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Beauty in the eyes and the hand of the beholder: Eye and hand movements' differential responses to facial attractiveness

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ABSTRACT

Faces carry significant social information and, as such, humans need to allocate attention to them. In particular, facial attractiveness is an important dimension that considerably influences social judgment. The allocation of attentional resources to facial attractiveness has been widely examined in social psychology, however mostly by measures of eye movement. While this literature demonstrates the influence of facial attractiveness on overt attention, how facial attractiveness drives covert attention is less known. In two studies, we tracked eye and hand movements while participants were engaged in a numerical task in the presence of faces of various degrees of attractiveness. Results show that both attractive and unattractive faces captured greater visual attention compared to moderate faces, whereas attractive faces attracted hand movement more strongly than both unattractive and moderate faces. The present study suggests that facial attractiveness guides attention for actions differently through eye and hand movements.

1. Introduction

The face is one of the most important visual objects in our environment (Leder & Carbon, 2004) and is a highly salient social signal, thus people pay attention to faces. Infants as young as 2 days old demonstrate a preferential orientation towards faces or face-like configurations over other equally complex non-face stimuli (Macchi Cassia, Valenza, Simion, & Leo, 2008; Morton & Johnson, 1991; Valenza, Simion, Cassia, & Umiltà, 1996). The face is an important channel of communication (Liang, Zebrowitz, & Zhang, 2010), and a rich source of information (Engell, Haxby, & Todorov, 2007) that informs and influences social judgments (Franklin & Adams, 2009). Among other facial attributes, facial attractiveness is an important dimension that captures attention to a great extent (Langlois et al., 1987; Rubenstein, Kalakanis, & Langlois, 1999). Attractiveness plays a significant role in mating behavior (Luxen & Van De Vijver, 2006) and further in other social judgment such as perceptions of goodness (Tsukiura & Cabeza, 2011), trustworthiness (Wilson & Eckel, 2006), intelligence (Zebrowitz, Hall, Murphy, & Rhodes, 2002), age stereotypes (Palumbo, Adams, Hess, Kleck, & Zebrowitz, 2017), and even social hierarchy (Belmi & Neale, 2014). Extensive research has examined how the eyes are driven by attractive faces (e.g., Guo, Liu, & Roebuck, 2011; Maner et al., 2003; Valuch, Pflüger, Wallner, Laeng, & Ansorge, 2015). However, eye movement is not the only indicator of attention. Attention is able to shift covertly to a target while the eyes remain fixed at a certain location (Wright & Ward, 2008). How covert attention is driven by facial attractiveness is currently less known.

In this research, we examine how eye and hand movements (as indicated by mouse movement) are influenced by facial attractiveness. In two experiments using mouse-tracking and eye-tracking methods, we show that facial attractiveness drives hand movement and eye movement in distinct patterns. In doing so, we demonstrate that hand movement is an additional correlate of attention. As a terminological note, we follow previous research which employed the same mouse-tracking method and used the term “hand movement” to refer to mouse movement (Freeman, 2018; Freeman & Ambady, 2011; Stillman, Medvedev, & Ferguson, 2017). However, we note that the hand movement referred to in this research should be distinguished from

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other forms of hand movement such as grasping and reaching. These actions are different from mouse movement in many aspects, one of which is that hand movements such as grasping and reaching potentially involve greater social signalling, as these actions explicitly demonstrate intentions of an agent.

In the following sections, we first differentiate the two types of attention, namely overt and covert attention. We then discuss the role of hand movement and eye movement in overt and covert attention, followed by how attention is influenced by facial attractiveness. Subsequently, we state our prediction regarding the differential mechanisms that facial attractiveness influences hand and eye movements.

2. Overt and covert attention

In the visual environment, directed eye movement, known as saccades, bring the fovea to objects of interest (Beauchamp, Petit, Ellmore, Ingeholm, & Haxby, 2001; Belopolsky & Theeuwes, 2009). These objects are brought into the center of gaze through an active, overt visual selection process (Findlay & Gilchrist, 2003). On the other hand, it has been long known that humans are able to also examine a target away from the point of gaze by allocating spatial attention towards that target (James, 1890), and they can do so without shifting gaze (Belopolsky & Theeuwes, 2009). Shifts in spatial attention can occur overtly with the eyes shifting, or covertly with the eyes remaining fixated (Wright & Ward, 2008). Similar to overt attentional shifts, covert attentional shifts result in enhanced processing to the attended location, which can be measured at behavioral and neural levels (Mangun et al., 2001; Posner, 1980). The two processes, overt and covert attention, are distinct aspects of attention (Schofield, Johnson, Inhoff, & Coles, 2012). Thus, understanding the relationship between them is important for understanding the function and mechanisms of spatial attention (Awh, Armstrong, & Moore, 2006; Belopolsky & Theeuwes, 2009).

While overt and covert shifts of spatial attention both involve activity in oculomotor control areas, a distinction between the two is that overt shifts of attention take place with saccadic eye movement, whereas covert shifts of attention are not accompanied by overt eye movement. This difference has a neural correlate, such that less activity was observed in the visuospatial network during covert shifts compared to overt shifts (Beauchamp et al., 2001). Thus, covert shifts of attention are thought of as consisting of a shift in spatial attention alone, whereas overt shifts of attention, also expressed as saccades, consist of a shift in spatial attention and a shift in eye position (Beauchamp et al., 2001). Neurophysiological studies show that visuomotor neurons (i.e., neurons that seem to represent a common shift plan, not yet committed to one or the other form of shifting spatial attention) follow the movements of attention, whereas other neurons (pure motor neurons, which are committed to the overt form of shifting attention) either are not modulated or are even inhibited during shifts of covert attention (Ignashchenkova, Dicke, Haarmeier, & Thier, 2004; Juan, Shorter-Jacobi, & Schall, 2004; Thompson, Biscoe, & Sato, 2005).

On the one hand, there is evidence supporting an interdependent relationship between covert and overt attentional orienting. The premotor theory of attention holds that both might be based on a common shift plan (Craighero, Fadiga, Rizzolatti, & Umiltà, 1999; Rizzolatti, Riggio, Dascola, & Umiltá, 1987). The ability to make eye movement can affect covert attention (Craighero, Nascimben, & Fadiga, 2004; Smith, Rorden, & Jackson, 2004). Further, saccades and covert shifts of attention can be subserved by similar neural mechanisms (Rizzolatti et al., 1987). Other neurophysiological studies in monkeys further demonstrate the close link between the two systems (Cavanaugh & Wurtz, 2004; Moore & Fallah, 2004; Muller, Philiastides, & Newsome, 2005).

