

# Investigating the Crossmodal Influence of Odour on the Visual Perception of Facial Attractiveness and Age

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## Abstract

We report two experiments designed to investigate whether the presentation of a range of pleasant fragrances, containing both floral and fruity notes, would modulate people's judgements of the facial attractiveness (Experiment 1) and age (Experiment 2) of a selection of typical female faces varying in age in the range 20–69 years. In Experiment 1, male participants rated the female faces as less attractive when presented with an unpleasant fragrance compared to clean air. The rated attractiveness of the female faces was lower when the participants rated the unpleasant odour as having a lower attractiveness and pleasantness, and a higher intensity. In Experiment 2, both male and female participants rated the age of female faces while presented with one of four pleasant fragrances or clean air as a control. Only the female participants demonstrated a crossmodal effect, with the pleasant fragrances inducing an older rating for female faces in the 40–49-years-old age range, whereas a younger rating was documented for female faces in the 60–69-years-old age range. Taken together, these results are consistent with the view that while the valence of fragrance (pleasant versus unpleasant) exerts a robust crossmodal influence over judgements of facial attractiveness, the effects of pleasant fragrance on judgements of a person's age appear to be less reliable. One possible explanation for the differing effect of scent in the two cases relates to the fact that attractiveness judgements are more subjective, hedonic, and/or intuitive than age ratings which are more objective, cognitive-mediated, and/or analytic in nature.

## Keywords

scent, face, crossmodal, age, attractiveness

## 1. Introduction

The last few years have seen a rapid growth of interest in the crossmodal modulatory effect of ambient odours on various aspects of human perception, especially those related to the visual perception of faces (see Spence, 2021; Syrjänen *et al.*, 2021, for reviews). One area of particular interest to researchers has been the hedonic modulations of facial attractiveness (e.g., Demattè *et al.*, 2007; Feng and Lei, 2022; Kirk-Smith and Booth, 1990; McGlone *et al.*, 2013) or likeability (Li *et al.*, 2007) induced by olfactory cues. For example, Demattè *et al.* demonstrated that young female participants rated the male faces that were briefly presented on a screen as significantly more attractive when they smelled a pleasant odour (geranium or a male fragrance, “Gravity” from Unilever Research) as compared to an unpleasant odour (synthetic male sweat odour or rubber, see also Damon *et al.*, 2021).

Li *et al.* (2007) similarly reported that the presentation of a pleasant compared to an unpleasant fragrance (lemon versus sweat, respectively) modulated ratings of facial likeability. Intriguingly, however, this crossmodal effect was only observed when the odours were presented at a subliminal level rather than at a suprathreshold level (cf. Demattè *et al.*, 2007). While the participants in both Demattè *et al.*’s and Li *et al.*’s studies had to detect the presence (versus absence) of the odours indicated by means of a key press before the onset of the face photo in each trial, a number of methodological differences make it hard to conclude whether people’s awareness regarding the presentation of fragrances was a critical factor. In sum, the results of these two studies provided some of the first convincing and complementary psychophysical evidence demonstrating that the presentation of olfactory cues can modulate human visual judgements on facial attractiveness. It should also be noted that when compared to the clean-air baseline condition, both studies demonstrated that the presence of the unpleasant odour appeared to lower the participants’ ratings of facial attractiveness rather than the pleasant odorant necessarily enhancing their rated attractiveness. This result echoed the participants’ pleasantness ratings demonstrating that clean air tended to be more pleasant than the unpleasant odours, but clean air was similar to the pleasant odours (Demattè *et al.*, 2007).

While facial attractiveness has been rated by participants in the majority of studies that have been published to date in the area, it is interesting to note how a variety of other judgements have been made concerning other personal qualities, such as gender (Kovács *et al.*, 2004), affect (Pause *et al.*, 2004; Walla, 2008), competence (Capparuccini *et al.*, 2010), and even intelligence (Marinova and Moss, 2014). However, when it comes to judgements of a person’s age based on viewing a static photo of his/her face, a perception which is suggested to involve a learned, analytic, higher-order cognitive mechanism

(Bzdok *et al.*, 2012; Chatterjee *et al.*, 2009; McGraw *et al.*, 1989; Seubert *et al.*, 2014), the literature concerning crossmodal olfactory modulations is far less clear (see Spence, 2021, for a recent review).

According to a patent application from Dr. Alan Hirsch (2006), an odorant or odorant mixture containing grapefruit (preferably pink grapefruit) effectively reduced age ratings of female faces by about 10%. The largest effect was when men rated women where a six-year age reduction was observed; by contrast, the grapefruit fragrance had no effect on women's ratings of the age of either male or female faces. Hirsch argued that smelling grapefruit odorant/odorant mixture reduced male anxiety and also elevated their sense of well-being, thus resulting in a positive view of the physical attributes of a woman, such as perceiving her to be younger than would have been the case had the fragrance not been presented. Hirsch also suggested that a familiar odorant may semantically prime thoughts of people of a given age, such as that one may associate lavender with older age if his/her grandmother often wore lavender. Taken together, these claims suggest that scent may exert both an indirect effect of mood induction and/or potentially a semantic priming effect if the fragrance is associated with people in particular ages.

Meanwhile, in the only peer-reviewed academic article that has assessed the effect of fragrance on both age and attractiveness of faces in the same experiment, Seubert *et al.* (2014) presented two faces sequentially on each trial with the first face as the standard while the second one had been morphed to show either 25% or 50% more or less wrinkles and blemishes. One of five fragrances varying parametrically between 100% rose scent (pleasant) and 100% fish odour (unpleasant) was presented preceding and overlapping with the presentation of the second face. The participants initially made a speeded two-alternative forced-choice (2AFC) judgement concerning whether the second face looked older or younger than the first, followed by one of the three memory-based tasks (i.e., after the offset of the second face) with equal probability: (1) attractiveness rating of the second face, (2) age rating of the second face, and (3) valence rating of the odour. In the latter memory-based ratings, as predicted, judgements of attractiveness were additively affected by the valence of the concurrently presented odour. By contrast, memory-based judgements of age were insensitive to the manipulations of wrinkles and blemishes when the *unpleasant* odorant was presented (see Note 1). Seubert *et al.* suggested that the presentation of the unpleasant odour may simply have captured the participant's attention, hence resulting in less attention being devoted to the more cognitively demanding age task rather than to the attractiveness task where the response is more intuitive.

Given the uncertainties in the literature that have been identified here, the primary aim of the two experiments reported in the present study was to extend the crossmodal study of olfaction's influence over human face perception. We

examined the olfactory influence of male raters on female facial attractiveness as complementary evidence to Demattè *et al.* (2007); in addition, we examined the reliability and sex differences in the olfactory modulations on age judgements of female faces (Hirsch, 2006; Seubert *et al.*, 2014). In particular, we investigated whether the presence of a fragrance would impact people's hedonic judgements of a person's attractiveness (Experiment 1), and thereafter putatively more cognitively demanding ratings of their age (Experiment 2).

## 2. Experiment 1: Male's Ratings of Female Attractiveness

In Experiment 1, a group of male participants rated the attractiveness of a series of briefly presented female faces selected to span a wide age range. The participants smelled either pleasant or unpleasant fragrances, or else clean air, during the presentation of the photos. Based on the research that has been published to date, our predictions were that: (1) on average, attractiveness ratings regarding the face shown in the photos should increase with the decreasing age of the individual in the photo; (2) participants would rate the faces as being more attractive when they were simultaneously exposed to the pleasant fragrances and/or clean air, as compared to when they were exposed to the unpleasant odour; and (3) we were also interested to see whether the olfactory modulation of facial attractiveness by pleasant versus unpleasant fragrance would differ as a function of the age of the face.

