

Article

Changes in Facial Shape throughout Pregnancy—A Computational Exploratory Approach

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Abstract: Facial cognition serves an important role in human daily interactions. It has been suggested that facial shape can serve as a signal for underlining biological condition, and that it is correlated with, among others, health, fertility, and attractiveness. In this study, 14 women were photographed during three consecutive trimesters of pregnancy, and the levels of their facial sexual dimorphism, asymmetry, and averageness were computed. Facial sexual dimorphism in first trimester was higher than in the second trimester ($F(2, 22) = 5.77; p = 0.01; \eta_p^2 = 0.34$, post-hoc Tukey HSD test $p = 0.007$). Similar pattern was visible for asymmetry ($F(2, 22) = 3.67; p = 0.04; \eta_p^2 = 0.25$, post-hoc Tukey HSD test $p = 0.05$). No statistically significant changes in measurement of averageness were observed. Results from Bayesian complementary analyses confirmed the observed effects for sexual dimorphism. The evidence for trimester differences in asymmetry and averageness was inconsequential. Based on the preliminary results of this exploratory study, we suggest that previously found decrease in observed facial attractiveness during pregnancy can be related to the decrease in computed facial femininity (possibly mediated by the changes in facial adiposity).

Keywords: facial sexual dimorphism; facial averageness; facial symmetry; femininity



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1. Introduction

Facial features are important to human social interactions [1,2] they can serve as cues to multiple character traits and biological quality, i.e., sexual openness [3], social status [4], maternal tendencies [5], or health [6] (however see [7] for no effect in women). Investigating variation in facial features and perception can therefore provide important insight into human daily interactions. Previous research has established that several aspects of facial appearance are frequently associated with attractiveness across different groups of judges and cultures. These globally attractive features include symmetry, averageness, and pronounced sexual dimorphism in women—see [8] for a theoretical review.

1.1. Facial Symmetry

Fluctuating asymmetry is defined as a random “deviation from ideal symmetry in bilateral physical traits that do not display any directional tendency” [9]. Levels of facial asymmetries can serve as a proxy for judging how efficient the body of an individual has been in developing bilaterally while facing environmental obstacles (e.g., pathogen exposure or energy shortages) [10]. Based on that assumption, physical symmetry is interpreted as a cue to developmental stability, and putative heritable genetic quality [11].

In fact, multiple studies found a link between facial symmetry and perceived health [12–14]; however, see [7,15] for null findings on relationship between facial attractiveness and measures of actual health.

1.2. Facial Averageness

A number of studies suggested that averageness is related to attractiveness [16–20]. This relation can be explained via number of mechanisms: (1) an average appearance can indicate a heterozygous genotype—an individual average in shape possesses genetic diversity useful in defending against parasites and pathogens, e.g., [19]; (2) average face is favored due to the avoidance of the extreme stimulus, e.g., [20,21]; or (3) faces similar to the population average demand less neural activity and are easier to process cognitively, which results in an explicit preference for them, e.g., [22,23].

1.3. Facial Sexual Dimorphism

In humans, secondary sexual traits that differ between men and women develop under the influence of sex hormones, mainly estrogens and androgens. Sex-typical facial features in women are, among others, narrower jaws, fuller lips, and less pronounced brow ridges. There appears to be an agreement that facial femininity in women is attractive although the strength of femininity influence on perceived attractiveness can vary [24,25]. Facial sexual dimorphism has been linked to health ([6], but see [26–39]), reproductive success [30], and stronger maternal tendencies in women [5].

1.4. Fluctuation of Attractiveness over Time

Women's facial attractiveness has been suggested to track current fertility status [31], fluctuating throughout menstrual cycle [32,33] and being related to sex hormone levels [34,35]. More recent studies, however, failed to support the claim of cyclical fluctuations in face shape [36], or failed to find significant relation between changes of sex hormones throughout menstrual cycle and changes in attractiveness [37]. As levels of sex hormones and overall fertility change throughout lifetime, one would expect also to see the effects of these more long-term physiological changes on facial attractiveness.