3. The role of hand and eye movements in overt and covert attention

Many studies that examine attention to faces, both in infants and adults, rely on eye movement (Amso, Haas, & Markant, 2014; Frank, Vul, & Johnson, 2009; Giorgio, Turati, Altoe, & Simion, 2012; Riby & Hancock, 2009; Theeuwes & Stigchel, 2006). Similarly, in the study of facial attractiveness, eye tracking methods have been employed to investigate a wide range of topics; for instance, selective processing biases for attractive faces (e.g., Maner et al., 2003), women's judgment and preference for facial masculinity/femininity in men (Burriss, Marcinkowska, & Lyons, 2014; Lyons, Marcinkowska, Moisey, Burriss, & Harrison, 2016), preferences for sexual dimorphism on attractiveness levels (Yang, Chen, Hu, Zheng, & Wang, 2015), individual differences in attention to attractive faces (Valuch et al., 2015), infants' visual preferences for facial traits associated with adult attractiveness judgment (Griffey & Little, 2014), and how judgment of age and attractiveness interacts (Kwart, Foulsham, & Kingstone, 2012). An exception is by Sui and Liu (2009), who used a reaction time paradigm to examine the effect of facial attractiveness on covert attention. They show that the presentation of attractive faces outside foveal vision can capture attention and automatically competes with an ongoing cognitive task for spatial attention.

While eye-tracking enables a dynamic measurement of overt visual attention, it does not measure covert attention (Schofield et al., 2012). Research that infers attention from reaction-time latency scores, and neurophysiological methods, may be better at capturing covert attentional shifts (Schofield et al., 2012). We propose that an additional measure of covert attention is hand movement. As we noted previously, a type of hand movement, also the one referred to in the present research, is indicated by mouse movement. The dynamic, non-ballistic, and continuous nature of computer mouse trajectories (Farmer, Cargill, Hindy, Dale, & Spivey, 2007) can potentially reveal patterns of covert attention that otherwise are not shown by looking at eye movement alone. Prior research shows that whereas saccadic eye movement is ballistic and straight, hand movement regularly involves a curvature (Goodale, Pélisson, & Prablanc, 1986; Tipper, Howard, & Jackson, 1997), and can thereby reveal continuous spatial attraction effects that might not be detected with other methods (Spivey, 2007). Moreover, there is some evidence that the programming of hand movement can be influenced by attended information on the visual field, which is independent of eye movement (Castiello, 1999).

Having said that, as eye movement usually precedes hand movement, it provides a more immediate index of cognitive processes than hand movement (Spivey, 2007) and offers an early glimpse into the micro-decisions in motor output (Dale, Kehoe, & Spivey, 2007). Thus, Spivey (2007) suggests that computer mouse trajectories are best seen not as a substitute for other methods but as an important complementary index in uncovering the continuous flow from mental to motor behavior, which can indicate the effects of covert attention.

4. Attention to facial attractiveness

Attractiveness, and facial attractiveness in particular, plays an important role in human life. Psychological research demonstrates an 'attractiveness halo' effect, whereby people with more attractive faces are judged more positively on a number of dimensions. For example, attractive people are thought to be trustworthy, competent, and are judged less severely when committing offenses (Desantts & Kayson, 1997; Etcoff, 1999). Attractiveness was shown to be even more important than trustworthiness in online markets where people are judged based on their profile photos (Jaeger, Sleegers, Evans, Stel, & Beest, 2018). These pervasive responses to beauty are thought to be innate (Langlois, Ritter, Roggman, & Vaughn, 1991) and shaped by evolutionary history (Gallup & Frederick, 2010; Grammer, Fink, Møller, & Thornhill, 2003; Rhodes, 2006). Past research (e.g., Langlois et al., 1987; Rubenstein et al., 1999) found that babies as young as 1 month looked at attractive faces for a longer time than unattractive faces, which the authors interpreted as infants' preferences for attractive faces. The behavioral effects of beauty have accompanying neural signatures. Attractive faces activate the fusiform (face) area and adjacent lateral occipital complexes even when participants are making identity judgments, suggesting that these regions respond to attractiveness automatically (Chatterjee, Thomas, Smith, & Aguirre, 2009). Moreover, facial attractiveness evokes activation in reward related brain areas such as the nucleus accumbens and the orbitofrontal cortex (O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001); this occurs even when subjects are involved in an unrelated perceptual task (Kim, Adolphs, O'Doherty, & Shimojo, 2007; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007).

Collectively, these studies suggest an inherent attraction to attractive faces. Mapping this observation onto hand movement, we predict that attraction towards attractive faces would drive hand movement. Previous research using mouse-tracking methods interpret the results in terms of attraction to a target. In a nutshell, mouse-tracking typically involves moving the mouse cursor from the central start box at the bottom of a computer screen to either the left or right targets at the top of the screen, with one of the targets being a distractor. When trajectories verge into the distractor's hemispace before turning into the correct hemispace, this is interpreted as attraction by the competing distracting stimulus (Fischer & Hartmann, 2014). This attraction by the competing distractor is measured by the deviation between an actual trajectory and the ideal trajectory (i.e., a straight line from the bottom-center start point to the selected response). Specifically, the curvature between the actual and the ideal trajectories demonstrates how much a selected response was spatially drawn to an unselected response during the decision-making process and can reflect an individual's cognitive effort to shift a decision towards the selected response (Ha et al., 2016). Mouse-tracking method has thus been widely used in domains in which a spatial attraction towards a competing choice is meaningful, such as self-control (Dshemuchadse, Scherbaum, & Goschke, 2013; Gillebaart, Schneider, & De Ridder, 2016; O'Hora, Carey, Kervick, Crowley, & Dabrowski, 2016; Scherbaum et al., 2016; Schneider et al., 2015), conflict in social categorization (Dale et al., 2007; Freeman, Dale, & Farmer, 2011) and conflict in decision making (Stillman et al., 2017) (also see Stillman, Shen, and Ferguson (2018) for a review). To illustrate, Stillman et al. (2017) examined children's self-control in resisting the temptation of unhealthy food. Children's mouse movements showed that even though they know that they should eat an apple instead of chocolate to be healthy, interference from the temptation (i.e., conflict) occurred when choosing the apple. Similarly, Davis and Haws (2017) showed adults' attraction to unhealthy snacks; Lazerus, Ingbretsen, Stolier, Freeman, and Cikara (2016) showed initial attraction to the positive label for in-group members.

