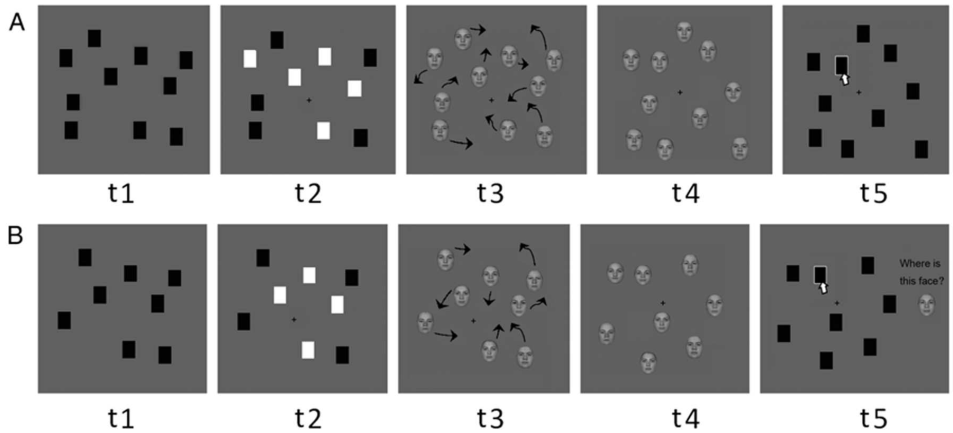

Figure 1. Illustration of the procedure used in the study. A. Procedure used in Experiments 1 and 2.
B. Procedure used in Experiment 3.
160x82mm (300 x 300 DPI)

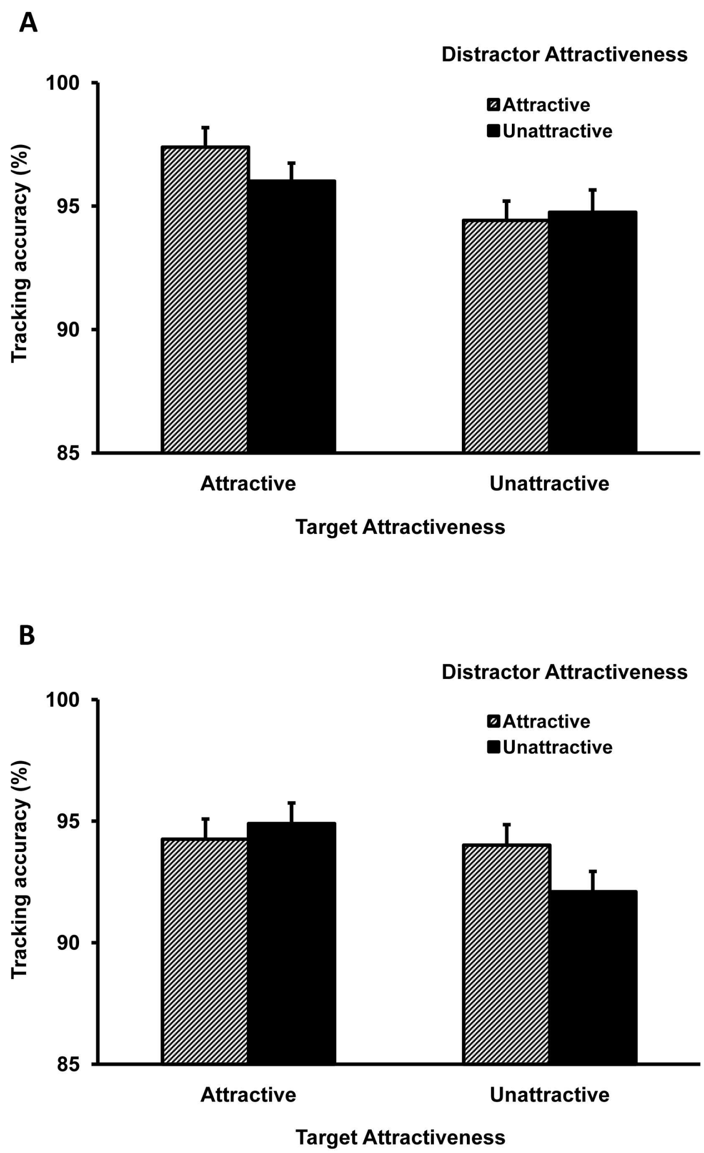

Figure 2. Tracking accuracy in Experiment 1 as a function of target and distractor attractiveness. A. Results of male faces. B. Results of female faces. Error bars represent standard errors.
152x243mm (300 x 300 DPI)

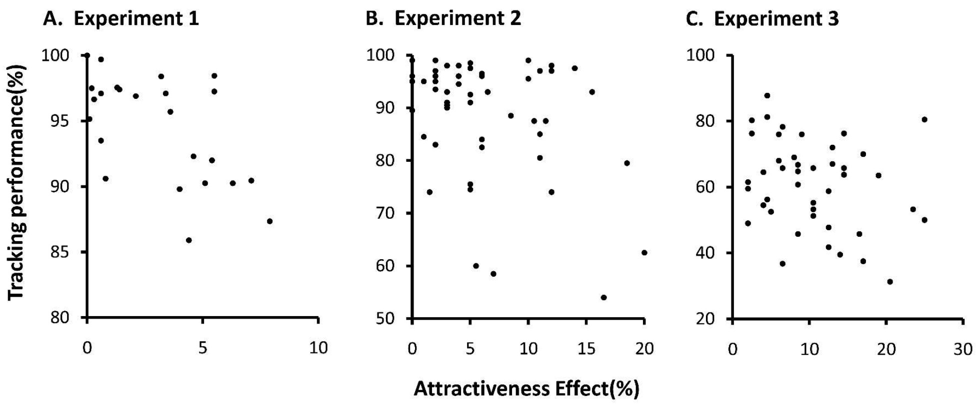

Figure 3. Scatter plots for the correlation between the size of attractiveness effect and tracking performance.
463x193mm (300 x 300 DPI)