Although facial attractiveness has been found to be related to parity [38], up to date there is only one study testing how facial attractiveness changes during reproductive period, and more precisely, throughout pregnancy. Using composite portraits derived from four different groups of women who were either non-pregnant or pregnant in one of the three trimesters of pregnancy, Danel et al. (2020) showed significant differences in female facial attractiveness. Men perceived the average portrait of non-pregnant women as the most attractive, and attractiveness ratings gradually decreased as the pregnancy progressed. The study, however, focused only on the general changes in attractiveness ratings. The average portraits, constructed from cross-sectional material, did not grant a possibility for an in-depth analysis allowing to detect which features may be responsible for the observed effect and if pregnancy longitudinally affects facial markers of the attractiveness within women.

1.5. Current Rationale

This exploratory study builds on previously found change in attractiveness judgments between three trimesters, and sets on to see whether we can measure the longitudinal changes in women's facial shape during this period of extensive physiological changes. Based on 36 facial photographs of women who were tracked throughout the entire pregnancy this pilot study aims to measure the computational changes leading to decrease in attractiveness.

2. Materials and Methods

2.1. Participants and Procedure

Study protocol was described in detail in Danel et al. (2020). Briefly, 136 healthy and pregnant women were photographed whilst awaiting routine pregnancy check-ups at a gynecological clinic in one of the regional hospitals in Wroclaw, Poland. In addition, during the meeting, women completed a survey and provided information about basic demographic data and the pregnancy. The onset of the pregnancy was established by the gynecologist and was defined as the first day of the last menstrual period. This day was used to precisely determine the week and, consequently, trimester of the individual pregnancy. Trimester I (T1) included women up to 13th week of the pregnancy, trimester II (T2) those between 14th and 26th weeks; and trimester III (T3) subjects above 27th week of the pregnancy.

Out of this group, 14 subjects who participated in the study in the first, second, and third trimester and reported no health problems (e.g., no diagnosed pathologies) during their pregnancy were included in the current project. Due to the inadequate quality of facial pictures (tilt of the head), two subjects were removed from further analyses. Accordingly, the final sample consisted of 12 women photographed in three consecutive trimesters of the pregnancy (36 portraits in total).

2.2. Photographs

Women were asked to sit straight on a chair facing the Sony Alpha 390 digital camera placed about 1.5 m away from the subject on a tripod. They were also advised to keep natural facial expression and pin back hair (if necessary). Before taking the picture, the operator adjusted the head of the photographed woman to the standard anatomical position (Frankfurt plane—position of the head most parallel to the surface of the earth, based on a plane passing through the inferior margin of the orbit and the upper margin of external auditory meatus.). For each picture, the lighting and background were kept constant.

2.3. Ethics Statement

The current study was conducted as part of a larger research project investigating changes in women's morphology and physical attractiveness during pregnancy. The project was approved by the Bioethics Committee at Wroclaw Medical University (KB/854/2010). All participants gave informed written consent to participate in the study.

2.4. Facial Shape Measurements

For each facial image a template was prepared based on 197 landmarks in PsychoMorph [39]. To account for rotation and size differences, all faces were Procrustes-aligned using the R package *geomorph* v3.0.6 [40]. Templates were also subjected to a principal component analysis; broken stick criterion was used in order to choose principal components (PCs) for subsequent sexual dimorphism analyses [41]. All three variables of interest (asymmetry, averageness, and sexual dimorphism) were assessed using methods described in Holzleitner et al. [42] and Marcinkowska and Holzleitner [36]. Asymmetry was calculated as the Euclidean distance between original and mirrored coordinates of each point of the template. Averageness was calculated as the Euclidean distance of individual face shape coordinates from the sample (all 14 photographed women) average. Sexual dimorphism was calculated by projecting individual template on a PCA shape vector describing shape differences between an average male and an average female facial representation created in a different study [42]. The code of geometric morphometric analysis is included in Electronic Supplementary Materials (ESM) S1.

