Exploring distinctiveness, attractiveness and sexual dimorphism in actualized face-spaces.

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Word Length: 7,364

4 tables.

4 figures.

Keywords: Multidimensional space; face-space; facial attractiveness; distinctiveness; gender.

Abstract

The multi-dimensional face-space metaphor has been a powerful explanatory force in face processing. Here, its predictive powers are considered for ratings of attractiveness, distinctiveness and sexual dimorphism using two different actualizations of face-space. One face-space was based on similarity ratings between pairs of faces and the other on facial feature eccentricity, both based on the same set of 200 faces. The two models both gave similar insights into the range of properties tested. Distinctive faces were located further from the center of these multi-dimensional face-spaces than typical faces. Attractiveness of males was linked to averageness within these models whereas for females, averageness had little effect on their attractiveness. Femininity was a better predictor of female face attractiveness, but masculinity showed a curvilinear relationship with the attractiveness of male faces. Together, these findings demonstrate the usefulness of the face-space metaphor in exploring ideas of the distinctiveness, attractiveness and the sexual dimorphism of faces.

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Philosophers, writers and artists have been interested in human faces since ancient times (Wilmer, 2017) and it is still one of the main topics of research in cognitive psychology. Human faces contain a great amount of information including gender, mood, age, ethnicity, attention, and, in particular, the identity of its owner (Bruce & Young, 1986). Faces are encoded on the basis of mental schema which develops through life by exposure (Brennan, 1985; Cabeza, Bruce, Kato, & Oda, 1999; Diamond & Carey, 1986; Goldstein & Chance, 1980; Valentine & Bruce, 1986a) until it becomes more fixed (Furl, Phillips, & O'Toole, 2002). Investigating the properties of this facial schema has led the idea that faces are represented in a multidimensional space (MDS) or face-space. The current paper explores how the MDS can account for and explain properties of faces such as distinctiveness, attractiveness and the differences between masculinity and femininity. To do this, two actualizations of face-space were generated using a set of faces as exemplars. The distribution of the exemplars within these spaces were compared with the rated properties of these faces.

The multidimensional space model

Valentine (1991) proposed a functional model for perceptual coding faces, known as the face-space, which is based on a MDS framework. The model is a metaphor in which faces are encoded as points in a multidimensional space. Valentine (1991) did not specify the MDS dimensions and assumed that any characteristic that can discriminate among faces may be considered a continuous dimension of face-space (Bruce, Burton, & Dench, 1994; Valentine, 1991, 2001; Valentine & Endo, 1992).

The center of the MDS face-space is defined as the central tendency of all the dimensions and it is assumed that exemplar faces are normally distributed (Bruce et al., 1994; Johnston, Milne, Williams, & Hosie, 1997; Lewis & Johnston, 1999; Valentine, 1991, 2001). Most of the faces are therefore encoded close to the center and considered typical or average looking, and faces that are encoded farther from the center are considered atypical or distinctive. Thus, typical faces with average features are located in a more densely populated regions of the face-space than distinctive faces (Valentine, 1991). Exactly what faces are typical depends on the exact population that someone is familiar with (Kleisner, Pokorný, & Saribay, 2019). Similarity of faces within face-space can be represented as the distance between the exemplars and therefore two typical faces are likely to be more similar to each other than two distinctive faces (Busey, 1998). While it is common to describe similarity in terms of simple Euclidean distances, measures based on cosine similarity or city-block distances have also been considered (Valentine, Lewis, & Hills, 2016). Simple Euclidean distances are used here because they conform to ideas of similarity within orthogonal spaces (Lewis, 2004; Scheuchenpflug, 1999). When imagining this type of face-space, some people suggest that the distribution of the faces will be such that most of the faces occur very close to the center with little variability in distinctiveness. However, Burton & Vokey (1998) described this as the typicality paradox, showing that as the number of dimensions increase, the number of faces that are at the very center of the face-space decreases and so it is not the case that most faces are typical faces.

The MDS face-space model (Valentine, 1991, 2001) has been extensively employed to explain a variety of phenomena associated with face recognition: Recognition of distinctive faces is faster and more accurate than that of typical faces (Lewis & Johnston, 1997; Light, Kayra-Stuart, & Hollander, 1979; Valentine, 1991, 2001; Valentine & Bruce, 1986a, 1986b; Wickham, Morris, & Fritz, 2000); Faces from the participant's race are better recognized than face from other races (Byatt & Rhodes, 1998; Caldara & Abdi, 2006; Valentine & Endo, 1992); Caricatures faces are better recognized than anti-caricatures faces (Byatt & Rhodes, 1998; Chang, Levine, & Benson, 2002; Lee, Byatt, & Rhodes, 2000; Lewis & Johnston, 1999). Valentine, Lewis and Hills (2016) provide a review of the impact that face-space has made to our understanding of face processing.