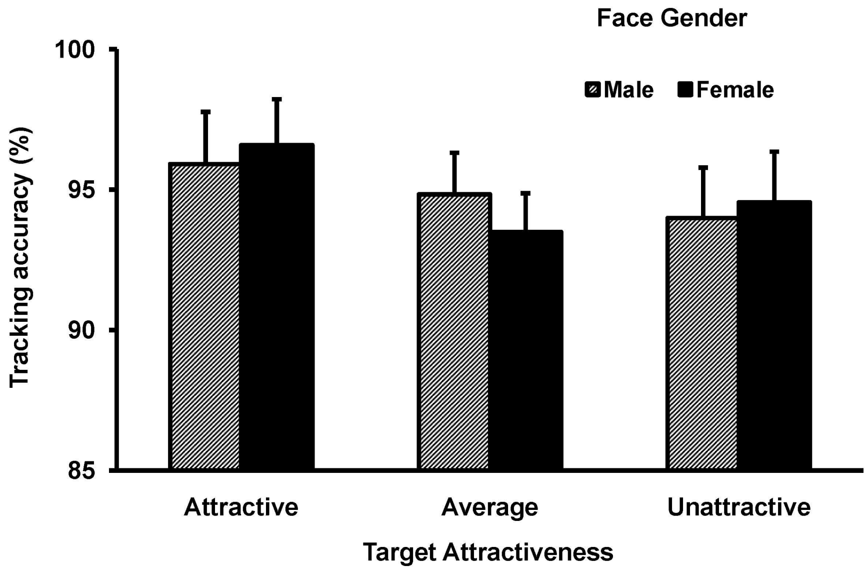

Figure 4. Tracking accuracy in Experiment 2 as a function of target attractiveness and face gender. Error bars represent standard errors.
231x146mm (300 x 300 DPI)

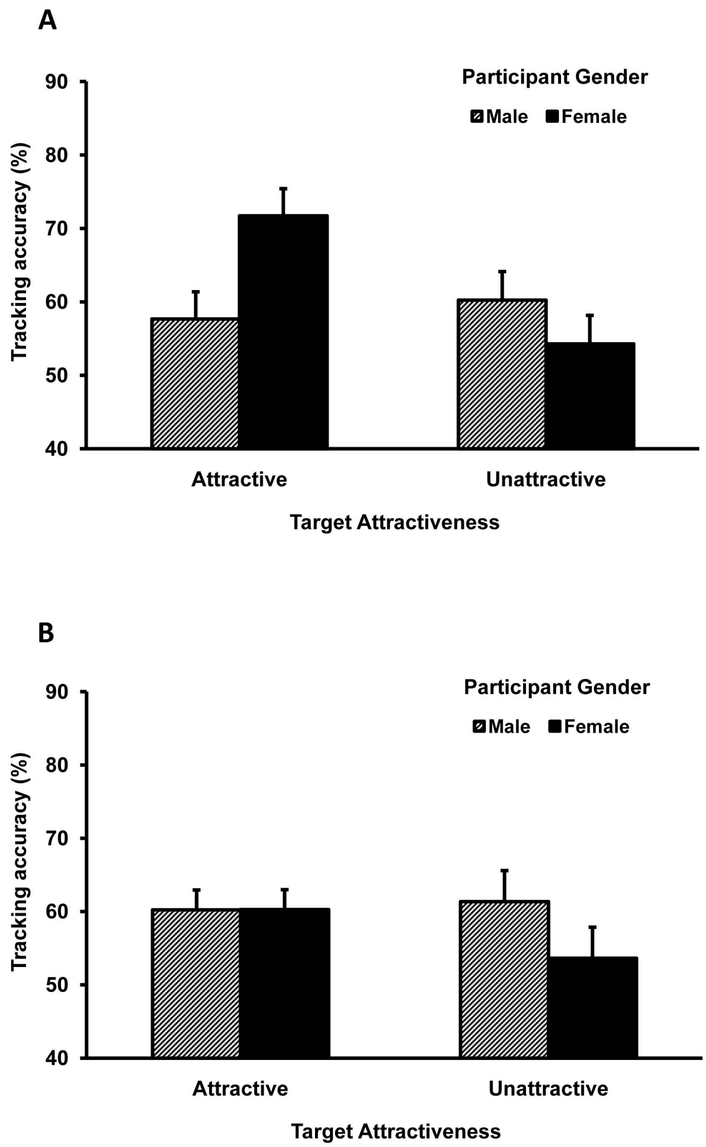

Figure 5. Tracking accuracy in Experiment 3 as a function of target attractiveness and face gender. A. Results of male faces. B. Results of female faces. Error bars represent standard errors.
152x243mm (300 x 300 DPI)

Running Head: ATTRACTIVENESS AFFECTS MULTIPLE-FACE TRACKING

Beauty is Better Pursued:

Effects of Attractiveness in Multiple-Face Tracking

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Abstract

Using the multiple-object tracking paradigm, this study examines how spontaneous appraisal for facial beauty affects distributed attention to multiple faces in dynamic displays. Observers tracked attractive faces more effectively relative to unattractive faces in this task. Tracking performance was only affected by target attractiveness, suggesting an absence of appraisal for distractor attractiveness. Attractive male faces also produced stronger binding of face identity and location for female participants. Together, the results suggest that facial attractiveness was appraised during tracking even though this was task irrelevant. Contrary to the theory that multiple-object tracking is driven by encapsulated low-level vision, our results show that the content of target representation is not only penetrable by social cognition but also modulates the course of tracking operations.