2.5. Statistical Analysis

Statistical analyses were conducted using Statistica (data analysis software system), version 13.1. All raw data are included in ESM S2. Values of all three facial measurements (asymmetry, averageness, and sexual dimorphism) were all z-transformed. Repeated-

measures ANOVA and Tukey's HSD post-hoc tests were used to determine differences in face measurements between three photographs taken during first, second, and third trimester (T1, T2, and T3) for each participant (within-subject variation).

Due to the small sample size and potential risk of obtaining underpowered results, we have conducted robustness tests employing a Bayesian approach. This method allows for investigation if the data are more expected under the null (i.e., there are no differences between trimesters in the examined facial measures) or alternative hypothesis (i.e., trimester differences are present). We run Bayesian repeated-measures ANOVA with default prior scales [43,44] separately for each facial feature. The analysis was conducted in JASP 0.14.

3. Results

The repeated-measures ANOVA showed that neither the effect of facial measurement ($F(2,22) = 0.00$; $p = 1.0$; $\eta_p^2 = 0.00$) nor the trimester of pregnancy ($F(2,22) = 2.80$; $p = 0.08$; $\eta_p^2 = 0.20$) was statistically significant (note that the measurements were z-scored therefore the null result for the former effect was anticipated). In other words, z-transformed facial shape scores were similar: (i) for all analyzed facial features (regardless of the time of pregnancy), and (ii) across all trimesters (irrespective of the measurement type). Nonetheless, the interaction between these two effects reached statistical significance level ($F(4, 44) = 3.18$; $p = 0.022$; $\eta_p^2 = 0.22$) indicating that overall differences in facial shape may be a function of the pregnancy progress and type of measurement. The post hoc analysis with Tukey's HSD test, however, did not show any statistically significant difference in facial shape scores calculated for particular trimesters and measurement type (all p 's > 0.21). Although these results (i.e., the statistically significant omnibus F-test and non-significant post hoc comparisons) seem contradictory, they are likely, especially if the sample sizes and differences between compared groups are small [45]. Such conditions applied to our model in which the study group consisted of $n = 12$ women, and all measurement scores were z-transformed (i.e., the means of the transformed samples are always zero). Therefore, to further explore the effect of changes in facial morphology during pregnancy, we used raw (non-standardized) shape scores and repeated analyses separately for each facial measurement. While the facial averageness did not differ significantly between the trimesters ($F(2,22) = 1.70$; $p = 0.21$; $\eta_p^2 = 0.13$; for all post hoc pairwise comparisons between trimesters $p > 0.23$; Figure 1A), statistically significant differences were found for the asymmetry ($F(2,22) = 3.67$; $p = 0.04$; $\eta_p^2 = 0.25$; Figure 1B) and sexual dimorphism ($F(2,22) = 5.77$; $p = 0.01$; $\eta_p^2 = 0.34$; Figure 1C). In the case of asymmetry, the highest values were observed for the T1 while the lowest for the T2. The pairwise post hoc comparisons showed marginally significant ($p = 0.05$) difference between these two trimesters. Comparisons between T1 vs. T3 and T2 vs. T3 were not statistically significant (all p s > 0.09). The analogous pattern of results was observed for sexual dimorphism. The scores were the highest for T1 and significantly different ($p = 0.007$) from T2 (the lowest values). There were no statistically significant differences between T1 and T3 as well as T2 and T3 ($p > 0.16$ for all group comparisons).

The reanalysis of data with Bayesian repeated-measures ANOVA further complemented results from the frequentist analysis. The Bayes factors indicated moderate evidence for trimester differences in sexual dimorphism ($BF_{10} = 5.25$; error % = 0.68). The post hoc comparisons suggested that data are more likely to occur under the hypothesis assuming differences in sexual dimorphism scores between T1 and T2 (posterior odds = 10.53). Other post hoc comparisons indicated evidence for no differences in sexual dimorphism between T1 vs. T3 (posterior odds = 0.36) and T2 vs. T3 (posterior odds = 0.62). The evidence for trimester differences in asymmetry was inconsequential ($BF_{10} = 1.96$; error % = 0.97) and suggested that our data were insensitive enough to distinguish between null and alternative hypothesis. Similarly, data inconclusiveness was implied by the anecdotal evidence for no trimester differences in averageness ($BF_{10} = 0.64$; error % = 0.61). Detailed results from the Bayesian analysis are presented in ESM S3.