There are two approaches for actualizing a face-space based on a set of real faces. The first method, which will be referred to here as a dimension ratings MDS (DRMDS), is to define a set of facial dimensions a priori and have faces located on each of these dimensions in order to populate the face-space with exemplars. Catz, Kampf, Nachson, and Babkoff (2009) did this for 200 faces based on 21 pre-defined dimensions. The second method, which will be referred to here as a similarity ratings MDS (SRMDS), is to collect similarity ratings for pairs of faces and use this to locate them within a space. This method has been actualized by using multidimensional scaling methods (Hopper, Finklea, Winkielman, & Huber, 2014; Johnston et al., 1997; Lee et al., 2000; Nishimura, Maurer, & Gao, 2009; Papesh & Goldinger, 2010). However, these previous papers have used relatively small sets of faces (between 20 and 40 faces) leading to between just two and six dimensions.

In spite of their differences, these two approaches to MDS models of face-space have each contributed to the understanding of face processing. They both enable locating the faces in a MDS in order to investigate predictions about face processing, such as the correlation between the location of a face in the space and its distinctiveness (compare Catz et al., 2009, and Hopper et al., 2014). Usually these two approaches have been set up using different sets of faces and so are difficult to compare; however, the present study compares these two methods for generating MDS face-spaces using the same sets of faces. Further, the present paper explores how other facial properties can be looked at using actualized face-spaces.

Attractiveness, masculinity and femininity

As well as identity, a human face contains a great wealth of information about the individual. A viewer can instinctively make a judgement as to the attractiveness of a face even when not looking for a mate. This attractiveness may or may not be associated with the visual distinctiveness of the face. Also, the person's gender is often very apparent from a face even when the strength of the masculinity or femininity of the face changes. The current research evaluates how these aspects of the face can be explored using actualized face-spaces. Below it is explained how attractiveness is related to averageness and sexual dimorphism.

Langlois and Roggman (1990) have shown a relation between the mathematical averageness of a face and facial attractiveness. Indeed, many studies have shown that average faces are perceived as highly attractive and faces that are not average faces are perceived as less attractive (Apicella, Little, & Marlowe, 2007; Bronstad, Langlois, & Russell, 2008; Langlois et al., 1987; Langlois, Roggman, & Musselman, 1994; Rhodes & Tremewan, 1996).

One explanation for the link between averageness and attractiveness is the larger exposure to typical faces compared to distinctive ones, and the efficiency with which those faces are processed (Trujillo, Jankowitsch, & Langlois, 2014). According to this averageness theory, faces are seen as attractive because of their similarity to the facial prototypes or mental schema. In fact, because the mental schema is the center of the

MDS, the closer a face is to this center, the more it is considered as average and hence attractive (Deffenbacher, Vetter, Johanson, & O'Toole, 1998; Vokey & Read, 1992).

Face attractiveness is also linked to sexual dimorphism, that is how typically female (or feminine) or typically male (or masculine) a face is. The relation between femininity and the attractiveness of female faces is clear; the more a female face is feminine the more attractive it is (Kościński, 2007, 2013; Lee et al., 2014; Little, Jones, Feinberg, & Perrett, 2014; Morrison, Clark, Tiddeman, & Penton-Voak, 2010; Saxton, DeBruine, Jones, Little, & Craig Roberts, 2011; Welling et al., 2008; Wen, Zuo, Wu, Sun, & Liu, 2014). Johnston and Franklin (1993) reports that using cosmetics to exaggerate feminine face features increase facial attractiveness. Similarly, computer-generated female faces are made more attractive by exaggerating feminine traits (Rhodes, 2006; Rhodes, Hickford, & Jeffery, 2000; Russell, 2003). Furthermore, Perrett, May, and Yoshikawa, (1994) reports that composite faces of very attractive female faces are preferred over average composite faces, because they have more feminine features, and faces with exaggerated femininity were judged as even more attractive. This demonstrates that there is an effect of femininity on attractiveness of female faces beyond the simple averageness of the face. Femininity in female faces is associated with youth and fertility (Perrett et al., 1998), health (Thornhill & Gangestad, 2006), and estrogen levels (Law Smith et al., 2006). Thus, for female faces, the more feminine faces are judged to be more attractive (at least if the perceived femininity is judged by a person of the same ethnical origin, Kleisner et al., 2017). However, the relationship between health, femininity and attractiveness is a complicated one. While more feminine and so attractive female faces are judged as healthier, this is not a good indicator of actual health with increased attractiveness making actual health difficult to perceive (Kalick, Zebrowitz, Langlois, & Johnson, 1998). Similarly, Jones (2018a) found that femininity and averageness were associated with perceived health but only averageness was associated with actual health.