### 2.1. Methods

#### 2.1.1. Participants

Thirty-two male volunteers (ranging from 21 to 38 years, mean age 28 years) took part in our first study. All of the participants were informed of their rights in accordance with the ethical standards laid down in the 1990 Declaration of Helsinki and signed a written consent form. Each participant received £15 UK Sterling in return for taking part in the study. All of the participants were naïve as to the purpose of the study, and all had normal or corrected-to-normal vision. All of the participants completed a confidential questionnaire before they started the experiment in order to ensure that they also had a normal sense of smell and no history of olfactory dysfunction. The study was approved by the ethics committee at the University of Oxford (MSD/IDREC/C1/2011/7).

#### 2.1.2. Apparatus and Materials

The visual stimuli were presented on a 15-inch colour CRT monitor (75 Hz refresh rate). The participants sat at a viewing distance of 40 cm from the monitor in a well-lit experimental chamber. The fragrances were presented by means of a custom-built computer-controlled olfactometer. The flow rate of medical air through the olfactometer was set at 3 LPM using a flow regulator (CONCOA 03-054, Utrecht, The Netherlands) connected to the gas cylinder



**Figure 1.** Photo of the experimental setup used in the present study.

(Medical Air Size G, BOC Gas, Woking, Surrey, UK). The participants rested their chin on a chin-rest and the fragrances were delivered from a glass nose cone (093513, SGE Europe Ltd., Milton Keynes, UK) placed 1–2 cm in front of their nose (see Fig. 1).

A face database providing a large number of photos of typical Caucasian female faces presented against a neutral white background was used. When searching for an appropriate database of female faces the requirement was that the photos should include a full view of the individual's hair and the facial expression should be as neutral as possible. Eventually, 50 female photos were selected from the CVL Dallas Database (Minear and Park, 2004). Twenty participants (six males, mean age 28 years) took part in a pilot study to rate the age of the female faces shown in the photos. According to the results, ten photos were selected for each of five age groups (20–29, 30–39, 40–49, 50–59, 60–69 years old, see Table 1 for the pilot results). The female faces were presented at a size of  $22.2^\circ \times 17.0^\circ$  (width  $\times$  height) on the monitor during the course of the experiment.

Four pleasant fragrances provided by Takasago (Takasago Europe Perfumery Laboratory S.A.R.L., Paris, France) were used as the olfactory stimuli in this experiment (see Table 2): PC FLOR 004BS (A1), JJ FLO 167AE (A2),

**Table 1.**

Mean and standard deviation (in parentheses) of the rated age of the ten photos in each age group (in years) in the pilot study ( $N = 20$  participants). These results show that the participants rated the faces as being of the appropriate age

Age (years)	20–29	30–39	40–49	50–59	60–69
Mean (st. dev.)	25.0 (1.6)	35.3 (3.2)	44.9 (2.3)	55.8 (1.8)	65.1 (1.8)

**Table 2.**

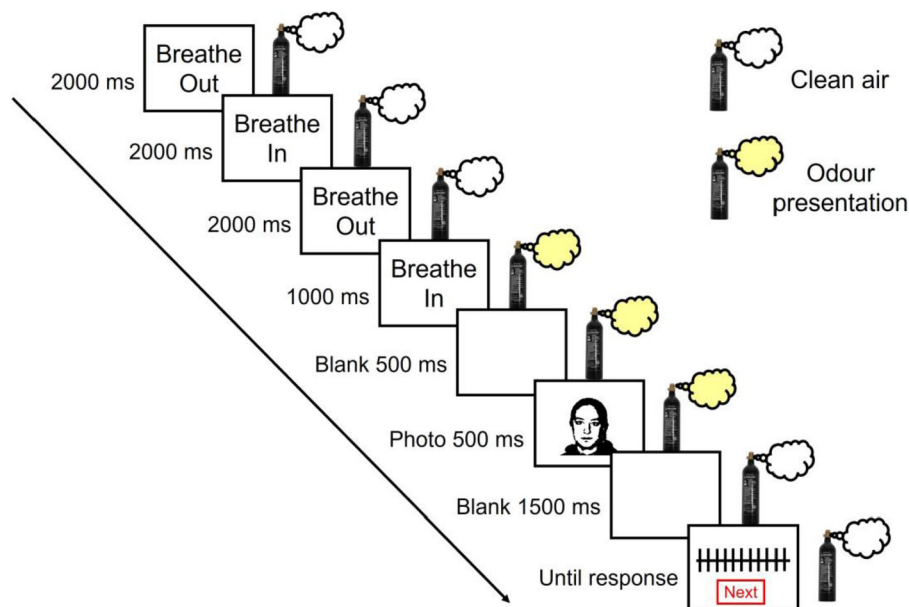
The four pleasant fragrances used in Experiment 1 in which the task was attractiveness rating

Fragrance	Scents	Characters			Similar product
		Sensual	Fresh	Fruity	
A1 PC FLOR 004BS	Lily of the valley	Low	No	No	Ralph Lauren, Blue
A2 JJ FLO 167AE	Oriental, floral, fruity	High	Low	Low	Dolce and Gabbana, The One (Female)
A3 RV 3539	Fruity, floral, chypre, musky	High	High	Medium	Chanel, Chance
A4 JJ FLO 292AF	Oriental, fruity, floral	High	High	High	Juicy Couture, Viva la Juicy

RV 3539 (A3), and JJ FLO 292AF (A4). These four fragrances were selected because they were distinct in terms of their degrees of sensual, fresh, and fruity characteristics. The unpleasant odour (UP) consisted of a mixture of 13 ml of chamomile oil (ICC 003058) and 7 ml of dipropylene glycol (DPG) as the solvent.

*2.1.3. Design and Procedure*

Two factors, odour (A1, A2, A3, A4, clean air, and UP) and age (20–29, 30–39, 40–49, 50–59 years old) of the female faces, were manipulated using a within-participants repeated-measures experimental design (Note 2). The six odour conditions presented with a given photo (i.e., 240 trials in total) were divided into six blocks of trials. The 40 photos were presented once in a completely randomized order in each block of trials. Note that it was not possible to balance the number of trials for each odour in a block perfectly, so six to seven of the photos were assigned to each of the six odour conditions in a block. The order in which the six blocks were presented was also randomized across participants. A block of trials took 10 minutes to complete. At the end of each block, the participants were instructed to take a 5-min break in order to avoid olfactory fatigue and/or adaptation.



**Figure 2.** The schematic procedure of a trial in Experiment 1. The photo was a color image of a female face adopted from the CVL Dallas Database (see text for details).

#### 2.1.4. Procedure

In the main experiment, the participants initiated a block of trials by pressing the Enter key on the keyboard placed in front of them. Figure 2 shows a schematic example of a trial sequence: Each trial started with an instruction to breathe out which lasted for 2000 ms. The onset of this period was accompanied by a 500 Hz tone which lasted for 200 ms; at the same time, clean air was delivered. Next, a breathe-in instruction (2000 ms) was presented, the onset of which was accompanied by a 1000 Hz tone presented for 200 ms. The breathe-out instruction frame (2000 ms) was presented again, followed by a breathe-in instruction frame lasting for 1000 ms. Subsequently, a blank frame (500 ms), the target photo (500 ms), and another blank frame (1500 ms) were presented. At the onset of the second breathe-in instruction frame, one of the five fragrances or clean air was delivered. The delivery of the olfactory stimulus was stopped at the offset of the photo. The participants had to indicate their rating of the attractiveness of the female displayed in each photo by clicking on the 10-point response scale anchored at either end with the labels “Less attractive” and “More attractive”. The participants then clicked “Next” in the frame to move on to the next trial.