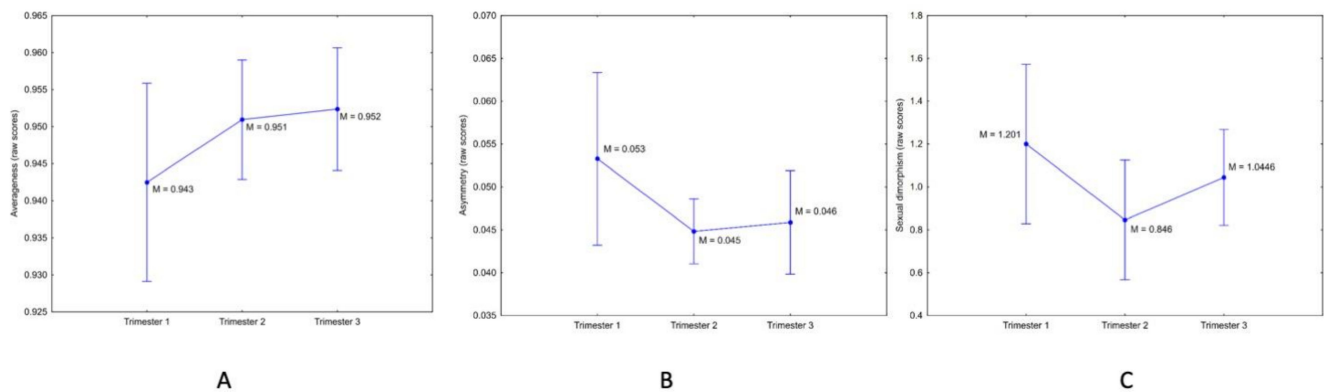


Figure 1. Mean (M; dots) of averageness (A), asymmetry (B), and sexual dimorphism (C) scores in three consecutive trimesters of pregnancy. Whiskers represents 95% confidence intervals.

4. Discussion

We found that women's facial sexual dimorphism and symmetry changed throughout pregnancy—faces of women during second trimester were less feminine and more symmetric than their faces during first trimester (with the difference between trimesters in asymmetry measurements being marginally significant). Based on our computational approach, we suggest that the change in ratings of attractiveness during pregnancy observed in our previous study [46] is related to the decrease in sexual dimorphism. Nonetheless, being aware of the limitations of our study, we highlight the preliminary and explorative nature of our results and advise to interpret them with caution.

Results obtained with this computation approach can be perceived as a support for the previous evolutionary interpretation of female beauty. Since the current conception probability for a pregnant woman is zero, sexual attractiveness (including facial dimorphic features), being a costly feature to maintain, is not crucial to be preserved in that moment. Ultimately, the results illustrate that female attractiveness as a cue to current fertility could follow the evolutionary logic. Proximately, the decrease of facial sexual dimorphism, could stem from fluctuations in fat percentage throughout pregnancy and/or in levels of steroid hormones. It cannot be ruled out that the observed final change in shape is a by-product of the physiological changes related to pregnancy.

4.1. Fat Percentage Fluctuations

Physiological changes during pregnancy lead to significant changes in women's body composition—i.e., fat percentage and water content abruptly increases while lean mass decreases during this period [47]. Nearly two-thirds of this gestational fat gain occurs before the third trimester [48]. This observation may suggest that our findings of significant change in facial shape occurring only between first and second (and not second and third trimester) are concordant with the idea that the change in facial shape reflects the ongoing change in maternal body weight and fat content.

Overall, facial adiposity has been found to correlate with perceived attractiveness [49], possibly due to signaling health [50]. It has also been suggested that facial adiposity is a better predictor of immune reaction than sexual dimorphism alone [51]. Previously observed drop in attractiveness [46] caused by changes in sexual dimorphism found in this study could be mediated by the facial adiposity changes.