Beauty is Better Pursued:

Effects of Attractiveness in Multiple-Face Tracking

It is well known that human observers pay greater attention to faces than to non-face objects (e.g., Ro, Russell, & Lavie, 2001). Moreover, some face stimuli attract more attention than others. Apart from certain facial expressions such as fear and anger (Palermo & Rhodes, 2007), attractive faces also trigger greater attention (Sui & Liu, 2009). Popular culture often suggests that a mere glance of a face elicits spontaneous appraisal of attractiveness. Humans may be predisposed to direct attention to attractive faces because of their biological and social significance. There is well-established evidence that even newborn babies look at attractive faces longer (e.g., Geldart, Maurer, & Carney, 1999; Langlois et al., 1987; Samuels et al., 1994; Slater et al., 1998). Adults also tend to spend more time looking at beautiful faces (Aharon et al., 2001; Kranz & Ishai, 2006), which are known to activate dopaminergic regions in the brain that are strongly linked to the reward system (Kampe, Frith, Dolan, & Frith, 2001).

Appraisal of facial beauty appears to depend on how well a face resembles the average in a population (Langlois & Roggman, 1990). Although symmetry also plays a role in facial beauty (e.g., Grammer & Thornhill, 1994), there is evidence that it is less important than averageness (Rhodes, Sumich, & Byatt, 1999; also see Rhodes, 2006, for an extensive review). Hence attentional capture by attractive faces may rely on preattentive computation of averageness in face stimuli.

However, little is known about how facial attractiveness affects attentional mechanisms. This issue may be addressed through the existing attention paradigms. For example, Maner, Gailliot, and DeWall (2007) employed a dot-probe paradigm to assess the effect of attractiveness on disengaging attention. Consistent with their hypothesis, their observers were slower at disengaging attention from attractive female faces relative to average-looking female or male faces. In another study, Maner, Gailliot, Rouby, and Miller (2007) used the same method and found that participants fixated on highly attractive faces within the first half second and took longer to stop looking at them when asked to shift their attention away. In a different approach, Sui and Liu (2009) investigated whether appraisal for attractiveness occurs when spatial attention has already been directed elsewhere. They employed a spatial cuing task, where participants were asked to judge the orientation of a cued target presented to the left or right visual field while ignoring a task-irrelevant face image flashed in the opposite field. They found that the presence of attractive faces significantly lengthened task performance. This suggests that facial beauty can automatically compete with an ongoing task for attention, although this does not necessarily mean that appraisal of facial beauty is a mandatory process (see Schacht, Werheid, & Sommer, 2008). The analysis of eye movements in Sui and Liu's study revealed that the effect of facial attractiveness was not due to foveal fixation on the target or face stimuli, hence there is a strong possibility that facial attractiveness can be detected outside the fovea. This has been confirmed by a recent investigation, where discrimination of facial beauty was measured at several eccentricities (Guo, Liu, & Roebuck, 2011).

Both dot-probe and cuing tasks require focused attention, where attention is directed to a single spatial location. However, attention in reality can be distributed to several different targets or spatial locations. For instance, a group activity requires attention to be paid to multiple individuals and locations. The main purpose of this research was to investigate the effect of facial attractiveness on distributed attention. Another motivation of this research comes from observation that spontaneous appraisal of attractiveness is rapid and transient (Schacht et al., 2008). It remains unclear whether such an appraisal only manifests in brief attentional shifts.

Hence the second purpose of this study was to investigate whether a similar kind of automatic appraisal for facial attractiveness occurs continuously when sustained attention is distributed among faces in multiple locations.

Pylyshyn and Storm (1988) designed a multiple-object tracking paradigm (MOT) to study how human observers maintain attention on multiple objects across space and time. In recent years, the issue of content addressability in object tracking is hotly debated. This issue was first raised by Pylyshyn (2004) who found that observers were remarkably poor at identifying the features or identity of correctly tracked objects. This phenomenon demonstrates a poor binding of object features and location. Pylyshyn's explanation is that MOT is implemented by early or low-level vision, where the information about individual identity is encapsulated and inaccessible from higher level cognition. His theory assumes that early vision picks out a small number of objects while ignoring their visual properties. Because of this, object identity differentiated by visual properties is not coded or accessible from higher level cognitive processes even when the objects with those properties are attended. However, recent evidence has challenged this position by showing that tracking is content addressable (Horowitz et al., 2007).