The relationship between attractiveness and masculinity is more ambiguous for male faces (DeBruine, Jones, Smith, & Little, 2010; Scott, Clark, Boothroyd, & Penton-Voak, 2012). Many researchers examined this issue and while some of them found that more attractive male faces are more masculine (e.g. DeBruine et al., 2006; Gildersleeve, Haselton, & Fales, 2014; Johnston, Hagel, Franklin, Fink, & Grammer, 2001; Koehler, Simmons, Rhodes, & Peters, 2004; Little, DeBruine, & Jones, 2013; Rhodes et al., 2011; Scheib, Gangestad, & Thornhill, 1999; Smith, Jones, DeBruine & Little, 2008) others have found that more attractive male faces are more feminine (e.g. Burriss, Marcinkowska, & Lyons, 2014; Little, Burt, Penton-Voak, & Perrett, 2001; Penton-Voak et al., 1999; Rhodes et al., 2000; Perrett et al., 1998; Saxton et al., 2011; Soler et al., 2012). Moreover, some researchers have found no significant relationship between male face attractiveness and masculinity (e.g. Morrison et al., 2010; Penton-Voak et al., 2001; Stephen et al., 2012) and others have found that attractive male faces have average levels of sexual dimorphism (e.g. Swaddle & Riersen, 2002). Scott et al. (2014) has shown that environment can affect the relationship between masculinity and attractiveness, but this is unlikely to explain the variation between studies because they have all taken place within similar environments.

One explanation for the variability in the effects of masculinity on facial attraction in males is that the relationship may be non-linear (Cunningham, Barbee, & Pike, 1990; Kościński, 2007; Rhodes, 2006). Evidence shows that there is an ‘n’ shaped curve relating masculinity to attractiveness (Holzleitner & Perrett, 2017). At low levels of masculinity, increasing masculinity will lead to increased levels of attractiveness whereas at high levels of masculinity, increasing masculinity will decrease attractiveness. The different results described above can therefore be reconciled if the different researchers are exploring different parts of the attractiveness-by-masculinity curve. One potential reason for the curvilinear relationship is that there is a trade-off in preferences of females towards males because men's masculine traits signal both positive and negative attributes (DeBruine et al., 2010; Fraccaro et al., 2010). While facial masculinity is associated with good health, physical strength, and reproductive, it is also associated with negative personality traits and behaviors, for example, low cooperativeness, dishonesty, unfaithful and poor quality as parents (DeBruine et al., 2010; Fraccaro et al., 2010). Another explanation for the variability in the effects of masculinity on facial attraction in males is that different researchers are using different methods of masculinity assessment. Mitteroecker, Windhager, Müller, and Schaefer (2015) showed that rated masculinity only has a moderate correlation with objective masculinity and so the method of manipulation or measurement of masculinity could affect the power of any effects.

The current research was able to explore the nature of attractiveness and sexual dimorphism within actualized face-spaces. To do this, it was first necessary to construct these face-spaces.

Experiment 1

The first experiment was conducted to compare two approaches to the MDS (DRMDS and SRMDS) using the same faces. Experiment 1a describes the process of building a MDS model based on similarity ratings (similar to models by Hopper et al., 2014). Separate MDS models were constructed for male and female faces. Experiment 1b used the facial feature measurements reported in Catz et al. (2009) to build dimension-based MDS models for male faces and female faces separately.

Experiment 1a: Building a MDS using similarity ratings (SRMDS)

In order to build SRMDS models of face-space, similarity ratings were obtained for pairs of faces. Pairs were always male-male or female-female allowing for two separate SRMDSs to be constructed: one for each gender. PROXSCAL was employed to fit the ratings into a face-space model (Busing, Commandeur, Heiser, Bandilla, & Faulbaum, 1997).