Prior to starting the main experiment, the participants’ olfactory detectability to the fragrances used in the study was estimated in a pre-test. The participants had to follow the breathe-out (2000 ms) and breathe-in (5000 ms)

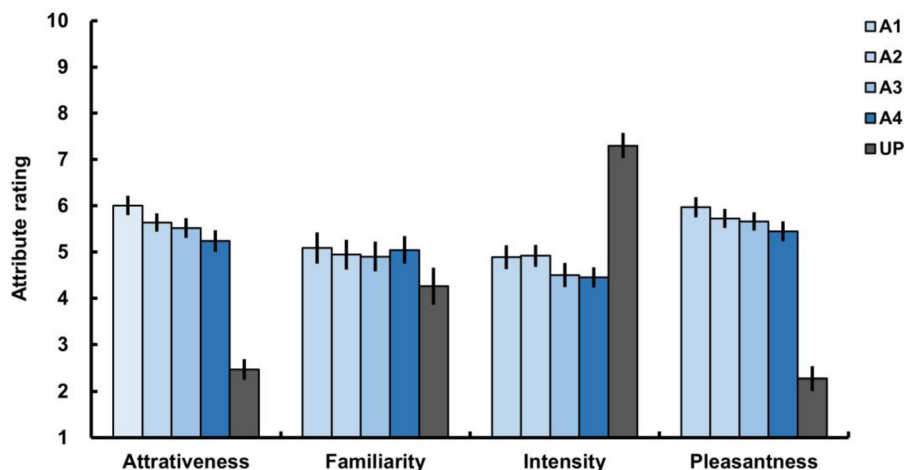
instructions. One of the five fragrances or else clean air was presented during the breathe-in frame. The participants were instructed to detect the presentation of any of the fragrances by pressing the Space bar on the keyboard. This olfactory detectability session consisted of five trials for each of the five fragrances. The data from these trials were used in order to estimate the participants' hit rate for the presence of the fragrance. Twenty-five trials of clean air were also presented in order to estimate the participants' false alarm (FA) rate. These 50 trials were presented in a completely randomized order. The participants' olfactory detectability to the fragrances was then estimated by calculating  $d'$  according to signal detection theory (Green and Swets, 1966; Macmillan and Creelman, 2005).

After the main experiment, the participants rated each of the five odorants in terms of four attributes (attractiveness, familiarity, intensity, and pleasantness). The participants followed the breathe-out and breathe-in instructions (twice, as in the main experiment), and then they viewed the four questions regarding each attribute sequentially. The attractiveness of the odour referred to whether the participant thought that a female wearing this odour would be attractive, while the familiarity, intensity, and pleasantness of the odour refers to whether the participant thought that the odour itself was familiar, intense, and pleasant or not, respectively. A 10-point rating scale was used, with 1 labelled as 'low' and 10 as 'high' for each attribute. There were five trials for each fragrance that participants had to rate, and the presentation order of these trials was randomized. The entire experiment (consisting of three sessions in total) took the participants approximately two hours to complete.

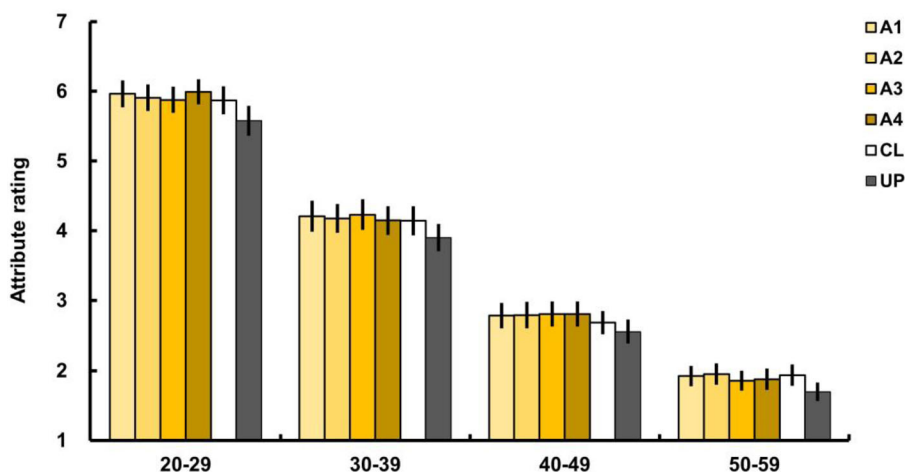
## 2.2. Results

The participants' mean olfactory detectability ( $d'$ ) of the presence of a fragrance (as compared to clean air) was 2.03 (SE = 0.13), which was significantly higher than threshold (compared to  $d' = 1$ ,  $t_{31} = 8.06$ ,  $p < 0.001$ , two-tailed) with neutral response tendency ( $c = -0.10$ , SE = 0.09,  $t_{31} = -1.19$ ,  $p = 0.24$ , two-tailed). The mean ratings of each attribute associated with each fragrance (see Fig. 3) were separately submitted to a one-way analysis of variance (ANOVA). The results of these analyses revealed that the participants' ratings of the attractiveness ( $F_{4,124} = 71.98$ ,  $p < 0.001$ ), intensity ( $F_{4,124} = 50.87$ ,  $p < 0.001$ ), and pleasantness ( $F_{4,124} = 75.39$ ,  $p < 0.001$ ) of the fragrances were significant. There was no main effect of familiarity ( $F_{4,124} = 1.94$ ,  $p = 0.11$ ). Post-hoc  $t$ -tests (with Bonferroni correction) revealed that A1, A2, A3, and A4 were all rated as more attractive than UP (all  $t_{31} > 9.21$ ,  $ps < 0.001$ ), and A1 was rated as more attractive than A3 and A4 (both  $t_{31} > 3.94$ ,  $ps < 0.005$ ). A1, A2, A3, and A4 were all rated as less intense than UP (all  $t_{31} < -7.94$ ,  $ps < 0.001$ ). Finally, A1, A2, A3, and





**Figure 3.** Mean attractiveness, familiarity, intensity, and pleasantness ratings for each of the five odorants used in Experiment 1 (maximum score = 10, which represents the highest level of each attribute). Error bars represent  $\pm 1$  SE of the mean. UP: unpleasant odour.



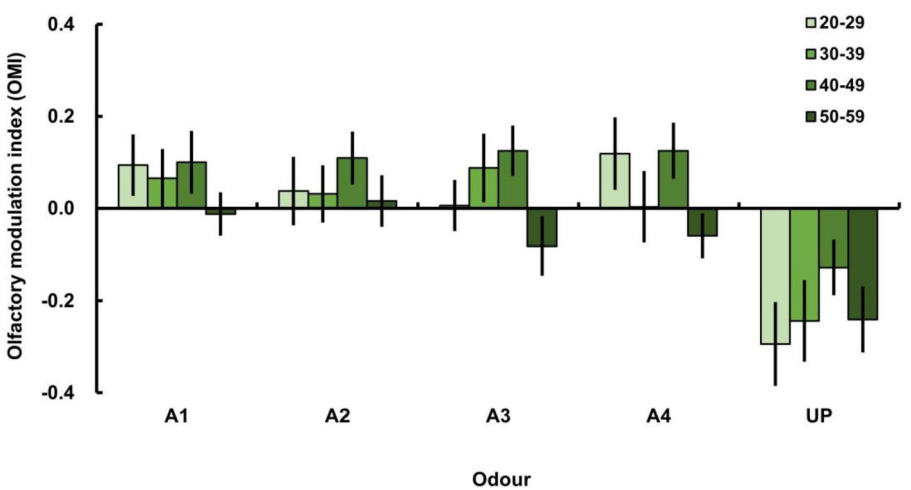
**Figure 4.** Mean attractiveness ratings (maximum score = 10) of the four age groups (in years) of female faces as a function of the various different odour conditions in Experiment 1. Error bars represent  $\pm 1$  SE of the mean. CL: clean air; UP: unpleasant odour.