If hand movement is driven by the attraction to attractive faces, would facial attractiveness drive eye movement in a similar fashion? Observational and experimental studies (e.g., Langlois et al., 1987; Liu & Chen, 2012; Slater et al., 1998) as well as other eye tracking studies (e.g., Guo et al., 2011; Maner et al., 2003; Valuch et al., 2015) have shown a visual attentional bias towards attractive faces. However, this stream of research often compares attractive and unattractive faces (Langlois et al., 1987; Slater et al., 1998) or attractive and average-looking (i.e., moderate) faces in pairs (Maner et al., 2003). Alternatively, facial traits such as 'natural faces' versus 'morphed faces' (Valuch et al., 2015) or facial averageness, symmetry and sexual dimorphism (Griffey & Little, 2014) are used as proxies for attractive versus unattractive faces. There is not much evidence on attention to moderate faces. It is worthwhile to include these faces together with attractive and unattractive faces. Specifically, it is not known whether unattractive or moderate faces received more visual attention. Although not in the domain of faces, prior research in visual attention shows that a visual attention system responds placidly when common stimuli are presented, while at the same time keep alert to anomalous visual inputs (Hou & Zhang, 2008). For instance, Becker, Pashler, and Lubin (2007) show that anomalous, odd items draw early saccades. Similarly, the eyes often spend more time fixated on the deviant objects than on other objects in a given scene (Henderson, Weeks Jr., & Hollingworth, 1999; Loftus & Mackworth, 1978). Itti and Koch (Itti, 2000; Itti & Koch, 2000, 2001) propose that local, competitive interactions between visual neurons result in a neural signal that is biased in favour of visually discrepant features. Moreover, once the eye lands on a deviant object, it may linger on that object or return to it later (Becker et al., 2007).

Drawing from this research suggesting that odd, discrepant, or anomalous objects attract visual attention, it could be that in the domain of facial attractiveness, any face that is unusual (i.e., at the tail of any distribution of features and further away from population mean) attracts greater visual attention. In other words, faces that are attractive or unattractive (i.e., the more extreme and unusual), might influence eye movement to a greater extent than moderate faces. Previous neuroscience research in facial attractiveness indeed shows a nonlinear response of amygdala to affectively significant faces depending on whether they are positively or negatively valenced (Fitzgerald, Angstadt, Jelsone, Nathan, & Phan, 2006). Liang et al. (2010) demonstrated heightened responses in numerous areas of the reward circuit to both rewarding and aversive faces. Similarly, higher activation in the amygdala was shown to faces high or low in attractiveness than those of medium attractiveness (Krendl, Macrae, Kelley, Fugelsang, & Heatherton, 2006; Winston et al., 2007). There is also some evidence for a positive non-linear effect of attractiveness in medial orbitofrontal cortex (Winston et al., 2007). It is possible that attention is paid to unattractive faces because of their (incorrect or not) perceived similarity to faces of individuals with bad genes and carrying diseases – a phenomenon called anomalous face overgeneralization (i.e., adaptive responses to individuals with diseases or bad genes generalize to normal individuals whose faces resemble those who are unfit, for instance, unattractive faces) (Liang et al., 2010; Zebrowitz, Fellous, Mignault, & Andreoletti, 2003; Zebrowitz & Rhodes, 2004). Further, unattractive faces, like expressions of anger and fear elicit differential physiological arousal and neural activation that is of great magnitude (Griffin & Langlois, 2006) due to overgeneralization of affect (e.g., Zebrowitz, 1997). Moreover, some evidence suggests that the attractiveness halo effect is driven more by the perception that 'ugly is bad' than by the perception that 'beautiful is good', thus unattractiveness is a disadvantage more than attractiveness is an advantage (Griffin & Langlois, 2006).

Taken together, we hypothesized that hand movement would be driven by attractive faces more than unattractive and moderate faces, whereas eye movement would be more responsive to attractive and unattractive faces than moderate faces.

5. Method

We conducted two studies, one using mouse tracking and one using eye tracking. The protocol for these studies was approved by the University's Institutional Review Board. All measures, manipulations, and exclusions in all studies are disclosed. Sample size was determined before any data analysis. We report a sensitivity power analysis for each sample (i.e., the minimum effect size detectable with 80% power, given the sample size), using G*Power software version 3.1.9.2.

5.1. Stimuli

Images were extracted from a standardized and validated database of Southeast Asian faces (see Yap, Chan, and Christopoulos (2016)). Twenty attractive faces, 20 unattractive faces, and 40 moderate faces (50% women and 50% men) were selected. Attractive and unattractive faces were selected based on the ratings of a different sample, where faces with an average rating of 0.5 standard deviations above (below) the mean among both female ($M_{\text{female raters}} = 3.9$, $SD = 0.45$) and male raters ($M_{\text{male raters}} = 3.66$, $SD = 0.64$) were categorized as attractive (unattractive). Moderate faces are those with ratings falling in between

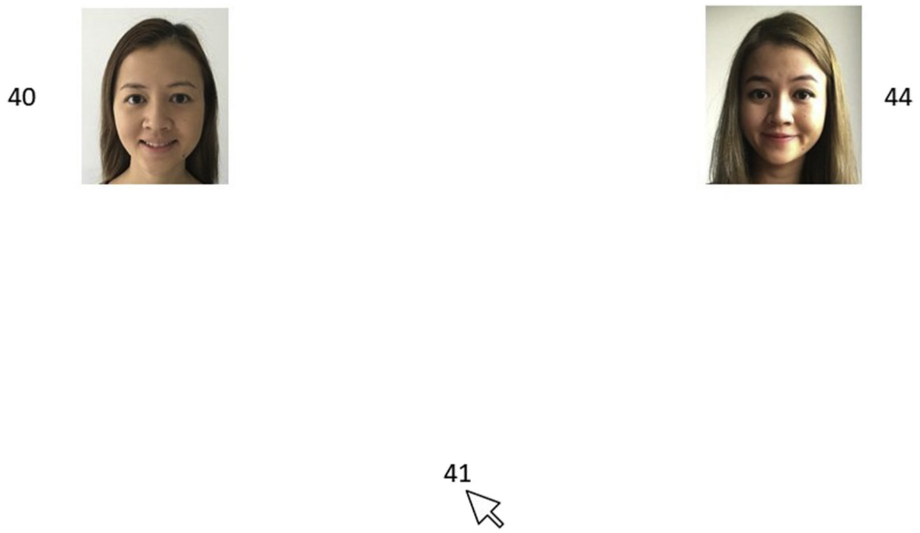

Fig. 1. A trial of the numerical judgment task. Participants first clicked the start button for the numbers (and faces) to appear. Their task was to click on the number that was closer to the basis number. In this trial, participants should click on the number that was closer to 41, which was 40. These images were only for illustration purposes. Faces in each pair were different faces, not different versions of the same face. Face images were standardized. All pictures were taken in the same room condition and camera parameters. Faces were without makeup.

the range of Mean ± 0.5 SD.