Method

Participants

Two hundred and ten Caucasian participants, 42 males and 168 females, aged between 20 and 45 (M=25.82, SD=6.56) participated in this experiment. As participants were only making judgements of facial similarity there was no need to ensure equal numbers of male and female participants.

Material

The stimuli were 200 frontal faces of Caucasian people aged 20–30 years and were previously used in Catz et al. (2009). Half of the faces were male, and half were female. All the faces presented a neutral expression and had no distinctive features (glasses, beards, moustaches and the like). All the faces were from people who would describe themselves as White or Caucasian. The faces were placed on white background without outer features such as hair and ears. The images were about 16cm long and 11cm wide, with a resolution of 72 pixels per inch (see Figure 1).

Procedure

Pairs of two faces, randomly selected from the same gender, were presented side by side (including some pairs of identical faces). The participants were asked to rate the similarity of two faces on a scale ranging from 1 (similar faces) to 7 (different faces). Once the response was made, a blank screen appeared for 0.5s followed by exposure of the next two faces. Every participant rated 100 pairs of faces, had a short break, and then rated another 100 pairs of faces. Over all the participants, every possible pair of faces were rated for their similarity by between 1 to 6 participants.

Results

MDS scaling

Two MDS (SRMDS) solutions were calculated using SPSS PROXSCAL (Busing et al., 1997), for male and female faces, separately. This method places the exemplars within a space such that it can account for the variability in the similarity judgements, thereby locating similar-rated pairs close to each other in a low dimensional space. As the number of dimensions of the space increased, amount of variability in the similarity ratings that can be accounted for increases until an optimal level is found. For both MDS models, four dimensions accounted for a large proportion of the observed variance (gaving a normalized stress score lower than 0.1 - sufficient for a good model of the data) and so these models were employed for the subsequent analyses following Hopper et al., (2014).

Distance from the SRMDS center

The simple Euclidean distance of a given face from the center of the SRMDS was defined in terms of its relative distance on each of the four dimensions by calculating the square root of the sum of squares of the distances from the center on each dimension. The distances from the center ranged between 0.37 and 0.85 (M=0.66, SD=0.10), for male faces, and between 0.34 and 0.97 (M=0.66, SD=0.12), for female faces. Distance to the sample center was extracted rather than density because, for same-race faces, the correlation between them is very high (Catz et al., 2009). Specific values on a density measure would be influenced by the particular sample of faces used whereas a distance-based measure would be consistent and determined by the properties of the population rather than the sample.

Experiment 1b: Building a MDS bases on 21 dimensions

The data collected and presented in Catz et al. (2009) were used to generate a single MDS regardless of gender of the faces. Here, the same data are used currently to form two different gender-specific MDS. This current re-analysis of those data is used to establish face proximity to the center of the gender-specific MDS spaces in order to compare them with those measures in Experiment 1a.

Method

Participants

Two-hundred and ten Caucasian participants, 105 males and 105 females, aged between 17 and 31 years (M=22.97, SD=2.38) participated in this experiment.

Material

The 200 faces using in Experiment 1a were also used here.

Procedure

The dimensions for the DRMDS were selected by ninety students who freely wrote facial features they considered as discriminatory among human faces. Fifty one features, visible in frontal view, were listed. Specific properties of features (such as mouth thickness, shape, and size) were categorized rather than general features (such as mouth). Dimensions that were mentioned by 10 or fewer people were not used as dimensions. The 21 chosen dimensions were: Cheeks (shape and size), chin (shape and size), eyebrows (shape and size), nose (shape and size), eyes (color, distance, shape and size), face (marks, hue, length, shape and size), forehead height, and mouth (thickness, shape and size). Other features may serve as dimensions, but the list was limited for parsimonious reasons.

The faces were presented to the participants in a random order. Each face was presented for 4 s followed by a blank screen. During this interval the Participants rated each face on a scale ranging between -5 (maximal deviation from a typical face) to +5 (maximal deviation to the opposite direction), through 0 (typical face on that dimension). Each participant rated the 200 faces on one dimension only (e.g. mouth size, eyes shape, and face length). Thus, 10 participants (half males and half females) rated each dimension from the 21 dimensions that were defined. Each dimension has a specific scale based on its characteristics. For example, mouth size ranged from very small mouth to very large mouth, through typical mouth size, and mouth thickness ranged from very thin mouth to very thick mouth, through typical mouth thickness. Once the response was made, the next face was presented (see Catz et al., 2009, for more details).