A4 were all rated as more pleasant than UP (all  $t_{31} < 9.76$ ,  $ps < 0.001$ ) as expected, and A1 was rated as more pleasant than A4 ( $t_{31} = 3.08$ ,  $p = 0.04$ ).

The male participants' judgements of the attractiveness of the female faces shown in the photos (see Fig. 4) were submitted to a linear mixed-effects model using odour and age as fixed effects, and participants and faces as random effects using the *lme4* package (version 1.1-28, Bates *et al.*, 2022)

in R (version 4.0.2) (Note 3). The analysis revealed a significant effect of age [ $\beta = -0.13$ , 95% confidence interval, CI = (0.15,  $-0.11$ )], suggesting that the facial attractiveness was rated lower as the age of face increased. In addition, the presentation of unpleasant odour significantly reduced the participants' attractiveness ratings as compared to clean air [ $\beta = -0.32$ , 95% CI = ( $-0.61$ ,  $-0.03$ )]; however, the presentation of the four pleasant odours did not modulate facial attractiveness judgements as compared to clean air [A1:  $\beta = 0.16$ , 95% CI = ( $-0.13$ , 0.45); A2:  $\beta = 0.04$ , 95% CI = ( $-0.25$ , 0.33); A3:  $\beta = 0.11$ , 95% CI = ( $-0.18$ , 0.40); A4:  $\beta = 0.19$ , 95% CI = ( $-0.10$ , 0.48)] (Note 4). Hence, the modulation of odours on facial attractiveness was mainly attributed to the reduced attractiveness by unpleasant odour (Demattè *et al.*, 2007; Li *et al.*, 2007). Such an olfactory effect was similar in each age group (i.e., no interaction between age and any odour was reported).

In order to better understand the crossmodal olfactory modulation of female facial attractiveness that resulted from the presentation of each odour across age groups, an olfactory modulation index (OMI) was calculated for each participant: The mean attractiveness rating in the condition in which the clean air was presented was subtracted from that reported when a fragrance was presented (see Fig. 5). Positive values therefore indicate that the participants rated the faces as being more attractive, while negative values indicate that they



**Figure 5.** Mean crossmodal modulation by the presentation of fragrances as compared to clean air in Experiment 1. The olfactory modulation index (OMI) was calculated by subtracting the attractiveness rating when only clean air was presented from those conditions in which a fragrance was presented individually. Hence, positive values indicate the participants rated the faces as being more attractive, while negative values indicate that they rated the faces as being less attractive when smelling a fragrance as compared to when clean air was presented instead. Error bars represent  $\pm 1$  SE of the mean.

rated the faces as being less attractive when smelling a fragrance as compared to when clean air was presented instead. The OMI in each condition for each participant was then submitted to a linear mixed-effects model using odour and age as fixed effects, and participants and faces as random effects using the *lme4* package in R (Note 5). The results demonstrated that, compared to unpleasant odour, all four pleasant fragrances enhanced facial attractiveness [A1:  $\beta = 0.48$ , 95% CI = (0.25, 0.72); A2:  $\beta = 0.37$ , 95% CI = (0.13, 0.60); A3:  $\beta = 0.44$ , 95% CI = (0.20, 0.67); A4:  $\beta = 0.51$ , 95% CI = (0.28, 0.75)], as expected. We then further examined whether the presentation of each fragrance was significantly effective in a particular age group (now the age was taken as a categorical factor since the age effect may not be linear, see Fig. 5). Compared to the 50–59 age group, A4 presented with the 20–29 age group [ $\beta = 0.18$ , 95% CI = (0.01, 0.34)], and A3 [ $\beta = 0.21$ , 95% CI = (0.02, 0.39)], A4 [ $\beta = 0.18$ , 95% CI = (0.02, 0.35)], and unpleasant odour [ $\beta = 0.14$ , 95% CI = (0.006, 0.28)] presented with the 40–49 age group, enhanced facial attractiveness. Note that these differences may be explained in terms of the A3, A4, and the unpleasant odour making the female faces in the 50–59 age group less attractive (as compared to clean air) while making the female faces of other ages somewhat more attractive.

In order to understand whether the crossmodal modulation of female facial attractiveness by olfaction for each participant was related to their ratings regarding the four attributes of each odour, correlations between the OMI (different age groups were collapsed first) and the attribute ratings were conducted (see Table 3). The results of these analyses revealed significant correlations only in the UP condition; in particular, positive correlations were observed between the OMI and attractiveness ratings, and between the OMI and pleasantness ratings, while a negative correlation was observed between the OMI and intensity ratings in the UP condition. These correlations therefore indicate that when a given participant rated the UP odour as less attractive, or less pleasant, he also tended to rate the female face as less attractive when it was presented with the UP odour as compared to when it was presented with clean

**Table 3.**

The correlations between the OMI (age group collapsed) and the attributes ratings of the each odour in Experiment 1 (\*:  $p < 0.05$ )

Odour	Attractiveness	Familiarity	Intensity	Pleasantness
A1	0.02	−0.19	0.21	−0.11
A2	−0.03	−0.08	−0.06	0.04
A3	−0.004	−0.14	−0.06	−0.04
A4	−0.22	−0.02	−0.03	−0.27
UP	0.44*	0.02	−0.43*	0.44*

air. At the same time, however, when a given participant rated the UP odour as more intense, he also tended to rate the female face as less attractive as well.

### 2.3. Discussion

The results in Experiment 1 revealed that the presentation of an unpleasant odorant (chamomile in this study) to male participants reduced the rated attractiveness of the female faces as compared to the presentation of clean air. Furthermore, the results of the analysis of the OMI revealed some subtle differences in the crossmodal influence of the pleasant fragrance: fragrances A3, A4, and the unpleasant odorant tended to increase the attractiveness of the females aged 40–49 years as compared to those who were above 50 years of age. Finally, only the OMI in the unpleasant odour condition was correlated with the participants' ratings of the attractiveness, intensity, and pleasantness of the unpleasant odour.

In summary, the results of Experiment 1 successfully demonstrated a cross-modal olfactory modulation of female facial attractiveness in a group of male participants. These results therefore provide complementary evidence to the findings reported previously in Demattè *et al.*'s (2007) study in which an olfactory modulation of male facial attractiveness was demonstrated amongst a group of female participants (see also McGlone *et al.*, 2013, for similar results). The results of Experiment 1 clearly replicated the effect when male participants rated female facial attractiveness whilst also showing that it generalizes to a range of pleasant/unpleasant fragrances, and across faces of different ages (ranging from 20 to 59 years of age). Intriguingly, just as in the earlier studies of Demattè *et al.* (2007) and Li *et al.* (2007), there was not really any significant positive olfactory modulation resulting from the presentation of the pleasant odours when compared to the clean-air baseline condition. Taken together, then, the present results reveal that if a male observer perceives an unpleasant odour, it will likely reduce the perceived attractiveness of any female that he happens to be looking at. Furthermore, any reduction of attractiveness in the presence of an unpleasant odour appears to be more pronounced when the odour itself is subjectively rated as more unattractive, more unpleasant, and/or more intense.

Having demonstrated the robustness of the impact of unpleasant odours on ratings of the attractiveness of female faces by men, we went on, in Experiment 2, to investigate whether the presence of a pleasant fragrance (putatively associated with someone who was either younger or older) would affect the rated age of the same set of female faces. However, this time, we decided to test both male and female participants, given Hirsch's (2006) suggestion that the effects of fragrance on age judgements concerning female faces might differ between male and female observers.