Face images were standardized such that the size of the face and the proportion of the face to the background are similar across images. All pictures were taken in the same room condition and camera parameters. Faces were without makeup.

5.2. *Design*

5.2.1. *Numerical judgment task*

Participants completed an alternate forced choice task (Fig. 1). For each trial, participants were presented with three two-digit numbers: the first one (“basis”) was located at the bottom of the screen and the other two (“targets”) located at the top left and right corners of the screen. Participants were to click on the target that was numerically closer to the basis. Next to each target one face was presented. Participants were asked to ignore the faces and execute the task correctly and fast. They had to make a choice within 5 s, otherwise the next trial was initiated automatically, and a message appeared which asked them to start moving earlier on. The maximum difference in value between the basis and the targets was five units. For instance, if the basis was 22, each of the two targets were not larger than 27. This is to ensure the difficulty of the task across all trials was consistent.

We arranged the pairs of faces according to three conditions: *congruent* (the correct number was paired with an attractive face), *incongruent* (the correct number was paired with an unattractive face), and *control* (the correct number was paired with either one of the two moderate faces). Each participant performed 40 trials, with women and men faces being equally distributed. Specifically, these included 10 congruent trials (5 attractive men's faces accompanying the correct number paired with 5 unattractive men's faces accompanying the incorrect number, and 5 attractive women's faces accompanying the correct number paired with 5 unattractive women's faces accompanying the incorrect number), 10 incongruent trials (5 attractive men's faces accompanying the incorrect number paired with 5 unattractive men's faces accompanying the correct number, and 5 attractive women's faces accompanying the incorrect number paired with 5 unattractive women's faces accompanying the correct number), and 20 control trials (10 moderate men's faces accompanying the correct number paired with 10 moderate men's faces accompanying the incorrect number, and 10 moderate women's faces accompanying the correct number paired with 10 moderate women's faces accompanying the incorrect number; women and men faces were equally distributed).

For all trials the correct choice was counterbalanced to appear in the top-left or top-right of the screen. Faces in each pair had similar eye, hair color and skin tone and were of the same cultural group/race. Face pairs were presented in a random order. Moreover, to increase randomization, we created two sets of stimuli that were randomly distributed to participants. In these two sets, a face was paired with a different face in each set, and a face accompanying the correct number in one set would accompany the incorrect number in the other set. Thus, we ensured that the same two faces were not always paired together, and that a certain face did not always accompany the correct choice.

5.2.2. *Mouse-tracking*

Seventy participants (54% females, $M_{\text{age}} = 22.66$, $SD = 1.87$) completed the task while we tracked mouse movement using the MouseTracker program (see Freeman and Ambady (2010)). A sensitivity power analysis with 80% power (using G*Power software version 3.1.9.2.) shows that our sample in the mouse-tracking study allows us to detect a minimum effect of $f^2 = 0.14$. Participants were recruited through the University's subject pool and participated in the study for monetary compensation. In each trial, participants were instructed to click a “Start” button at the bottom-center of the screen, in order for the faces to appear.

5.2.3. *Mouse-tracking metrics*

For each participant, we obtained trajectories for congruent, incongruent, and control trials. To obtain a measure of movement bias towards the unselected face, we followed Freeman and Ambady's (2010) method and focused on averaged deviations in trajectories towards one response or another. We used three metrics: Maximum Deviation, Distance travelled, and reaction time. Maximum Deviation is the length of a perpendicular line between the idealized straight-line trajectory and farthest point from that straight line in the observed trajectory. This measure assesses the degree of attraction towards an unselected response, indexing the magnitude of activation for each response option as the decision process unfolds over time (see Freeman and Ambady (2010) for details). Distance is the length of the path that the mouse travelled, from the start to the end point of each trial (refer to Fig. 2 for an illustration of Maximum Deviation and Distance). In terms of measure units of Maximum Deviation and Distance, it should be noted that all trajectories are rescaled into a standard MouseTracker coordinate space. Specifically, the top-left corner of the screen corresponds to [−1.00, 1.50] and the bottom-right corner corresponds to [1.00, 0.00]. In a standard 2-choice design such as ours, the start location of the mouse corresponds to [0.00, 0.00]. The standard space thus represents a 2 × 1.5 rectangle (Freeman & Ambady, 2010). Reaction time is the amount of time participants spent from the onset of the trial till they submitted their response. Reaction time is measured in milliseconds.

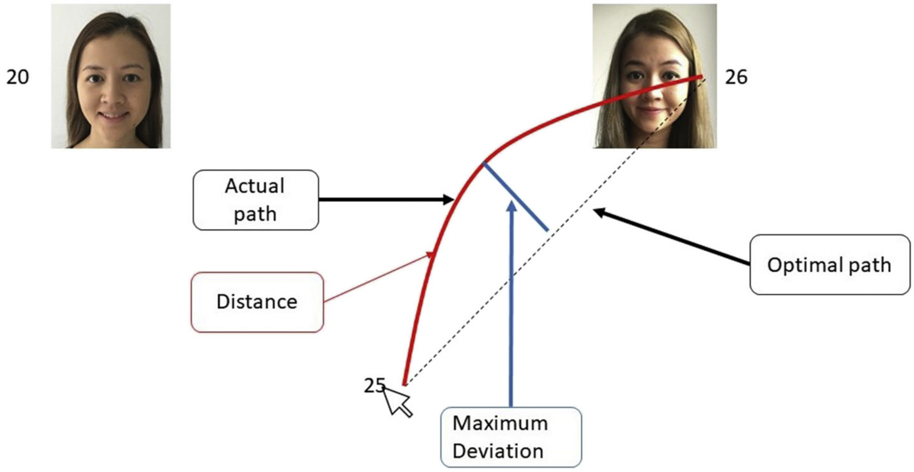

Fig. 2. Metrics in mouse-tracking analysis: maximum deviation (MD) and distance.

5.2.4. *Eye-tracking*

A second set of participants completed the numerical judgment task while we tracked their eye movement. Sixty-three participants (58% females, $M_{\text{age}} = 22.65$, $SD = 2.37$) took part in the eye-tracking study. A sensitivity power analysis with 80% power (using G*Power software version 3.1.9.2.) shows that our sample in the eye-tracking study allows us to detect a minimum effect of $f^2 = 0.16$. Eye movement was recorded using a Tobii eye-tracker (version T120). Each trial started with a cross in the center of the screen for 1000 ms for participants to fixate their eyes, followed by a pair of faces.

5.2.5. *Eye-tracking metrics*

To assess eye movement we examined two metrics, number of fixations and total fixation duration on a specific face.

Number of fixation, also referred to as fixation count, measures the number of times the participant fixates on an Area of Interest (i.e., a face in our study). If at the end of the recording the participant did not fixate on the Area of the Interest, the fixation count value will be registered as zero. Zero values indicate the participant did not pay any (visual) attention to the face at all, and are thus meaningful in our studies.