Results

The data collected were used to locate each face within its gender specific DRMDS. The center of each gender within the DRMDSs was calculated as the average of every dimension based only on the faces from the same gender. The simple Euclidean distance of each face from this center was calculated as the square root of the sum of squares of its distances from the gender center on each dimension. Distances from the center ranged between 3.41 and 10.83 (M=6.54, SD=1.38) for male faces and between 3.71 and 9.96 (M=6.39. SD=1.25) for female faces.

Exploratory factor analyses with Varimax rotation were conducted for the data for male and female faces separately. Dimension reduction was performed and the criteria that was used to decide the number of factors that fit the model was the 'eigenvalue greater than one rule' (or K1 rule) suggested by Kaiser (1960). This led to spaces with 7 dimensions for each gender separately. There was good consistency of how the dimensions loaded onto the factors for the two genders. The only exceptions were for eyebrows shape and size and the complexion of the faces. Eyebrow shape and size were omitted from subsequent analysis (because it is likely that this reflects the different amount of grooming that is applied to male and female eyebrows). Complexion was extracted and used as an isolated dimension for further analyses. The analysis of the male faces and female faces accounted for 66.40% and 65.80% of the variance, respectively.

Based on those results we calculated the factor scores for each face based on dimensional loadings. The seven factors were defined as follows: Size referred to the sizes of the face, the chin, the forehead, and the eyebrows; *Form* referred to the face's shape and length, the cheeks size and shape, and the chin's shape; *Mouth* referred to its thickness, shape, and size; *Eyes* referred to their shape and size; *Color* referred to the face hue and eye colors; *Nose* referred to the nose's size and shape, and the distance between the eyes; and *Complexion* referred to facial marks (wrinkles, freckles, moles, dimples, and scars). The order of the factors conducted in the factor analyses for male faces was; *Mouth*, *Color*, *Form*, *Eyes*, Size, *Nose and Complexion*, and the order of the factors conducted in the factor analyses for female faces was; *Form*, *Mouth*, *Eyes*, *Nose,* *Color*, *Complexion* and *Size*.

Correlations between the SRMDS and the DRMDS

The compatibility between the SRMDS and the DRMDS was investigated in two ways. First, by exploring how the distance from the center of the space compared for the 200 items. Second, by exploring the correlations between the dimensions of the two spaces.

The correlations between the distance from the center for the 100 faces (for each gender) according to the SRMDS and the distance from the center according to the

DRMDS were calculated. These produced significant correlations of r =.60 ($p < .001$) for male faces and $r = .62$ ($p < .001$) for female faces.

The pattern of correlations between values on the four MDS dimensions and the seven factors are shown in Table 1. These correlations show slightly different patterns between the two genders. The first dimension from the SRMDS significantly correlated to the *color* and *mouth* factors for male faces and to *color*, *Complexion* and *eyes* factors for female faces. The second dimension from the SRMDS significantly correlated to the *size*, *eyes* and *nose* factors for male faces, and to the *shape* factor for female faces. The third dimension from the SRMDS significantly correlated to the *size* and *shape* factors for male and female faces, but in the opposite directions. And lastly the fourth dimension from the SRMDS significantly correlated only to the *size* factor for male faces.

Discussion

Experiment 1 reports the construction of four MDSs from the same sets of faces. Two of these were based on described dimensions (DRMDS): one each for male and female faces. The DRMDSs were built on 21 dimensions that are similar for male and female spaces. The other two MDSs were extracted from similarity ratings (SRMDS) without the need to define the dimensions a priori. This enable the dimensions which were derived from this process to be defined differently for male and female faces, and therefore their results should be analyzed carefully.

Both methods of constructing MDS show consistent relationships regarding distance to the center of the spaces. Thus, for male and female faces, the closer a face is to the SRMDS center the closer it is to the DRMDS center.

The dimensions that are extracted from the different MDS's are different but can be mapped onto each other to a degree (as shown on Table 1). The defined DRMDS dimensions can give structure to some of the abstract and derived dimensions of the SRMDS. For example, SRMDS dimension 1 for male faces maps onto the DRMRS dimensions of *color* and *mouth* and so represents a combination of these features. This also demonstrated the difference in genders because the SRMDS dimension 1 for female faces maps onto DRMDS dimensions of *color, complexion* and *eyes*. This demonstrates that the nature of the MDS for the two genders is different with different features having differing degrees of relevance in identify similarities between faces.