### 3. Experiment 2: Male and Female Ratings of Female Age

In Experiment 2, we investigated whether presenting olfactory cues that were supposed to be associated with people of different ages would modulate people's judgements regarding the age of the same database of female faces. As noted earlier, the evidence is far more ambiguous as to whether age-related (as opposed to attractiveness) judgements are similarly influenced by the presence of ambient odours. The participants in this experiment rated the photos of women in terms of their age. While doing this, they could be presented with one of four different fragrances, or else with clean air as a baseline control condition. Our question was whether the participants might rate the faces as looking younger when they smelled the putatively 'younger' fragrances, while rating the faces as looking older when they smelled the putatively 'older' fragrances instead. Given Hirsch's (2006) earlier suggestion that crossmodal effects on age judgements might differ between males and females, we decided to test both sexes in Experiment 2. Nevertheless, we used the same complete set of validated face stimuli established for Experiment 1, this time spanning the entire range from 20 to 69 years of age, as recommended by Seubert *et al.* (2014). Most of the details in this experiment were the same as in Experiment 1, and exceptions are detailed below.

#### 3.1. Methods

##### 3.1.1. Participants

A total of 32 volunteers (15 males, ranging from 30 to 44 years, mean age 36 years, and 17 females, ranging from 29 to 50 years, mean age 38 years) took part in Experiment 2.

##### 3.1.2. Apparatus and Materials

The photos of five age groups (20–29, 30–39, 40–49, 50–59, and 60–69 years old), including the same photos of four younger groups used in Experiment 1, were used as visual stimuli. Four fragrances provided by Takasago were used as the olfactory stimuli (see Table 4). These fragrances were selected because, according to internal research from Takasago, two of them were associated with a woman of an older age (O1: JJ FLO 163W; O2: FJ FT 18001) than the other two fragrances (Y1: IF FRUI 14G; Y2: FJ FLO 024). Both O1 and O2 were characterized as relatively heavy with an obvious oriental and opulent aspect, typically more associated with an older age group; in contrast, both Y1 and Y2 can be characterized as lighter with an obvious fruity aspect, which were targeted at a younger age group who tend to prefer the fruity characters.

##### 3.1.3. Design and Procedure

Three factors, odour (O1, O2, Y1, Y2, and clean air), age (20–29, 30–39, 40–49, 50–59, 60–69 years), and sex (female or male participants) were manipulated in this study, with the former two factors as within-participant

**Table 4.**  
The four fragrances used in Experiment 2 in which the task was age rating

Fragrance	Scents	Characters				Similar product
		Intensity	Oriental	Opulent	Fruity	
O1 JJ FLO 163W	Floral, fruity, powdery	Heavy	High	High	No	Guerlain, Insolence
O2 FJ FT 18001	Chypre, floral, fruity	Heavy	High	High	No	Chanel, Coco Mademoiselle
Y1 IF FRUI 14G	Fruity, fruity, pineapple	Light	No	No	High	Escada, Miami Blossom
Y2 FJ FLO 024	Floral, fruity, rose	Light	No	No	High	Chloé (2008)

repeated measures while the last one was a between-participant factor. The participants’ olfactory detectability with respect to the fragrances was tested before starting the main experiment. This olfactory detectability session consisted of five trials for each of the four odorants. The data from these trials were used in order to estimate the participants’ hit rate for the presence of the fragrances. Twenty additional trials with clean air were presented in order to estimate the participants’ FA rate. These 40 trials were then presented in a completely randomized order.

Five blocks of trials were presented in the main experiment. The five odour conditions presented with a given photo (i.e., 250 trials in total) were assigned to each of the five blocks of trials. All 50 photos were presented once in each block of trials, and a fifth of the photos were assigned to each of the five odour conditions. The 50 photos were presented in a completely randomized order within each block of experimental trials. The order in which the five blocks of trials were presented was randomized across participants. A horizontal scale ranging from 15 to 75 years of age, and increasing in units of one year, was then presented in the middle of the monitor until the participants responded. The participants had to rate the age of the female displayed in each photo by clicking the age on the response scale. A grey bar then displayed the actual age that the participants had chosen. The participants were allowed to change their mind by clicking on the scale corresponding to another age if they desired. The participants then clicked ‘Next’ in the frame to move on to the next trial.

After the main experiment, the participants rated the ages associated with each of the four fragrances. The participants still followed the breathe-out and breathe-in instructions (twice, as in the main experiment), and then they viewed the age scale for making their rating. One of the four fragrances was delivered at the onset of the second breathe-in instruction and stopped after

**Table 5.**

Mean and standard error of mean (in parentheses) of the rated age (in years) of the four fragrances used in Experiment 2

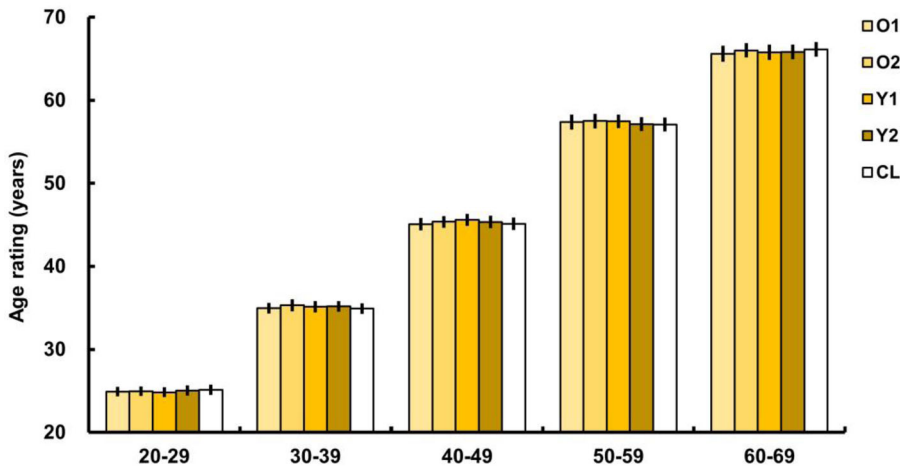
	O1 JJ FLO 163W	O2 FJ FT 18001	Y1 IF FRUI 14G	Y2 FJ FLO 024
Mean (SE)	39.8 (1.4)	37.9 (1.5)	38.5 (1.5)	38.6 (1.6)

the participants responded. There were five trials for each fragrance that participants had to rate, and the presentation order of these trials was randomized. The whole experiment (consisting of the three sessions) took a participant approximately two hours to complete.

### 3.2. Results

The participants' mean olfactory detectability ( $d'$ ) of the presence of any one of the fragrances (as compared to the clean air) was 1.43 (SE = 0.15), which was significantly higher than threshold ( $d' = 1$ ,  $t_{31} = 2.94$ ,  $p = 0.006$ , two-tailed), while they adopted a slightly reserved criterion ( $c = 0.24$ , SE = 0.09,  $t_{31} = 2.82$ ,  $p = 0.008$ , two-tailed). One unexpected result to emerge from this study was that the mean ratings of the ages associated with each fragrance turned out not to differ (see Table 5). Indeed, when the mean ratings were submitted to a one-way ANOVA, there was no difference in the age associated with any of the four fragrances ( $F_{3,93} = 0.51$ ,  $p = 0.68$ ). Contrary to expectation, the participants judged all four fragrances as being appropriate for a woman of about the same age (i.e., between 37 and 40 years of age). This contrasts with the suggestion from Takasago, who provided the fragrances for use in the study.