This debate has an important implication for the present study. If the information content of tracked faces is not processed, tracking performance should not be affected by facial attractiveness. It is known that information about face identity (i.e., individuation of face stimuli by features and configurations) is not completely lost in tracking tasks (Ren, Chen, Liu, & Fu, 2009). If representations of the tracked faces are to some extent content addressable, there is a chance that other high-level information such as facial attractiveness is also available for processing. If processing of such information is spontaneous, this could in turn affect multiple face tracking. The experiments in this study were designed to test this hypothesis. The outcome should reveal the extent to which a high-level social cognition can penetrate and influence the low-level visual perception. Appraisal for facial beauty requires high-level vision, because a main criterion for beauty—averageness—cannot be determined solely from low-level visual features such as luminance, contrast, and size. Computing averageness requires identifying the landmarks of higher level facial features such as the eyes, the mouth, and the face shape. The operations for image normalization, alignment, and comparison with the average in the hypothetical multi-dimensional face space also require high-level vision. To ensure that our results were controlled for the low-level contribution, we carefully scaled all our tracking stimuli to the same size, luminance, and contrast.

Other high-level information accompanying appraisal of facial attractiveness could also contribute to multiple-face tracking performance. As Dion, Berscheid, and Walster (1972) showed in their seminal study, beautiful people are generally perceived to possess more positive attributes. They called this the "beauty-is-good" stereotype. Many studies have since produced evidence for this positive association between attractiveness and goodness (see Eagly, Ashmore, Makhijani, & Longo, 1991, and Langlois et al., 2000, for reviews). It is also referred to as the halo effect of attractiveness. This well established duality of beauty could predict a similar effect on tracking based on attractive and valence measures. Moreover, if the reward system is involved in perception of attractive faces (Kampe et al., 2001), arousal could also be responsible for any effect of attractiveness on tracking performance. To address these questions, we compared whether valence and arousal affect tracking performance in the same way as attractiveness.

Experiment 1

The main purpose of Experiment 1 was to investigate how target and distractor attractiveness may affect tracking performance differently. Given the prior finding that the target face identity is content addressable (Ren et al., 2009), we hypothesized that the target faces could be automatically appraised for their attractiveness. Attractive distractors, on the other hand, could impair tracking performance if they were also appraised for attractiveness.

Method

Participants. A total of 25 undergraduate students (19 females) from the University of Hull participated in this study. The age of the participants ranged from 18 to 28 years (*Mdn* = 19). All participants had normal or corrected-to-normal vision.

Stimuli. The face database was obtained from the University of St. Andrews. It contains 702 frontal-view Caucasian faces with no external features (hair and clothing). The size of the faces was normalized according to the face width. The resulting image measured 3.0 × 3.8 cm (2.8 × 3.6º) on screen. All images were scaled to the same mean luminance and root-mean-square contrast.

All faces in the database were rated by 19 raters (aged between 18 and 29 years, 12 females) for attractiveness on a 7-point scale. To contrast the effect of attractiveness, only the 149 most attractive and the 132 least attractive faces were used in this experiment. The mean ratings for the two groups of faces were 3.91 (3.96 for females, 3.72 for males. *SD* = 0.39) and 2.39 (2.35 for females, 2.46 for males. *SD* = 0.38), respectively. These were significantly different from each other ($p < .001$). Slightly more than half (58.3%) of the faces were females. Each attractive or unattractive face was only used once for each participant: 80 were randomly chosen from the pool of attractive faces, and another 80 were randomly chosen form the pool of unattractive faces.

We performed an additional norming study on the face stimuli to measure how attractiveness is related to valence and arousal. Twenty undergraduate students, aged between 18 and 33 years ($M = 21.1$, $SD = 4.4$), rated a total of 452 faces for valence and arousal. The image set consisted of the attractive and unattractive faces in this experiment as well as the additional 171 average faces used in Experiment 3. The faces were rated one at a time. The presentation order was random. To avoid response bias, the raters were not informed until the end of the experiment that the rating data would be used to study facial attractiveness. The details of our procedure were identical to that for the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008). A 9-point rating scale was used where 1 represented completely unhappy/calm, whereas 9 completely happy/excited respectively for the valence and arousal judgments. Table 1 shows the mean rating results for each face category. To determine whether valence and arousal ratings vary according to levels of attractiveness, we conducted separate analyses of variance (ANOVA) for the two variables. The main effect of valence was significant, F (1, 449) = 43.24, MSE = 19. 41, $p < .001$, *partial* $\eta^2 = .17$, where the valence for attractive faces was higher than for average-looking and unattractive faces ($p < .001$), and the valence for average-looking faces was higher than for unattractive faces ($p < .001$). On the other hand, the main effect of arousal was not significant, F (1, 449) = 1.49, MSE = .41, $p = .23$, *partial* $\eta^2 = .01$.

The tracking stimuli were displayed on a 21" monitor (SONY Trinitron, GDM-F520). A central square area with 22.8 × 22.8º of visual angle was designated for stimulus presentation. The background color of the display was gray. E-Prime (Version 1.2) was used to generate the dynamic tracking and still displays and to control the flow of the experiment.

Design. We employed a within-subject design. The independent variables were target attractiveness (attractive vs. unattractive) and distractor attractiveness (attractive vs. unattractive), and face gender (male vs. female). Following this design, the target faces, which were either all attractive or unattractive, were tracked among distractor faces, which were also either all attractive or unattractive.