Total fixation duration, measured in seconds, measures the sum of the duration of all fixations within an Area of Interest. If the participant did not fixate on the Area of Interest, the total fixation duration will be registered as zero.

5.2.6. *Attractiveness alternate forced choice task*

After the mouse-tracking or the eye-tracking task, participants did a 10-minute filler task, followed by an explicit attractiveness alternate forced choice task. Participants were shown a pair of faces in each trial and were to click on the face that they think is more attractive. The pairs of faces are the same as in the numerical judgment task and were shown without accompanying numbers.

6. Results

6.1. *Manipulation check of attractiveness categorization*

Results of the attractiveness alternate forced choice task confirmed our categorization of attractive and unattractive faces. Within the attractive-unattractive face pairs, the pre-classified attractive faces were chosen more often compared to the unattractive faces (inter-rater agreement across participants greater than 80%). For pairs of moderate faces, if inter-rater agreement across participants was greater than 80% (that is, if more than 80% of the participants chose a specific face over the other face), we converted them to attractive-unattractive face pairs, and thus congruent or incongruent trials accordingly. We note the rationale for our approach as follow. While the original pre-categorization was a judgment task, which was deemed essential to allow categorising faces in a continuum (necessary for the design of our experimental task), the main experimental task was essentially a choice task where faces were not perceived in isolation but in comparison. It is established that while judgment-based and choice-based responses to a great extent represent the same set of preferences, they are many times incompatible and demonstrate reversals (Hsee, Loewenstein, Blount, & Bazerman, 1999; Schkade & Johnson, 1989). Specifically, in our case, there are cases in which faces that were pre-rated to be moderately attractive (i.e., receiving ratings that are in the same range), when put together in comparison, one face was chosen as more attractive more often than the other. Thus, an alternate forced choice task that happens after the actual experiment task is necessary. Using this approach, we take into account the sample-specific preferences space in facial attractiveness perception.

6.2. *Data cleaning*

We removed one participant from the mouse-tracking study and three participants from the eye-tracking study, due to technical issues. We excluded trials with errors (i.e., the choice of number was incorrect), and trials that were outside the range defined by the mean reaction time ± 2 standard deviations (i.e., between 634.46 and 2467.34 ms for mouse-tracking task and between 454 and 2786 ms for eye-tracking task). In the mouse-tracking task, after removing trials with errors, 2470 trials (out of 2760 trials) remained, and then 2347 trials remained after we removed trials outside the $(M + -2SD)$ range. In the eye-tracking task, participants made errors in more trials; only 1778 trials (out of 2400 trials) remained after removing trials with errors. Further, 1691 trials remained after removing trials outside the $(M + -2SD)$ range.

6.3. *Mouse-tracking*

Following standard procedures (Freeman & Ambady, 2010), hand trajectories were standardized so that each trajectory was divided into 101 steps. Trajectories were also space-normalized so that trajectories were extrapolated into a standard space to permit averaging across multiple trials. Fig. 3 demonstrates the sample trajectory of one participant in congruent and incongruent trials.

We used a linear mixed-effects model using SPSS software. In all analyses, we entered congruency (congruent, control, incongruent) as the fixed factor, and Maximum Deviation, Distance and reaction time as dependent variables. In all analyses, we specified subjects and face pairs

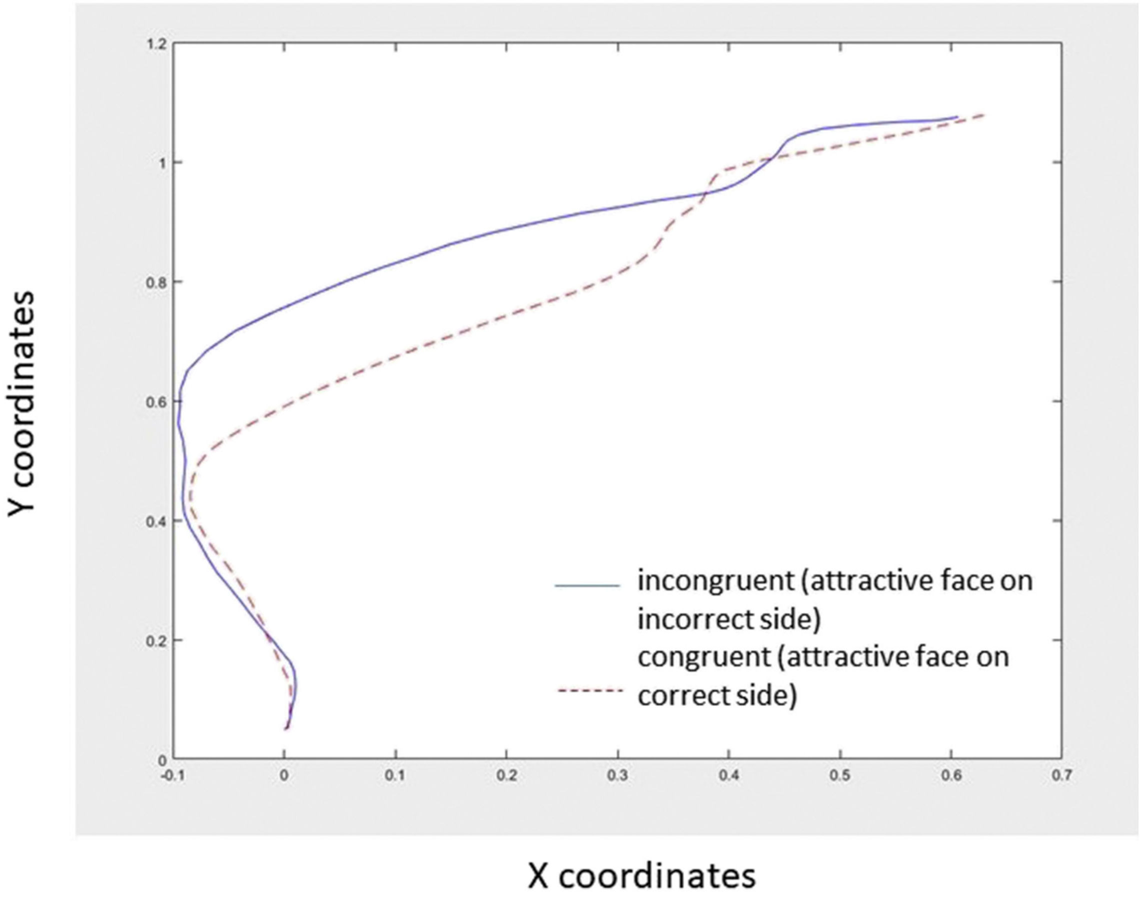

Fig. 3. A sample trajectory from one participant across two conditions congruent (attractive face is next to the correct choice) and incongruent (attractive face is next to the incorrect choice).

as random factors to control for their associated intra-class correlation.