So far, the two approaches to the MDS models were compared and it was shown that they have similar distribution of faces in the space, even though they have differences in the dimensions structure. Following on from this, it is possible to analyze the relationships between MDS properties and other characteristic of faces such as distinctiveness, attractiveness, masculinity (for male faces) and femininity (for female faces). The ability of both approaches to predict these facial characteristics would show the utility of the MDS model proposed by Valentine (1991). Distinctiveness, attractiveness, masculinity, and femininity are theoretically connected to location with MDS and thus predicting those attributes using the MDS models would contribute both to the MDS models and both to understand better those attributes.

Experiment 2: Attractiveness, sexual dimorphism and distinctiveness

This experiment was conducted in order to analyze the relations between the two MDSs, distinctiveness, attractiveness, and sexual dimorphism. Because the distance from the center of both MDSs were highly correlated, it was hypothesized that more attractive faces will be closer to the averages within the two MDSs. Beyond this, it was possible to assess which dimensions specifically affect attractiveness. The dimensions in the DRMDS are easily interpretable and one would predict that some would affect attractiveness (e.g. complexion) whereas others might not be related to attractiveness (e.g., size). The dimensions in the SRMDS are not so easy to define, but yet, it can still be explored whether some of the dimensions that fall out of similarity judgments are related more strongly to attractiveness than others.

Further, the relative importance of distinctiveness and femininity was investigated for the attractiveness of female faces and similarly, for male faces, the relative importance of distinctiveness and masculinity on attractiveness was investigated. As described above, while the relation between femininity and female faces attractiveness is clear, the relation between masculinity and male faces attractiveness is more nuanced.

In order to identify the factors that predict attractiveness and distinctiveness of male and female faces, the 200 faces used in Experiment 1 were assessed. Ratings of attractiveness were obtained together with either their masculinity (for male faces) or femininity (for female faces). These measures were combined with distinctiveness ratings obtained in previous research (Catz et al., 2009). Finally, the distances from the center of the MDSs and its factors, obtained in Experiment 1, were also investigated.

Method

Participants

Ninety-six Caucasian participants, half males and half females, aged between 20 and 48 (M=26.72, SD=6.13) participated in this experiment.

Material

The 200 faces using in Experiment 1 were also used here.

Procedure

The participants completed two tasks: attractiveness rating and femininity-masculinity rating. The order of those tasks was counter balanced.

Attractiveness rating

The participants were asked to rate the attractiveness of the faces on a scale ranging from 1 (not attractive) to 7 (very attractive). The faces were presented in a random order. Each face was presented until the participant pressed one of the seven response (1-7) keys. Once a response was made, a blank screen appeared for 1s followed by exposure of the next face. The reliability of the attractiveness ratings for male and female faces was Cronbach $\alpha = 0.92$ and 0.96, respectively.

Masculinity / Femininity rating

Participants rated the masculinity of the male faces and the femininity of the female faces. Half of the participants rated the masculinity of the 100 male faces on a scale ranging from 1 (not masculine) to 7 (very masculine), and then rated the femininity of the 100 female faces on a scale ranging from 1 (not feminine) to 7 (very feminine). The other half of the participants did the tasks in the opposite order: first the female faces and second the male faces. Once again, the faces were presented in a random order. Each face was presented until the participant responded. Once the response was made, a blank screen appeared for 1s followed by exposure of the next face. The reliability of the masculinity ratings for male face was Cronbach $\alpha=0.88$ and the reliability of the femininity for female faces was also Cronbach $\alpha=0.88$.

Distinctiveness rating

The images had been previously rated on their distinctiveness (see Catz et al., 2009) and these values were also used in the analyses below. These distinctiveness values were obtained from the ratings of 32 Caucasian participants (half males and half females), aged between 17 and 35 (M=24.00, SD=2.90). Participants assessed the relative difficulty of recognizing a stranger in the crowd on the basis of his face photograph on a scale ranging from 0 (easy) to 5 (difficult). The reliability of the distinctiveness ratings for male and female faces was Cronbach α=0.82 and 0.81, respectively.

Results and Discussion

In order to understand how facial properties related to each other and the properties of the MDSs, a series of analyses were carried out. First, the correlations between the facial properties were explored for the male and female faces. This was followed by an investigation into how these facial properties related to the extracted properties of the two MDS methods. Finally, both linear and quadratic predictive powers of the factors for attractiveness were investigated.