Procedure. Participants were tested individually. An adjustable headrest was used to fix the participant's viewing position, which was set 60 cm away from the computer monitor. The faces presented in each trial were of the same sex. They were randomly chosen for each trial from the pool of 281 faces. The chosen images were not repeated in the subsequent trials until all faces in the pool were used. The procedure for each trial of the experiments is illustrated in Figure 1A. Each trial was initiated by a key press. It began with 10 stationary black rectangles on the screen. The location of the rectangles was randomly assigned, with the constraint that none would occlude the others and the center-to-center distance was not less than twice of their size. Five of the rectangles would then start to blink twice for 2 *s*, signaling the target location. Following this, the rectangles changed abruptly into 10 faces, and started to move in random directions. The faces bounced off each other when the center-to-center distance was less than twice of their size. They avoided the edge of the display area when the center to edge distance was less than their size. Participants were asked to track the five moving targets. The velocity of the face images varied between 3.9 and 6.3 ° / *s* with a mean of 5.1° / *s*. All faces moving about the screen for 5 *s*. As soon as the motion stopped, all the faces were again occluded by black rectangles. The task was to pick out the five targets by clicking on the rectangles. Once being clicked, the rectangle was highlighted with a yellow border which could be switched on and off by clicking. Participants were forced to select 5 items and were allowed to guess. Once 5 items were selected, they clicked a "finish" button to start the next trial. The experiment lasted about 30 minutes.

A total of 80 experimental trials were run after 4 practice trials. Each of the eight conditions (2 target attractiveness × 2 distractor attractiveness × 2 face gender) had 10 trials. All 80 trials were mixed in random order in one block.

Results and Discussion

An alpha level of .05 was used for all statistical analyses in this report. Results of tracking accuracy are shown in Figure 2. The data were analyzed using repeated-measures ANOVA. There was a significant main effect of target attractiveness, $F(1, 24) = 8.50$, $MSE = 18.52$, $p < .01$, *partial* $\eta^2 = .26$, where attractive faces were tracked better than unattractive faces. However, there was no difference between results for attractive and unattractive distractors, $F(1, 24) = 1.77$, $MSE = 27.74$, $p = .20$, *partial* $\eta^2 = .07$. There was also a main effect of face gender, $F(1, 24) = 7.47$, $MSE = 23.31$, $p < .01$, *partial* $\eta^2 = .24$, where male faces were tracked better than female faces. However, face gender did not interact with other factors, *p*s > .57. None of the other two-way or three-way interactions was significant, *p*s > .15.

The experiment shows that tracking performance was affected by appraisal of facial attractiveness. This effect was only present for the target faces, while the influence of attractive distractors was negligible. Although male faces were tracked better than female faces, the effect was not modulated by attractiveness.

The effect of attractive faces on tracking performance could be due to varying levels of involuntary attention to task-irrelevant information. Some participants might be able to suppress or control attention to the task-irrelevant information better than others. If this is the case, it would be possible that those who were poor at the tracking task would show a stronger attractiveness effect, because they are poor at suppressing the attractiveness information. To test this prediction, we analyzed the correlation between the size of attractiveness effect and overall tracking performance. Consistent with this prediction, a negative correlation was found between the two, $r = -0.59$, $p < .001$. Figure 3A shows a scatter plot of this correlation.

Because the attractive faces had greater valence rating than unattractive faces in our norming study, we evaluated how the difference of valence contributed to the attractiveness effect in this experiment. This was done by an item-based analysis of covariance (ANCOVA), where facial attractiveness was treated as a random factor, and the valence a covariate. ANCOVA measures whether attractiveness had an effect on tracking performance after removing the covariate valence. Because only the target attractiveness had an effect on tracking performance, we only used target attractiveness in our ANCOVA as an independent factor. Hence the target faces were used as random sample, and corresponding valence for these faces as covariate. Results showed a significant main effect of target attractiveness, F (1, 278) = 3.57, MSE = .07, p < .03, *partial* η^2 = .02, where attractive targets were tracked better than unattractive targets. However, the covariate was not significant, F (1, 278) =.59, MSE =.001, p = .44, *partial* η^2 = .002, suggesting that the valence made no contribution to the attractiveness effect found in this experiment.

Experiment 2

In Experiment 1, the target faces were either attractive or unattractive. When the targets had a similar level of attractiveness, attention might be more or less evenly distributed among the targets. However, if attractiveness varies considerably among targets, attention and consequently tracking performance for a given target could be affected by its attractiveness relative to other targets. To test this hypothesis, we varied level of target attractiveness in this experiment such that the targets consisted of attractive, average, and unattractive faces. We then compared the performance for these different types of targets.

Another issue concerning the use of all attractive or all unattractive targets was that attractive faces may be more visually similar to one another than unattractive faces. Yantis (1992) showed that similarity among targets improves tracking. Because of this, the tracking advantage for attractive targets may not reflect attractiveness directly, but rather through featural similarity. The design in the present experiment was able to eliminate this problem because an effect of attractiveness would no longer be due to greater similarity among the attractive targets.

Method

Participants. A different group of 61 undergraduate students (48 females and 13 males) from the University of Hull participated in this study. The age of the participants ranged from 17 to 34 years (*Mdn* = 20). All participants had normal or corrected-to-normal vision.

Stimuli. The attractive and unattractive face stimuli were the same as in Experiments 1 and 2. In addition, we also added average-looking faces. The mean ratings for the average-looking faces was 2.99 (*SD* = 0.11, *N* = 171). As in the previous experiments, each face category consisted of 80 faces randomly selected from the respective pool of stimuli for each participant. Each trial contained one attractive, one unattractive, and three average-looking target faces. The distractors in this experiment consisted of average-looking faces. Because 8 average faces were used in each trial and 80 trials in total, this requires a total of 640 average faces (80 × 8). Since there were 171 average faces available, each face was repeated about 4 times (640 ÷ 171 = 3.7).