6.3.1. *Maximum deviation*

Results revealed congruency had a significant effect on the Maximum Deviation ($F(2, 2358.04) = 3.98$, $p = .019$). Specifically, the Maximum Deviation was larger in incongruent trials compared to congruent trials ($\beta = -0.065$, $SE = 0.03$, $t(2357.81) = -2.61$, $p = .009$), and compared to control trials ($\beta = -0.052$, $SE = 0.02$, $t(2358.35) = -2.36$, $p = .019$) (see Table 1 for Descriptive results and Fig. 4). There was no significant difference between congruent and control trials ($p = .55$) (Fig. 4).

6.3.2. *Distance*

Results revealed a significant effect of congruency on the travelled distance ($F(2, 2350.24) = 4.75$, $p = .009$). The distance travelled was longer for incongruent trials compared to congruent trials ($\beta = -0.13$, SE = 0.047, $t(2349.95) = -2.68$, $p = .007$), and compared to control trials ($\beta = -0.12$, SE = 0.04, $t(2350.64) = -2.77$, $p = .006$). There was no significant difference between congruent and control trials ($p = .80$) (Fig. 4).

Table 1
Descriptive results of mouse-tracking variables.

Variables	Incongruent		Congruent		Control	
	M	SD	M	SD	M	SD
Maximum deviation	0.45	0.46	0.39	0.43	0.40	0.43
Distance	1.92	0.87	1.79	0.83	1.80	0.81
Reaction time	1518.9	330.84	1478.5	332.81	1483.26	353.12

6.3.3. *Reaction time*

The effect of congruency on reaction time ($F(2, 2348.01) = 2.78$, $p = .062$). Specifically, participants spent longer time in incongruent trials compared to congruent trials ($\beta = -40.37$, $SE = 19.35$, $t(2347.02) = -2.09$, $p = .037$), and compared to control trials ($\beta = -35.67$, $SE = 17.12$, t(2348.99) $= -2.08$, $p = .037$). There was no significant difference in reaction time between congruent trials and control trials ($p = .78$) (Fig. 4).

6.4. *Short discussion of mouse-tracking experiment*

The larger Maximum Deviation of the trajectories in incongruent trials compared to congruent and control trials demonstrated that trajectories for incongruent trials deviated from the optimal path to a greater degree compared to the other conditions. When the attractive face was not aligned with the correct choice (i.e., incongruent trials), participants' hands were drawn to the attractive face before eventually moving to the (correct) number next to the unattractive face. In contrast, when the attractive face was aligned with the correct choice (i.e., congruent trials), there was less attraction to the unattractive face; the hand moved more directly to the side of the attractive face. This attraction effect of attractive faces for hand movement was further indicated by the greater travelled distance of the hand movement towards these faces and the longer reaction time despite that they were not the correct answer.

6.5. *Eye-tracking*

6.5.1. *Number of fixations and fixation duration*

We conducted a linear mixed model analysis using SPSS software

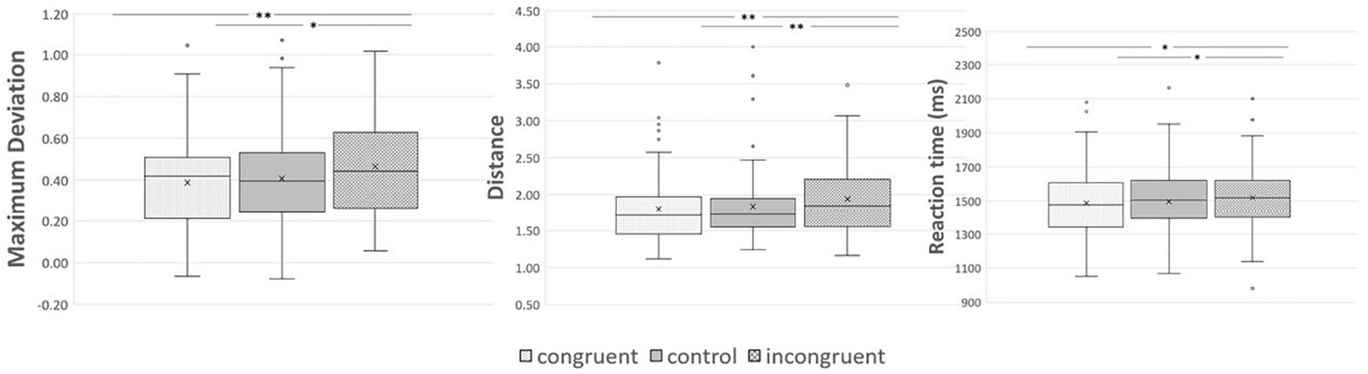

Fig. 4. Maximum deviation, distance, and reaction time across congruent, control, and incongruent trials. Maximum deviation and distance measurement unit was based on a 2 × 1.5 rectangle standard mouse-tracker coordinate space. Reaction time was measured in milliseconds. Center lines denote the median values. $^{**}p < .01$, $^{*}p < .05$.

with congruency (congruent, incongruent, and control) and attractiveness (attractive, unattractive, and moderate) as independent variables and number of fixations/fixation duration as dependent variables. In all analyses, we specified subjects and face pairs as random factors. Results revealed a significant interaction effect of congruency and attractiveness on the number of fixations ($F(1, 1689) = 222.41$, $p < .001$). Similarly, results revealed a significant effect of attractiveness ($F(1, 1689) = 5.41$, $p = .02$), and a significant interaction effect of congruency and attractiveness ($F(1, 1689) = 207.64$, $p < .001$) on fixation duration.

Table 2
Descriptive results for eye-tracking metrics.