Correlations between face attractiveness, sexual dimorphism ratings and distinctiveness

To test the correlations between attractiveness, sexual dimorphism rating and distinctiveness, Pearson correlations were obtained. As seen in Table 2, more feminine female faces are seen as significantly more attractive, however, for male faces there is no significant correlation between masculine and attractiveness. On the other hand, the rated distinctiveness of male faces significantly positively correlated with attractiveness such that more attractive faces were more typical, however, for female faces there is no significant correlation between distinctiveness and attractiveness.

Correlations between the face attractiveness, sexual dimorphism , distinctiveness and the two MDS models

In order to test the correlations between attractiveness, sexual dimorphism rating, and distinctiveness and the two MDS methods, separately for male and female faces, Pearson correlations were obtained (see Table 3).

Attractiveness: For male faces attractiveness was significantly negatively correlated with SRMDS and DRMDS distances showing that faces closer to the average were seen as being more attractive regardless of type of MDS model. Looking at the specific dimensions, attractiveness was significantly negatively correlated with dimension 1 in the SRMDS model and the *color* and *complexion* factors in the DRMDS model. Female faces attractiveness was not significantly correlated with SRMDS and DRMDS distances. Looking at the specific dimensions, attractiveness was significantly negatively correlated with dimension 1 in the SRMDS model and positively with dimension 2 in this model. Likewise, attractiveness was significantly negatively correlated with the *color* and *complexion* factors and positively with the *mouth* factor in the DRMDS model.

Sexual Dimorphism: For male faces, masculinity was significantly negatively correlated with DRMDS distance, and positively with dimensions 1 and 4 in the SRMDS model and the *color*, *complexion*, and *mouth* factors in the DRMDS model. For female faces, femininity was significantly positively correlated with dimension 2 in the SRMDS model and with the *eyes* factor in the DRMDS model. Additionally, femininity was significantly negatively correlated with the *color*, *complexion*, and *nose* factors in the DRMDS model.

Distinctiveness: For male faces, distinctiveness was significantly positively correlated with SRMDS and DRMDS distances. In addition, distinctiveness was significantly negatively correlated with dimension 1 in the SRMDS model and the *color* and *nose* factors in the DRMDS model, and positively with the *shape* and *complexion* factors in the DRMDS model. For female faces, distinctiveness was also significantly positively correlated with SRMDS and DRMDS distances. Further, distinctiveness was significantly negatively correlated with dimension 1 in the SRMDS model and the *color* and *nose* factors in the DRMDS model.

Interpreting the correlations

Analysis of the dimensions of the DRMDS reveals that there are similar patterns of attractiveness for the two genders. Attractiveness of male and female faces significantly correlate negatively with *color* and *complexion* showing that these dimensions are important for both genders. This is, in spite of the fact, that these dimensions have different relationships with masculinity and femininity: masculinity significantly correlates positively with *color* and *complexion*, while femininity significantly correlates negatively with *color* and *complexion*. This means that despite the fact the both *color* and *complexion* are each characteristics of attractiveness they have differing relationships to sexual dimorphism. So, for example, a smooth complexion could be seen as being more attractive for both males and females, but smoothness is associated with femininity whereas a rough complexion is associated with masculinity. This highlights the issue that masculinity has a complicated relationship with attractiveness.

From each of the MDS models, it was possible to obtain a measure of the distance from the central tendency of the space to each face in that space. The research showed that there was a good correlation between these measures of distance within the models and the subjective ratings of facial distinctiveness as predicted by previous research (Catz et al., 2009; Johnston et al., 1997; Lee et al., 2000). Distinctiveness has often been shown to be related to visual processing properties of the face such as ease of recognition (Catz et al., 2009; Lewis & Johnston, 1997; Light et al., 1979; Valentine, 1991, 2001; Valentine & Bruce, 1986a, 1986b; Wickham et al., 2000) or speed of deciding that an image is a face (O'Toole et al., 1998; Valentine & Endo, 1992). Here it is shown that the visual processing properties are related to the relative location of the faces within the MDS models whether derived from similarity judgments or based on feature estimates (Valentine, 1991). How these MDS models fare in explaining other aspects of face processing such as cross-race effects or facial adaptation will remain to be seen.