Design. This was again a within-subject design. The independent variables were target attractiveness (attractive, average, and unattractive) and face gender. Because Experiment 1 showed no effect of distractor attractiveness, this variable was not included in this and the next experiments.

Procedure. This was identical to Experiment 1.

Results and Discussion

The tracking results are shown in Figure 4. The main effect of target attractiveness was significant, F (2, 120) = 4.96, MSE = 61.83, $p < .01$, *partial* $\eta^2 = .10$. No significant effect was found for face gender, F (1, 60) = 0.01, MSE = 93.25, p = .98, or interaction between face gender and target attractiveness, F (2, 120) = 0.90, MSE = 70.68, p = .41. Post hoc comparisons of means with Bonferroni correction revealed better tracking performance for attractive targets relative to average or unattractive targets ts (60) > 2.66, ps < .02. There was no difference between results for average and unattractive targets, t (60) = 0.11, p = 1.00. The results suggest that attractive faces were attended more favourably whereas unattractive and average-looking faces were not treated differently during tracking.

Consistent with Experiment 1, there was a significant negative correlation between participants' overall tracking performance and the size of the attractiveness effect, r = -0.22, p < .04. A scatter plot of this correlation is shown in Figure 3B.

Results of ANCOVA for Experiment 2 show that there was a significant main effect of target attractiveness, F (1, 448) = 7.37, MSE = .07, p < .01, *partial* η^2 = .03, where attractive faces were tracked better than average-looking and unattractive faces (ps < .01), and there was no difference between average-looking faces and unattractive faces (p = .51). The covariate, or valence of the faces, was also significantly related to the tracking performance, F (1, 448) = 9.90, MSE = .09, p < .01, *partial* η^2 = .02. This indicates that the valence of faces also contributed to the attractiveness effect in this experiment.

Experiment 3

The tracking task in Experiments 1 and 2 did not explicitly require binding of a target identity with its location. If target attractiveness is appraised, it is possible that the location of an attractive target is monitored more accurately relative to an unattractive target. To test this hypothesis, we employed a variant of the MOT paradigm, where one of the faces was randomly chosen from the targets and probed at the end of each trial. The task here was to specify the

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location of the probe face.

Method

Participants. A different group of 50 undergraduate students (25 females and 25 males) from the University of Hull participated in this study. The age of the participants ranged from 18 to 35 years (*Mdn* = 20). All participants had normal or corrected-to-normal vision.

Stimuli. These were the same as Experiment 1.

Design. This was again a within-subject design. The independent variables were attractiveness, face gender, and participant gender. Although not originally planned, potential participant gender difference was included in our analysis because the number of participants in each gender group was fully balanced.

Deleted: more balanced than Experiment 1. However, it should be stressed that because gender difference was not originally planned as an aim of this study, the number of participants in each gender group was far from balanced. Also, because Experiment 1 showed no effect of distractor attractiveness, this variable was not included in this and the next experiments. The distractors were selected in the same way as in Experiment 1

Procedure. The procedure of this experiment was identical to Experiment 1 except that at the end of each trial one of the faces was randomly chosen from the targets and probed (see Figure 1B). The participant was required to specify the specific location of the probe face by clicking on one of the occluded faces with a mouse. The occluder of the chosen face was then removed to reveal the answer after the mouse click. This feedback was used to engage the participants. Because this task was harder than the standard task, the number of faces in each trial was reduced to 8, with the number of target faces reduced to 4. The task began with four practice trials followed by 40 experimental trials (10 trials × 4 conditions).

Results and Discussion

The locations of attractive targets were identified better than unattractive targets, F (1, 48) = 4.70, MSE = 241.50, p < .04, *partial* η^2 = .11. Neither face gender nor participant gender produced a significant main effect, Fs (1, 48) = 1.08 and 0.001, ps = .30 and .98, respectively. However, this was qualified by a significant two-way interaction between participant gender and attractiveness, *F* (1, 48) = 9.97, *MSE* = 241.50, $p < .01$, *partial* η^2 = .17, as well as a marginally significant interaction between participant gender and face gender, *F* (1, 48) = 3.80, *MSE* = 204.27, $p = .057$, *partial* η^2 = .07. The three-way interaction also approached the level of significance, *F* (1, 48) = 2.78, *MSE* = 168.51, $p = .10$, *partial* η^2 = .06. The two-way interaction between face gender and attractiveness was not significant, (1, 48) = 1.63, $p = .21$, *partial* η^2 = .03. The interaction effects are illustrated in Figure 4.

To investigate the interaction effects, we conducted separate ANOVAs for the two participant genders. Results for the female participants showed a significant main effects of attractiveness, *F* (1, 24) = 14.73, *MSE* = 246.00, $p < .001$, *partial* η^2 = .38, and face gender, *F* (1, 24) = 4.45, *MSE* = 478.39, $p < .05$, *partial* η^2 = .16. There was also a significant interaction between attractiveness and face gender, *F* (1, 24) = 7.55, *MSE* = 96.54, $p < .01$, *partial* η^2 = .24. Further analyses of the interaction via pairwise comparisons of means revealed that female participants identified the spatial locations for attractive male targets more accurately than for unattractive male targets, *t* (24) = 4.73, $p < .001$. In contrast, the locations for these attractive and unattractive male targets were identified equally well by male participants, *t* (24) = -0.51, $p = .61$. In contrast to the results for female participants, ANOVA did not find any main effects of face gender and attractiveness, or the interaction between the two for the male participants, *F*s (1, 24) < 0.42, *ps* > .53.