	Number of fixations	Fixation duration	Reaction time
	M(*SD*)	M(*SD*)	M(*SD*)
Attractive/correct	1.22 (0.95)	0.24 (0.22)	1.49 (0.43)
Unattractive/correct	1.22 (0.96)	0.24 (0.22)	1.55 (0.44)
Moderate/correct	0.77 (1.07)	0.15 (0.24)	1.53 (0.47)
Attractive/incorrect	0.73 (0.82)	0.14 (0.18)	1.55 (0.44)
Unattractive/ incorrect	0.59 (0.76)	0.10 (0.15)	1.49 (0.43)
Moderate/incorrect	0.28 (0.61)	0.05 (0.13)	1.53 (0.47)

To better understand the interaction effect, we conducted separate analyses for faces that were placed beside the correct/incorrect numbers. First, we looked at fixation to faces that were placed next to the correct numbers (see Fig. 5 and Table 2 for descriptive results). Results from a mixed-model analysis with subjects and face pairs specified as random factors revealed that attractive faces and unattractive faces equally attracted participants' eyes. Congruency had a significant effect on the number of fixations ($F(2, 1688) = 41$, $p < .001$), and a significant effect on fixation duration ($F(2,1688) = 30.75$, $p < .001$) on the correct face. Specifically, the number of fixations and fixation duration on either attractive (congruent trials) or unattractive faces (incongruent trials) were not different (number of fixations: $\beta = 0.002$, $SE = 0.06$, $t(1688) = 0.03$, $p = .98$; fixation duration: $\beta = 0.001$, $SE = 0.01$, $t(1688) = 0.11$, $p = .91$). Importantly, participants fixated more frequently and for longer duration on attractive faces compared to moderate faces (number of fixations: $\beta = 0.46$, $SE = 0.06$, $t(1688) = 7.55$, $p < .001$; fixation duration: $\beta = 0.09$, $SE = 0.01$, $t(1688) = 6.59$, $p < .001$); and also fixated more on unattractive faces compared to moderate faces (number of fixations: $\beta = 0.46$, $SE = 0.06$, $t(1688) = -7.89$, $p < .001$; fixation duration: $\beta = -0.09$, $SE = 0.01$, $t(1688) = -6.80$, $p < .001$).

For faces that were placed next to the incorrect answers (refer to Fig. 5 and Table 2 for descriptive results), results revealed a significant effect of congruency on the number of fixations ($F(2, 1688) = 61.71$, $p < .001$) and on fixation duration ($F(2, 1688) = 47.49$, $p < .001$). Participants fixated on attractive faces (i.e., incongruent trials) more

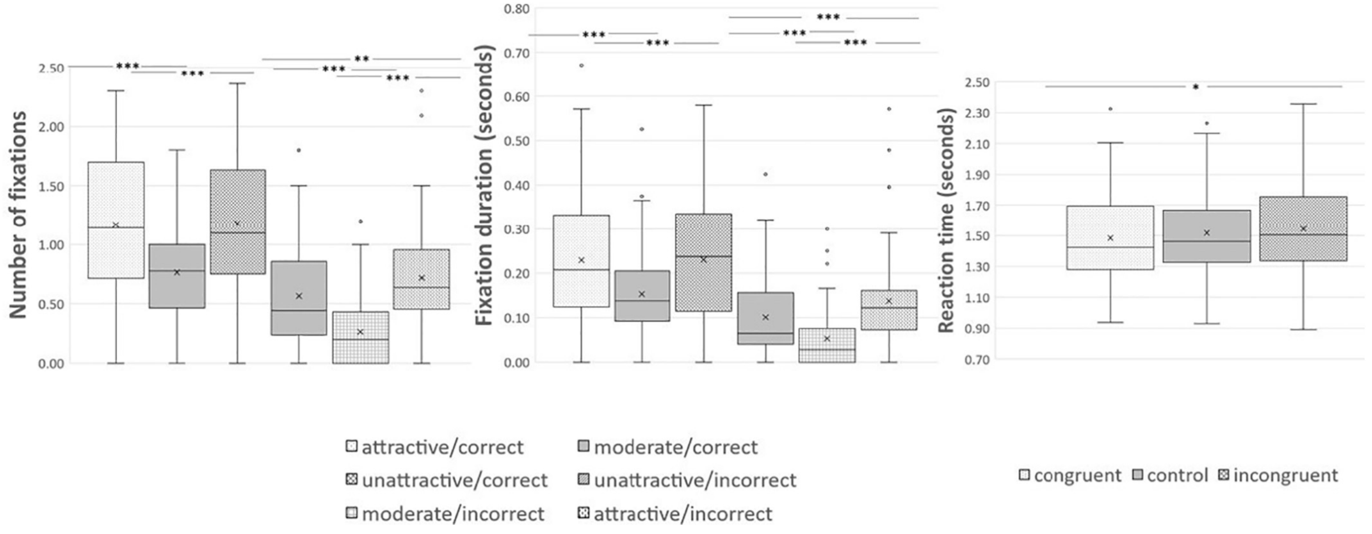

Fig. 5. Number of fixations and fixation duration to faces accompanying correct/incorrect number, and reaction time across congruent, control, and incongruent trials. $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$. Center lines denote the median values.

frequently and for longer duration compared to unattractive faces (i.e., congruent trials) (number of fixations: $\beta = -0.14$, $SE = 0.04$, $t(1688) = -3.15$, $p = .002$; fixation duration: $\beta = -0.04$, $SE = 0.01$, $t(1688) = -3.86$, $p < .001$). Moreover, both attractive and unattractive faces that accompanied the incorrect answer attracted participants' eyes more than moderate faces, indicated by the higher number of fixations (attractive vs. moderate faces: $\beta = 0.46$, $SE = 0.04$, $t(1688) = 10.84$, $p < .001$; unattractive vs. moderate faces: $\beta = 0.31$, $SE = 0.04$, $t(1688) = 7.12$, $p < .001$), as well as longer fixation duration (attractive vs. moderate faces: $\beta = 0.09$, $SE = 0.01$, $t(1688) = 9.70$, $p < .001$; unattractive vs. moderate faces: $\beta = 0.05$, $SE = 0.01$, $t(1688) = 5.31$, $p < .001$).

6.5.2. Reaction time

Participants spent longer time in incongruent trials compared to congruent trials ($\beta = -0.06$, $SE = 0.03$, $t(1688) = -2.1$, $p = .036$). There was no significant difference between control and incongruent trials ($p = .436$), and between congruent trials and control trials ($p = .16$) (Fig. 5).

6.6. Short discussion of eye-tracking experiment

Eye-tracking results showed that eye movement was driven by levels of facial attractiveness such that faces of high, low, and moderate attractiveness drew more eye movement in that order. Notably, participants spent more time on attractive and unattractive faces (i.e., “extreme faces”) more than on moderate faces, regardless of whether these faces were aligned with correct or incorrect number. The fact that attractive faces attracted attention away from the unattractive faces when they accompanied the incorrect answer provides evidence that a beauty attentional effect exists, similar to hand movement. However, even in this case greater attention was paid to both attractive and unattractive faces compared to moderate faces. This result is consistent with the neuroscience literature indicating that brain areas respond to both attractive and unattractive faces (e.g., Krendl et al., 2006; Winston et al., 2007).