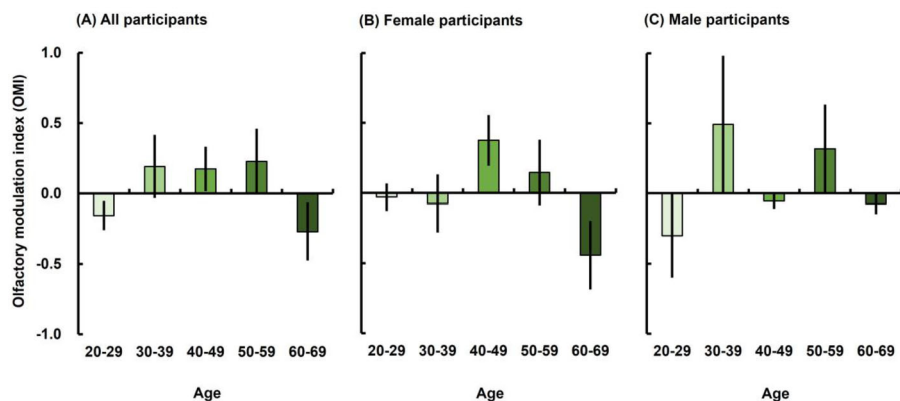
Participants' judgements of the age of the females shown in the photos (see Fig. 6) were submitted to a linear mixed-effects model using odour, age, and sex as fixed effects, and participants and faces as random effects (Note 6). The analysis revealed a significant predictability of age [ $\beta = 1.08$ , 95% CI = (1.03, 1.14)], suggesting that the rated age did increase with the age of faces. The factor of sex also demonstrated a significant difference in that females compared to male participants tended to rate the faces older [ $\beta = 3.00$ , 95% CI = (0.29, 5.72)]. Critically, age and sex interactively modulated the performance of facial age judgements [ $\beta = -0.09$ , 95% CI = (-0.13, -0.05)]. It should be noted, however, that none of the odour significantly modulated the rated age of faces as compared to clean air [O1:  $\beta = 0.08$ , 95% CI = (-1.48, 1.64); O2:  $\beta = 0.13$ , 95% CI = (-1.43, 1.70); Y1:  $\beta = 0.21$ , 95% CI = (-1.35, 1.77); Y2:  $\beta = 0.76$ , 95% CI = (-0.80, 2.32)], nor was any level of modulations between odour and age and/or sex (i.e., all 95% CIs of  $\beta$  covered 0).



**Figure 6.** Mean age ratings (in years) of the five age groups of female faces in the different odour conditions in Experiment 2. Error bars represent  $\pm 1$  SE of the mean. CL: clean air.

Calculating the OMI allowed us to better estimate the modulation by the fragrances of participants’ judgements of female facial age as compared to the baseline clean-air condition. Positive values indicate that the participants rated the faces as being older, while negative values indicate that they rated the faces as younger when smelling a fragrance as compared to when clean air was presented instead. Given that there were no obvious differences between the effects elicited by the four fragrances when compared to clean air in the previous analysis, the odour factor was then collapsed in our subsequent analysis in order to increase statistical power (Note 7). The OMI values were then submitted to a linear mixed-effects model using age and sex as fixed effects, and participants and faces as random effects, where the age was taken as a categorical factor (the 60–69 age group as the baseline) since the age effect may not be linear (see Fig. 7A). The results demonstrated that the presentation of fragrances significantly increased the rated age in the 40–49 as compared to the 60–69 age group [ $\beta = 1.02$ , 95% CI = (0.26, 1.78)], and this effect was also modulated by participants’ sex [ $\beta = -1.00$ , 95% CI = (–1.87, –0.13)]. Further analysis which decomposed participants’ sex demonstrated that such olfactory modulation of older ratings of the 40–49 as compared to the 60–69 age groups was only significant in female participants [ $\beta = 1.02$ , 95% CI = (0.08, 1.97), see Fig. 7B] rather than in male participants [ $\beta = 0.02$ , 95% CI = (–0.89, 0.93), see Fig. 7C].





**Figure 7.** Modulation of age judgements of female faces (in years) by the presentation of a pleasant fragrance as compared to clean air in Experiment 2. The olfactory modulation index (OMI) was calculated by subtracting the mean age rating in the condition in which the clean air was presented from that seen when a fragrance was presented. Positive values indicate that the participants rated the faces as being older, while negative values indicate that they rated the faces as being younger when smelling a fragrance as compared to when clean air was presented. Error bars represent  $\pm 1$  SE of the mean.

### 3.3. Discussion

The results of Experiment 2 demonstrated that the participants rated the ages of the females depicted in the photos in good agreement with the results highlighted in our pilot study (see Table 1). The difference lies in the fact that the participants only viewed the photos for 500 ms in Experiment 2, while those in the pilot study viewed them until they responded. Hence, people appeared to correctly judge a female's age even when only presented briefly (cf. Greene and Oliva, 2009). Given the high precision of our participants in rating the ages of the females shown in a photo, information provided by the other senses, such as fragrances may be less likely to modulate their age judgements. This result is consistent with the 'modality precision hypothesis' which states that the sense having more reliable information would be dominant in multisensory interactions (Alais and Burr, 2004; Ernst and Banks, 2002; Welch and Warren, 1980). One prediction here is therefore that if the participants' task were to be made harder (e.g., if the faces were briefly presented and then masked), then olfactory cues might induce a larger effect on their age ratings of faces (see Fink and Matts, 2008, for the results of a study of the factors modulating judgements of female age).

Crucially, however, the participants in Experiment 2 did not agree with the ages associated with four fragrances (as had been suggested by Takasago). That is, our participants rated all four fragrances as being likely to be associated with a woman of 37–40 years of age (see Table 5). This may therefore

have reduced the likelihood of our observing any age modulation resulting from the presentation of a specific fragrance. It remains an open question as to why the participants tested in Experiment 2 did not associate the different fragrances supplied by Takasago with women in different age groups. One possibility is that the associated age of a given fragrance might be dominated by its packaging or any other relevant marketing material, rather than solely by the sensory properties of the odorant itself.

On the other hand, if one considers only the difference in participants' ratings in the conditions where a fragrance was presented and where no fragrance (clean air) was presented (i.e., the OMI), it can be seen that our participants demonstrated a contrast between 40–49-year-old and the 60–69-year-old females — the former were rated to be older whereas the latter, to be younger. Critically, this result mainly came from the ratings of female rather than male participants, contrasting with Hirsch's (2006) report suggesting that males were more susceptible to fragrances (specifically, pink grapefruit) than females when rating the age of female faces. These observations would certainly be worthy of additional testing of more types of scents on both sexes in future research.

Nevertheless, it is perhaps worth noting that such olfactory modulation of facial age was quite small (i.e., less than one year change in the mean rated age of the faces, and hence presumably of little practical significance). In future research using this paradigm, according to Hirsch (2006), it would therefore be worthwhile using fragrances that are clearly associated with particular ages. So, for example, heliotropin, which provides the smell of Johnson and Johnson's baby powder, might elicit an association of very young age (i.e., a baby) or remind observers of the time/age when they were themselves using the product. It might also be interesting to investigate the interactions between fragrances and natural body odours that are associated with people of differing ages (e.g., Mitro *et al.*, 2012). Alternatively, Hirsch also suggested that the mechanism behind pleasant scent's influence on age ratings is mediated by its effect on the rater's mood. However, our results did not demonstrate a general reduction of age judgements when smelling pleasant fragrances as compared to clean air. That is, the trial-by-trial approach to scent delivery used in the present study would presumably have been unlikely to induce such a mood effect. Hirsch himself suggested that the fragrances should be smelled for at least 20 s in order to maximize the olfactory effect on age ratings. This statement seems to limit the relevance of the underlying crossmodal effect when age judgement was completed within the first half-minute glance (the result reported in Experiment 2).