Consistent with Experiments 1 and 2, the performance was again negatively correlated with the size of attractiveness effect, $r = -0.29$, $p < .03$. Figure 3C shows a scatter plot of this correlation.

To determine whether valence has also contributed to tracking performance, we performed an ANCOVA on the data following the same statistical procedure as Experiment 1. Results

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showed a significant main effect of target attractiveness, F (1, 278) = 3.22, *MSE* =.78, $p < .04$, *partial* $\eta^2 = .02$, where attractive faces were tracked better than unattractive faces. The valence, as a covariate, did not significantly affect the tracking performance, F (1, 278) =.39, *MSE* =.09, $p = .53$, *partial* $\eta^2 < .001$.

The data in this experiment suggest that an attractive target was more likely to create a stronger identity-location binding in female participants for attractive male targets. The difference between identity-location binding for attractive and unattractive female targets was not significant. Consistent with Experiment 1, valence did not contribute to the binding advantage of attractive targets.

General Discussion

Results in these experiments suggest a facilitative effect of facial attractiveness in multiple-face tracking. Experiment 1 showed a better tracking performance when attractive faces were assigned as targets. Experiment 2 showed that attractive targets were more likely to be tracked successfully when they were mixed with unattractive or average looking targets. Finally, Experiment 3 found that attractive targets could induce a stronger binding of face identity and location.

Given that attractive faces may be more visually similar to one another than unattractive faces and that Yantis (1992) showed that similarity among targets improves tracking, one may argue that the tracking advantage for attractive targets may not reflect attractiveness directly, but rather through featural similarity. The replicated attractiveness advantage of Experiment 2 has eliminated this equivocal problem. Furthermore, attractive targets and attractive distractors were likely to be more similar than unattractive targets and unattractive distractors in Experiments 1 and 3. This may make tracking more difficult (Makovski & Jiang, 2009) and predict an opposite

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In both Experiments 1 and 2, the target faces were either attractive or unattractive. When the targets had a similar level of attractiveness, attention might be more or less evenly distributed among the targets. However, if attractiveness varies considerably among targets, attention and consequently tracking performance for a given target could be affected by its attractiveness relative to other targets. To test this hypothesis, we varied level of target attractiveness in this experiment such that the targets consisted of attractive, average, and unattractive faces. We then compared the performance for these different types of targets. ¶
Another issue concerning the use of all attractive or all unattractive targets was that attractive faces may be more visually similar to one another than unattractive faces. Yantis (1992) showed that similarity among targets improves tracking. Because of this, the tracking advantage for attractive targets may not reflect attractiveness directly, but rather through featural similarity. The design in the present experiment was able to eliminate this problem because an effect of attractiveness would no longer be due to greater similarity among the attractive targets.¶
Method¶
Participants. A different group of 61 undergraduate students (48 females and 13 males) from the University of Hull participated in this study. The age of the participants ranged from 17 to 34 years (*Mdn* = 20). All participants had normal or corrected-to-normal vision.¶
Stimuli. The attractive and unattractive face stimuli were the same as in Experiments 1 and 2. In addition, we also added average-looking faces. The mean ratings for the average-looking faces was 2.99 (*SD* = 0.11, *N* = 171). As in the previous experiments, each face category consisted of 80 faces randomly selected from the respective pool of stimuli for each participant. Each trial contained one attractive, one unattractive, and three average-looking target faces. The distractors in this experiment consisted of average-looking faces. Because 8 average faces were used in each trial and 80 trials in total, this requires a total of 640 average faces (80 × 8). Since there were 171 average faces available, each face was repeated about 4 times (640 ÷ 171 = 3.7).¶ ... [1]

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unattractiveness advantage. From this point, the tracking advantage for attractive targets is less likely to reflect featural similarity of attractive faces.

Facial beauty would not produce an effect on these tracking tasks if facial features and their holistic information were not processed during the process of tracking. Therefore, given the pattern of our results, the representations of the target items must be content addressable. There is already evidence that face or object identities are processed in multiple target tracking (Horowitz et al., 2007; Oksama & Hyönä, 2008; Ren et al., 2009). The present study shows further that facial attractiveness is also processed during tracking. As the results in Experiment 1 indicate, attractiveness appeared to be assessed only for the target items, because distractors had negligible effects on tracking performance. This finding is consistent with the observation that only target identity is processed in multiple-object or multiple-face tracking (Pylyshyn, 2006; Ren et al., 2009).

Contrary to the suggestion that multiple object tracking is purely driven by low-level vision, of which higher level cognitive processes are unable to penetrate, tracking performance appeared to be modulated by the information content of target items. Content addressability may depend on whether the information is important to the observer and whether the observer is predisposed to process the type of information. Like face identity, attractive faces may automatically engage the attention system. The appraisal for attractiveness in our experiments was spontaneous because it was task irrelevant. Although the effects of such automatic appraisal in this and other studies (e.g., Sui & Liu, 2009) can be quite small, they are consistent and replicable. A small effect in these studies may suggest that task-irrelevant processing can be largely suppressed by the central control. The present study revealed that a participant's tracking performance was negatively correlated with the size of attractiveness effect. This suggests that some individuals may have weaker central control than others: Those who were not as good at tracking showed a larger attractiveness effect because they might not have as much central control and were more easily distracted by the irrelevant information.[1]