4.2. Changes in Sex Steroid Levels

Fluctuations in femininity can also be influenced by hormonal changes occurring during pregnancy. This period is characterized by gradual increase in levels of estrogens (estrone, estradiol, and estriol) and progesterone with progesterone being approximately 9-times higher than any of the estrogens [52]. Levels and sources of enhanced sex steroids production differs throughout pregnancy being of placental, maternal, and fetal origins [53].

Additionally, some studies have demonstrated significant associations between current levels of sex hormones and facial femininity [54]. Thus, even in the absence of direct hormonal measurements, it is plausible to assume that the decline in sexual dimorphism observed in this study could be caused by fluctuations in sex steroids occurring during pregnancy, either directly or indirectly via fat storage determination.

4.3. Fluctuations in Asymmetry

Changes in facial adiposity most probably would not directly affect the asymmetry measurements. Although the change in asymmetry was marginally significant, the direction of the change was opposed to the expected one (based on judgements of the attractiveness from [46]). Lack of common direction of the changes in attractiveness judgement and sexual dimorphism measurement (they both drop from first to second trimester), and the change in facial symmetry (which increases from first to second trimester) could serve as a partial evidence for lack of connection between attractiveness judgements and facial symmetry [55,56].

Alternatively, it is possible that the increase in symmetry is mediated by the increasing levels of sex steroid hormones. Changing levels of progesterone during pregnancy suppresses the immune function [57], putatively allowing for more energy being directed towards maintenance of bilateral symmetry. As the rise of fluctuating asymmetry is suggested to stem from insufficient energy being allocated to developing and maintaining bilateral symmetry [10], a decrease in immune functions could lead to increased energy resources for body maintenance. Although levels of progesterone increase over the whole period of pregnancy, during the first trimester its production is maintained at the lower level mainly by corpus luteum [58]. Once pregnancy is established beyond the first trimester, progesterone production is sustained by placenta at levels far beyond the unpregnant state [57]. The difference in asymmetry between first and second trimester of pregnancy observed in our study may thus represent the switch in production of progesterone from maintained mainly by corpus luteum to placenta.

4.4. Future Directions

This pilot study was set to test whether a computational approach can be employed in the exploration of sources of facial shape variation and facial cognition. Due to the length of period for gathering visual data (photographed individuals had to remain in the study for more than 6 months) and high dropout rates related to it, we were unable to gather a greater number of participants. Possibly, this could have led to insignificant difference between measurements in first and third trimester. Next, explorations based on this pilot study should plan for a greater sample size.

Furthermore, in addition to a great sample size, actual judgements of facial femininity and symmetry of real faces could be conducted. In the current sample, we did not ask for permission to present facial photographs of particular individuals. Accounting for this inadequacy in future studies could aid in understanding whether the observed (and not greatly pronounced) computational differences between measurements between trimesters are actually also observable by random judges.

Future study measuring facial shape changes during pregnancy while simultaneously controlling for levels of sex hormones and fat percentage would help to clarify the mechanisms underlining changes in facial shape during that metabolically and endocrinologically intense period.

Additionally, it is possible that cues other than shape are responsible for variation in attractiveness judgements—i.e., skin texture and coloring. Particularly, during pregnancy some physiological skin changes may be observed in women, including bilateral hyperpigmented patches also referred to as “the mask of pregnancy” which are reported by up to 70% of pregnant women, e.g., [59]. To explore further this hypothesis participants should be photographed in strictly controlled light conditions.

5. Conclusions

Previous study has found that women's perceived facial attractiveness decreases during pregnancy [46]. Here, based on the same sample of women, we have provided the computational evidence that this drop in attractiveness is not driven by changes in averageness, but possibly by decrease in facial femininity. Due to the small sample size however, it is possible that the effect sizes may be overstated. We suggest that the influence of sexual dimorphism on attractiveness judgements previously found can be mediated by facial adiposity or hormonal changes.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/sym13101944/s1>. ESM S1: Housekeeping and shape data; ESM S2: Asymmetry (T1, T2, T3), averageness (T1, T2, T3) and sex diomorphism (T1, T2, T3); ESM S3: Bayesian repeated measures ANOVA.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Bioethics Committee at Wroclaw Medical University (KB/854/2010).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data supporting reported results can be found in the ESM2.

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