#### 4. General Discussion

Two experiments were conducted in order to investigate the crossmodal olfactory modulation of people's perception of female faces that were displayed briefly on a computer screen. In Experiment 1, an olfactory modulation of the attractiveness was demonstrated when males judged female faces. Specifically, the olfactory modulation mainly came from the reduced facial attractiveness induced by the presentation of an unpleasant odorant (chamomile), while no enhanced attractiveness was observed in response to the presentation of pleasant fragrances (Demattè *et al.*, 2007; Li *et al.*, 2007). These results are entirely consistent with the olfactory effects when females judge male faces (Demattè *et al.*, 2007; McGlone *et al.*, 2013; see also Herz and Cahill, 1997). Further analysis in terms of the OMI measure revealed that certain odours (A3, A4, and chamomile) likely increased the attractiveness of women's faces in the 40–49 age group compared to those older than 50 years of age. In Experiment 2, an olfactory modulation of the age of female faces was assessed. There was no significant olfactory modulation of the fragrances used here. Nevertheless, the presentation of the fragrances did appear to exert a younger age rating only of *female* participants on females in the 60–69 age group compared to the 40–49 age group.

Taken together, the results of the two experiments reported here are consistent with those of Seubert *et al.* (2014) who also documented a crossmodal olfactory effect on attractiveness judgement, and a less reliable olfactory modulation of age judgements. It is worth considering the underlying difference in the visual attractiveness versus age judgements: attractiveness judgements can be thought of as reflecting a *hedonic* (i.e., more subjective) response to faces, whereas age judgements presumably involve a rating of the *sensory-discriminative* (i.e., more objective featural) attributes of a face (McGlone *et al.*, 2013; Seubert *et al.*, 2014). If the olfactory modulation of visual facial judgements were to be mediated by any changes in the viewer's affect or mood, then any crossmodal effects should be more apparent when using a relevant measure (such as the attractiveness or likeability of faces, Demattè *et al.*, 2007; Li *et al.*, 2007; McGlone *et al.*, 2013), rather than necessarily in sensory-discriminative measures (Experiment 2; cf. Risso *et al.*, 2021). Accordingly, it is plausible that the presentation of pleasant fragrances may improve the observers' mood and, in turn, increase the favourable impression of the person associated with this pleasant odour (see Hirsch, 2006). Note, though, that this account does not help to explain why pleasant fragrances elicited subtly different olfactory effects on different age groups in Experiment 2.

One limitation worth considering here relates to the fact that pictures shown on a computer screen do not normally smell. Hence, it is, in a very real sense, quite remarkable that so many crossmodal studies that have been published in

the literature over the years should have documented such a robust effect (see comments in Spence, 2021). At the same time, however, there are a number of important differences from real-life multisensory experience that should also be kept in mind. These include everything from the fact that people's faces tend to be dynamic in real-life interaction rather than static. Indeed, the research using morphing faces suggests that scent may have less impact (see Novak *et al.*, 2015; Roberts *et al.*, 2009; Syrjänen *et al.*, 2017). Furthermore, in real life, we typically see people before we get close enough to smell them (or their fragrance), while the onset of the odours typically precedes the onset of the face photos in the majority of the laboratory research (see Spence, 2021, on this point). Finally, many of the people we meet are familiar to us, whereas it is rare to rate the attractiveness of strangers' faces on screen. Our impression of those whom we already know, or are familiar with, is presumably less likely to be influenced by the presence of a scent than is our impression of a stranger.

Another consideration to highlight is the fact that all the faces used here were Caucasian. The relative absence of research using faces of other races has recently been emphasized as an important lacuna in the literature on face perception (Barratt, 2021; Cook and Over, 2021). Note, however, that our choice of stimuli was constrained by the available databases which are themselves biased. Addressing this issue also represents an important topic on cultural differences of sensory preferences and beauty.

In future research it will be interesting to assess the extent to which the laboratory-based crossmodal effects of olfaction on visual ratings of attractiveness, age, or any other attribute, be it of others or of the self, extend to the typical situations of everyday life (Kirk-Smith and Booth, 1987; Roberts *et al.*, 2009; Sczesny and Stahlberg, 2002). Bridging the wide gap between well-controlled laboratory studies and the real world is certainly critical, one the one hand, to demonstrate the results are ecologically valid, and, on the other hand, to contribute to practitioners and knowledge users.

### Conflict of Interest Statement

The experiments reported here were funded by contract research grants from Takasago. The authors confirm that the company had no involvement in the writing or analysis of this study. Takasago did, however, provide all of the fragrances that were presented to participants.

### Notes

1. As is typical for all of the studies that have been published on the cross-modal olfactory modulation of visual facial attributes, Seubert *et al.* (2014) make no mention of their participants being told anything about the link

between the odorants that they had been presented with and the visual stimuli that they were expected to evaluate.

2. The oldest group of faces (those aged 60–69 years) were not used in Experiment 1 in order to help prevent the experiment from becoming too long.
3. The fitting model was  $\text{lmer}(\text{ratedAttractiveness} \sim 1 + \text{Age} * \text{Odour} + (1|\text{ID}) + (1|\text{Face}))$ . The factor of Odour was categorical where the clean air was set as the baseline condition.
4. The crossmodal olfactory modulation effect of visual face attractiveness was confirmed by comparing each of the pleasant odours to the unpleasant odour: A1:  $\beta = 0.48$ , 95% CI = [0.19, 0.77]; A2:  $\beta = 0.37$ , 95% CI = [0.08, 0.66]; A3:  $\beta = 0.44$ , 95% CI = [0.15, 0.73]; A4:  $\beta = 0.51$ , 95% CI = [0.22, 0.80].
5. The fitting model was  $\text{lmer}(\text{OMI} \sim 1 + \text{Age} * \text{Odour} + (1|\text{ID}) + (1|\text{Face}))$ . The factor of Odour was categorical where the unpleasant odour was set as the baseline condition.
6. The fitting model was  $\text{lmer}(\text{ratedAge} \sim 1 + \text{Age} * \text{Odour} * \text{Sex} + (1|\text{ID}) + (1|\text{Face}))$ . The factor of Odour was categorical where the clean air was set as the baseline condition.
7. We compared two models either including the Odour factor or not (Model 1:  $\text{OMI} \sim 1 + \text{Age} * \text{Sex} + (1|\text{ID}) + (1|\text{Face})$ ; Model 2:  $\text{OMI} \sim 1 + \text{Age} * \text{Sex} * \text{Odour} + (1|\text{ID}) + (1|\text{Face})$ ), and the results demonstrated that the two models explained the participants' age judgements similarly ( $X^2(30) = 8.00$ ,  $p > 0.99$ ). We therefore reported the results of Model 1.

## References

- Alais, D. and Burr, D. (2004). The ventriloquist effect results from near-optimal bimodal integration, *Curr. Biol.* **14**, 257–262. DOI:10.1016/j.cub.2004.01.029.
- Barratt, E. L. (2021). Face stimuli in psychology are often all white. That needs to change, *The BPS Newsletter*, 22 October. Available at <https://digest.bps.org.uk/2021/10/22/face-stimuli-in-psychology-are-often-all-white-that-needs-to-change/>.
- Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., Dai, B., Scheipl, F., Grothendieck, G., Green, P., Fox, J., Bauer, A. and Krivitsky, P. (2022). Linear mixed-effects models using 'Eigen' and S4. Available from <https://CRAN.R-project.org/package=lme4>.
- Bzdok, D., Langner, R., Hoffstaedter, F., Turetsky, B. I., Zilles, K. and Eickhoff, S. B. (2012). The modular neuroarchitecture of social judgments on faces, *Cereb. Cortex* **22**, 951–961. DOI:10.1093/cercor/bhr166.