Perhaps due to the extent of the central control, not all evidence to date shows that appraisal of attractiveness is spontaneous or mandatory. Schacht, Werheid, and Sommer (2008) found that attractiveness appraisal depended on whether facial attractiveness was task relevant (e.g., beauty rating). This led them to conclude that attractiveness appraisal requires voluntary attention to the attractiveness dimension. The findings of our study show that facial attractiveness can be appraised even when it is not task relevant. Our analyses of the correlation between the effect of attractiveness and tracking performance in the three experiments provide preliminary evidence that participants with higher tracking performance tend to produce a smaller attractiveness effect. This may be due to these participants' better central control to suppress task-irrelevant appraisal of facial attractiveness. Task irrelevant processing of facial beauty has been reported in brain research. Chatterjee, Thomas, Smith and Aguirre (2009) found that the ventral occipital region remained responsive to facial beauty when the task of their participants was to judge facial identity rather than to attend explicitly to attractiveness. They proposed that this region, which includes the fusiform gyrus, the lateral occipital cortex and medially adjacent regions, is activated automatically by beauty and may serve as a neural trigger for pervasive effects of attractiveness in social interactions (see also Kampe et al., 2001). Undoubtedly, the exact level of control that the central executive can have over automatic processing of certain task-irrelevant stimuli will require systematic future research.

The present study also provides preliminary evidence that target tracking is spontaneously affected by gender detection. Experiment 1 showed that male faces were tracked better than female faces. This could be due to a gender bias as participants in this experiment were mainly comprised of females. When we tested equal number of male and female participants in Experiment 3, results showed that female participants tracked the location of an attractive male face more accurately relative to an unattractive male face. However, it is unclear why the same effect was not found for female faces. The gender effect found in Experiment 3 may be similar to Bayliss et al (2005), who found that averted eyes of a face or nonpredictive arrows produce a stronger reflexive shift of attention in females than in males. Given that the participants in our Experiments 1 and 2 were predominantly females, the results in these experiments could be largely driven by certain aspects of gender difference. The role of gender difference in attentive tracking is therefore an important area for future investigation.

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Consistent with prior research, attractive face stimuli in this study were also rated more positively on the valence dimension. Although valence did not contribute to the tracking advantage of attractive faces when the tracked faces had similar attractiveness (Experiments 1 and 3), it did contribute to the tracking performance when the target faces consisted of a full range of attractiveness (Experiment 2). Thus, the lack of valence effect in Experiments 1 and 3 may be due to the much smaller range of this variable associated with the attractive targets. Positive valence is a central trait of facial beauty. It is therefore not surprising that it produced a similar effect to attractiveness on distributed attention. It should be noted, however, that the differences in valence ratings of attractive and non-attractive faces were quite small. No significant difference was found in arousal ratings of attractive and non-attractive faces. These rating data may suggest a moderate link between facial attractiveness and valence, whereas the link between facial attractiveness and arousal is negligible.

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Although it is difficult to separate attractiveness from positive valence due to the very nature of beauty, it is possible to study whether valence in other types of stimuli produces a similar effect on multiple object tracking. A similar conclusion can be made about the relationship between attractiveness and averageness. It would not be possible to separate attractiveness from averageness because averageness is a defining feature of attractiveness. However, it is possible to study whether averageness in non-face stimuli also produces a similar advantage in a multiple object tracking task. There is little evidence that averageness in other kinds of stimuli also attracts attention although it is highly likely that beautiful things in general attract more attention. Unlike faces, the relationship between averageness and other types of beautiful things remains to be seen. In face research, this relationship is established through image morphing techniques. However, it is often difficult to use the same method that requires well-defined corresponding features to build an average for other categories of things such as beautiful sunsets, because obvious correspondence in such images is often absent.

The attentional bias for attractive faces found in this study suggests that multiple object tracking is modulated by underlying biological significance of the tracked targets. It may reflect biological interests of the observer. The preference for attractive faces may be deeply rooted in evolution (Langlois et al., 2000; Rhodes, 2006). Prior research has demonstrated an automatic reaction to facial beauty in focalized attention. The present study shows a similar response to beauty in distributed attention. Because multiple object tracking depends on attentional resources in the working memory (Oksama & Hyona, 2004), our results may suggest higher working memory capacity and greater attentional resources for attractive faces.

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Footnote

[1]We thank Dr. Trafton Drew for suggesting this idea.

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Table 1

Mean ratings of valence and arousal. Values in parentheses represent standard deviation.

Attractiveness	*Valence*	*Arousal*
Attractive	5.08 (0.65)	4.03 (0.48)
Average	4.68 (0.62)	3.94 (0.52)
Unattractive	4.33 (0.74)	3.99 (0.56)

Figure Captions

Figure 1. Illustration of the procedure used in the study. A. Procedure used in Experiments 1 and 2. B. Procedure used in Experiment 3.

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Figure 2. Tracking accuracy in Experiment 1 as a function of target and distractor attractiveness. A. Results of male faces. B. Results of female faces. Error bars represent standard errors.

Figure 3. Scatter plots for the correlation between the size of attractiveness effect and tracking performance.

Figure 4. Tracking accuracy in Experiment 2 as a function of target attractiveness and face gender. Error bars represent standard errors.

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Figure 5. Tracking accuracy in Experiment 3 as a function of target attractiveness and face gender. A. Results of male faces. B. Results of female faces. Error bars represent standard errors.

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Experiment 3

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