We found that overall, in incongruent trials participants spent more time on the task (i.e., total reaction time) compared to congruent trials. This result is similar to mouse-tracking results, which was expected as reaction time measure (i.e., amount of time when participants clicked on the number) is an indicator of hand movement. This result is in line with previous research such that attractive faces are a distractor that slows down a cognitive task unrelated to attractiveness judgments (Sui & Liu, 2009).

7. General discussion

In two studies we show that attentionally driven hand movement and attentionally driven eye movement were responsive to facial attractiveness in different patterns. Both attractive and unattractive faces captured greater eye fixations compared to moderate faces, whereas attractive faces attracted hand movement more strongly than unattractive and moderate faces. These effects occurred when participants were engaged in a task unrelated to beauty. Our findings contribute to the literature by demonstrating that, at least in the domain of facial attractiveness, hand movement can be a meaningful additional measure of attention besides eye movement, such that the two types of movement reveal different effects. While overt attention can be understood by eye movement, hand movement is important particularly for understanding covert attention which occurs without eye shifts.

From a broad point of view, our methodological paradigm opens up significant directions for future research. The two process tracing methods we employed provide novel insights into otherwise opaque processes in judgment (Figner & Murphy, 2010) and allow us to capture dynamic changes in participants' attention (Schulte-Mecklenbeck, Kühberger, & Rob Ranyard, 2011). We highlight that the behavioral choice is an outcome of different signals and decision mechanisms made by an individual. Decision mechanisms are biased by whether eye or hand motor systems are involved. We show that these pathways play different roles in attention to movement, and thus are worthwhile to add as a variable of interest in attention research. Thus, our study offers evidence, and the tools, to go beyond the behavioral choice and explore preceding decision mechanisms.

The literature on embodied cognition emphasizes the importance of bodily responses in choice formation (Meier, Moeller, Riemer-Peltz, & Robinson, 2012; Meier, Schnall, Schwarz, & Bargh, 2012; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). Our studies suggest that in response to facial attractiveness, different motor systems prioritize different decision criteria; the same face stimuli are interpreted in dissimilar ways as evidenced by different motor-perceptual engagements. When an individual evaluates a face, multiple decision processes involving different decision and response criteria occur in parallel.

The underlying reason driving these differences between eye and hand movements needs further investigation. As we outlined in the introduction, hand movement seems to be driven by attraction (e.g., attraction to unhealthy snacks (Davis & Haws, 2017), initial attraction to the positive label for in-group members (Lazerus et al., 2016)). Our findings demonstrate the attraction towards beautiful faces. Eye movement, on the other hand, is not necessarily driven by attraction. Our results show that the eyes tend to fixate on faces on the extreme ends of the attractiveness spectrum.

It should be noted that there might be other possible interpretations of our results. While we interpret hand movement towards attractive faces as an attraction effect, another possible explanation for our results is social signalling. That is, moving towards attractive faces might be a way to intentionally express one's social interest and preferences, potentially signalling a desire for social engagement. Although a further investigation is certainly needed, it is possible that hand movement carries stronger social signalling as it is perceptually more obvious and could be more easily detected than eye movement. In the domain of facial attractiveness, this might involve signalling one's preference for attractive faces. From an evolutionary perspective, not only humans are attracted to beauty and need to detect it, they also need to express their preferences towards beauty. As attractiveness is an important cue in mate choice and sexual selection (Buss & Schmitt, 1993; Luxen & Van De Vijver, 2006), demonstrating one's preference towards attractive targets might be a way to convey one's interest. Thus, while an attraction effect demonstrates that an individual, without intention, is being drawn to attractive faces, social signalling entails intentionally conveying preference for them. A follow-up examination would be useful to further understand the mechanism of our effects.

We further contributed to the existing research on beauty and facial attractiveness. First, we add to the literature in attention to facial attractiveness which mostly compared attractive and unattractive faces, or attractive and average-looking faces alone. We examined the facial attractiveness at three different levels, attractive, moderate, and unattractive. Our results revealed that more extreme faces (i.e., both attractive and unattractive faces) capture greater visual, overt attention (i.e., indicated by eye movement) more than faces of moderate attractiveness. Thus, our results show an additional visual attentional bias towards unattractive faces compared to moderate faces, adding to the visual attentional bias towards attractive faces demonstrated in prior research (e.g., Guo et al., 2011; Maner et al., 2003; Valuch et al., 2015). Second, we show that “being moved” by beauty might not simply be a metaphor. Rather, beauty automatically engages hand movement. Third, we demonstrate that people are distracted by attractive faces even when doing so presents a cost (i.e., choosing the incorrect number in our study). Fourth, we show that eye and hand movements respond differently to beauty valuation. Specifically, compared to moderate faces, both attractive and unattractive faces capture greater attention driving eye movement, whereas attractive faces capture more attention driving hand movement compared to unattractive and moderate faces. Thus, beauty is not only in the eyes, but also in the hand, of the beholder.

7.1. Limitations

There are noteworthy limitations in the current research. First, due to technical constraints, we tested mouse movement and eye movement separately. As Spivey (2007) noted, eye movement often precedes and thus might influence mouse movement. It would be of interest if the two mechanisms were examined simultaneously. Second, our small sample size did not allow us to test the effect of gender (i.e., gender of the participant and gender of the face). We found an effect on an integrated level (collapsed gender). Future research however could follow up and examine the effect for each gender combination (i.e., women's attention to men's/women's faces or men's attention to women's/men's faces). As eye movement is driven by anomalous, deviant stimuli (Becker et al., 2007; Henderson et al., 1999), we speculate that our observation that more extreme faces (i.e., both attractive and unattractive faces) capture greater visual attention is likely to hold regardless of gender combination of stimulus and viewer. Hand movement, on the other hand, might follow different patterns depending on gender. For instance, as a woman's attractiveness is important to men (Li, Balley, Kenrick, & Linsenmeier, 2002; Shackelford, Schmitt, & Buss, 2005) whereas a man's status, intelligence, and resources are crucial to women (Buss & Schmitt, 1993; Sprecher, Sullivan, & Hatfield, 1994). The effect on hand movement might be stronger for men viewing attractive women's faces than for women viewing attractive men's faces. For same-sex participant/face stimulus, as women mostly compete on attractiveness, while men, on the other hand, compete mostly on status and intelligence (Luxen & Van De Vijver, 2006), the attraction effect of hand movement might be stronger for women/women (versus men/men) combination. Further, it is possible that women's hand movement towards other attractive women's faces is influenced by a competitive mechanism related to threat (Faust, Chatterjee, & Christopoulos, 2018).

Author contributions

All authors developed the study concept and study design. Natalie T. Faust collected the data; all authors analyzed the data and wrote the manuscript. All authors approved the final version of the manuscript for submission.

Open practices

Our research data files are available at https://osf.io/4mfxj/.

Data availability statement

The authors declare that the datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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