- Capparuccini, O., Berrie, C. P. and Mazzatenta, A. (2010). The potential hedonic role of olfaction in sexual selection and its dominance in visual cross-modal interactions, *Perception* **39**, 1322–1329. DOI:10.1068/p6736.
- Chatterjee, A., Thomas, A., Smith, S. E. and Aguirre, G. K. (2009). The neural response to facial attractiveness, *Neuropsychology* **23**, 135–143. DOI:10.1037/a0014430.
- Cook, R. and Over, H. (2021). Why is the literature on first impressions so focused on white faces?, *R. Soc. Open Sci.* **8**, 211146. DOI:10.1098/rsos.211146.
- Damon, F., Mezrai, N., Magnier, L., Leleu, A., Durand, K. and Schaal, B. (2021). Olfaction in the multisensory processing of faces: a narrative review of the influence of human body odors, *Front. Psychol.* **12**, 750944. DOI:10.3389/fpsyg.2021.750944.
- Demattè, M. L., Österbauer, R. and Spence, C. (2007). Olfactory cues modulate judgments of facial attractiveness, *Chem. Senses* **32**, 603–610. DOI:10.1093/chemse/bjm030.
- Ernst, M. O. and Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion, *Nature* **415**, 429–433. DOI:10.1038/415429a.
- Feng, G. and Lei, J. (2022). The effect of odor valence on facial attractiveness judgment: A preliminary experiment, *Brain Sci.* **12**, 665. DOI:10.3390/brainsci12050665.
- Fink, B. and Matts, P. J. (2008). The effects of skin colour distribution and topography cues on the perception of female facial age and health, *J. Eur. Acad. Dermatol. Venereol.* **22**, 493–498. DOI:10.1111/j.1468-3083.2007.02512.x.
- Green, D. M. and Swets, J. A. (1966). *Signal Detection Theory and Psychophysics*. Wiley, New York, NY, USA.
- Greene, M. R. and Oliva, A. (2009). The briefest of glances: the time course of natural scene understanding, *Psychol. Sci.* **20**, 464–472. DOI:10.1111/j.1467-9280.2009.02316.x.
- Herz, R. S. and Cahill, E. D. (1997). Differential use of sensory information in sexual behavior as a function of gender, *Hum. Nat.* **8**, 275–286. DOI:10.1007/BF02912495.
- Hirsch, A. (2006). *Method of Altering Age Perception*. Australia Patent AU2005203565A1. Available at <https://patents.google.com/patent/AU2005203565B2/en>.
- Kirk-Smith, M. D. and Booth, D. A. (1990). The effect of five odorants on mood and assessment of other people, in: *Chemical Signals in Vertebrates 5*, D. W. Macdonald, D. Müller-Schwarze and S. E. Natynczuk (Eds), pp. 48–54. Oxford University Press, Oxford, UK.
- Kovács, G., Gulyás, B., Savic, I., Perrett, D. I., Cornwell, R. E., Little, A. C., Jones, B. C., Burt, D. M., Gál, V. and Vidnyánszky, Z. (2004). Smelling human sex hormone-like compounds affects face gender judgment of men, *Neuroreport* **15**, 1275–1277. DOI:10.1097/01.wnr.0000130234.51411.0e.
- Li, W., Moallem, I., Paller, K. A. and Gottfried, J. A. (2007). Subliminal smells can guide social preferences, *Psychol. Sci.* **18**, 1044–1049. DOI:10.1111/j.1467-9280.2007.02023.x.
- Macmillan, N. A. and Creelman, C. D. (2005). *Detection Theory: a User's Guide*, 2nd edn. Lawrence Erlbaum Associates, Mahwah, NJ, USA.
- Marinova, R. and Moss, M. (2014). The smell of success? — The impact of perfume-gender congruency on ratings of attraction and the halo effect, *Adv. Chem. Eng. Sci.* **4**, 491–502. <http://dx.doi.org/10.4236/aces.2014.44051>.
- McGlone, F., Österbauer, R. A., Demattè, M. L. and Spence, C. (2013). The crossmodal influence of odor hedonics on facial attractiveness: behavioural and fMRI measures, in: *Functional Brain Mapping and the Endeavor to Understand the Working Brain*, F. Signorelli and

- D. Chirchiglia (Eds), pp. 209–225. InTech Publications, Rijeka, Croatia. <http://dx.doi.org/10.5772/56504>.
- McGraw, K. O., Durm, M. W. and Durnam, M. R. (1989). The relative salience of sex, race, age, and glasses in children's social perception, *J. Genet. Psychol.* **150**, 251–267. DOI:10.1080/00221325.1989.9914595.
- Minear, M. and Park, D. C. (2004). A lifespan database of adult facial stimuli, *Behav. Res. Meth. Instrum. Comput.* **36**, 630–633. DOI:10.3758/BF03206543.
- Mitro, S., Gordon, A. R., Olsson, M. J. and Lundström, J. N. (2012). The smell of age: perception and discrimination of body odors of different ages, *PLoS ONE* **7**, e38110. DOI:10.1371/journal.pone.0038110.
- Novak, L. R., Gitelman, D. R., Schuyler, B. and Li, W. (2015). Olfactory-visual integration facilitates perception of subthreshold negative emotion, *Neuropsychologia* **77**, 288–297. DOI:10.1016/j.neuropsychologia.2015.09.005.
- Pause, B. M., Ohrt, A., Prehn, A. and Ferstl, R. (2004). Positive emotional priming of facial affect perception in females is diminished by chemosensory anxiety signals, *Chem. Senses* **29**, 797–805. DOI:10.1093/chemse/bjh245.
- Risso, P., Maggioni, E. and Gallace, A. (2021). A preliminary study on the effect of gender-matched odours on the evaluation of emotional, cognitive and aesthetic characteristics of faces, *Flavour Fragr. J.* **36**, 436–445. DOI:10.1002/ffj.3653.
- Roberts, S. C., Little, A. C., Lyndon, A., Roberts, J., Havlíček, J. and Wright, R. L. (2009). Manipulation of body odour alters men's self-confidence and judgements of their visual attractiveness by women, *Int. J. Cosmet. Sci.* **31**, 47–54. DOI:10.1111/j.1468-2494.2008.00477.x.
- Sczesny, S. and Stahlberg, D. (2002). The influence of gender-stereotyped perfumes on leadership attribution, *Eur. J. Soc. Psychol.* **32**, 815–828. DOI:10.1002/ejsp.123.
- Seubert, J., Gregory, K. M., Chamberland, J., Dessirier, J.-M. and Lundstrom, J. N. (2014). Odor valence linearly modulates attractiveness, but not age assessment, of invariant facial features in a memory-based rating task, *PLoS ONE* **9**, e98347. DOI:10.1371/journal.pone.0098347.
- Spence, C. (2021). The scent of attraction and the smell of success: crossmodal influences on person perception, *Cogn. Res. Princ. Implic.* **6**, 46. DOI:10.1186/s41235-021-00311-3.
- Syrjänen, E., Liuzza, M. T., Fischer, H. and Olofsson, J. K. (2017). Do valenced odors and trait body odor disgust affect evaluation of emotion in dynamic faces?, *Perception* **46**, 1412–1426. DOI:10.1177/0301006617720831.
- Syrjänen, E., Fischer, H., Liuzza, M. T., Lindholm, T. and Olofsson, J. K. (2021). A review of the effects of valenced odours on face perception and evaluation, *i-perception* **12**, 20416695211009552. DOI:10.1177/20416695211009552.
- Walla, P. (2008). Olfaction and its dynamic influence on word and face processing: cross-modal integration, *Prog. Neurobiol.* **84**, 192–209. DOI:10.1016/j.pneurobio.2007.10.005.
- Welch, R. B. and Warren, D. H. (1980). Immediate perceptual response to intersensory discrepancy, *Psychol. Bull.* **88**, 638–667. DOI:10.1037/0033-2909.88.3.638.