For both genders there was a significant correlation between distinctiveness and distance to the center of the two MDSs. However, for the other properties (attractiveness and masculinity/femininity) there was only a significant correlation with distance to the center of the MDSs for male faces and not female faces. This difference emphasizes the importance of distinctiveness for both genders and shows that attractiveness and masculinity or femininity has a complex relationship with the MDS, consistent with Jones (2018a) showing that there is a link between femininity, averageness and health in female faces.

Predicting facial attractiveness linearly and quadratically

Quadratic regression analyses were employed to specify the kind of relation between faces attractiveness and distance from the center of the MDS, distinctiveness and sexual dimorphism. In each regression, the independent effects of linear and quadratic variable were considered (separately for male and female faces), with the attractiveness as the predicted variable. All the variables were centered around the means (as recommended by Tabachnick & Fidell, 2007). The quadratic regression analyses were chosen because of the hypothesis that the relationship between face attractiveness of male faces and masculinity may be non-linear (Cunningham et al., 1990; Kościński, 2007; Rhodes, 2006). Increasing low levels of masculinity lead to increased levels of attractiveness and increasing high levels of masculinity will decrease attractiveness.

As seen in Table 4, male-face attractiveness was significantly predicted by the SRMDS distance both linearly and quadratically (see Figure 2), while it was significantly predicted by the DRMDS distance and distinctiveness only linearly. In addition, male-face attractiveness was significantly predicted by masculinity only quadratically (see Figure 3). However, female faces attractiveness was significantly predicted by femininity both linearly and quadratically (see Figure 4). Importantly, female-face attractiveness was not significantly predicted by MDS distances or distinctiveness, either linearly or quadratically. It can be observed that the link between sexual dimorphism and attractiveness is stronger for female faces than for male faces. One potential explanation for this is there is more consistency in what is considered to be an attractive female face than what it an attractive male face.

The results show that, in general, more attractive male faces are closer to the center of the two MDSs (i.e., more average). This supports the averageness theory which claims that faces that are closer to the mental schema are seen as attractive (Deffenbacher et al., 1998; Vokey & Read, 1992). However, very average faces are not the most attractive as indicated by the negative non-monotonic quadratic curve between male attractiveness and distance from the SRMDS center. One explanation for this is that the center of the SRMDS is not the center of the actual face-space because it is derived from similarity ratings. If the distribution of faces were skewed on any dimensions then the center of the SRMDS may be located away from the area of greatest density of exemplar faces. As the DRMDS is based on estimates of deviations from each dimensions' central tendency, the same kind of mis-location of the center of the face-space would not be expected. Overall, there is a strong relationship between the center of the face-spaces and attractiveness that is consistent with previous accounts (Potter & Corneille, 2008).

An important result concerning attractiveness of male faces is the negative non-monotonic quadratic curve between attractiveness and masculinity. This curvilinear relationship means that for less masculine faces, the more a face is masculine the more attractive it is; and for high masculinity faces, the less a face is masculine the more attractive it is. This result is consistent with other demonstrations of a curvilinear relationship between masculinity and attractiveness (see Cunningham et al., 1990; Holzleitner & Perrett, 2017; Kościński, 2007; Rhodes, 2006) although, here, a random distribution of real faces was used to demonstrate the effect.

This pattern of data can explain why studies that have investigated the relationship between masculinity and attractiveness have shown such variety of results. The studies that show a positive correlation between masculinity and attractiveness (e.g. (e.g. DeBruine et al., 2006; Gildersleeve et al., 2014; Johnston et al., 2001; Koehler et al., 2004; Little et al., 2013; Rhodes et al., 2011; Scheib et al., 1999; Smith et al., 2008) could be showing the relationship at low levels of masculinity, and the studies that show a negative correlation between masculinity and attractiveness (e.g. Burriss et al., 2014; Little et al., 2001; Penton-Voak et al., 1999; Rhodes et al., 2000; Perrett et al., 1998; Saxton et al., 2011; Soler et al., 2012) could be showing the relationship at high levels of masculinity.

Unlike male faces, female faces do not show a relationship between attractiveness and distinctiveness within the range of faces used here. Neither is attractiveness related to the distance from the center of MDS spaces. Hence, female faces that are closer to the mental schema are not seen as more attractive - contrary to some previous findings (e.g. Trujillo et al., 2014). There are a number of differences between the current experiment and that previous one. In that previous one the categorization task was between female faces and chimpanzee faces whereas here it was between male faces and female faces. Also, in the current one faces were shown without hair, which can be used as an extra-facial clue to gender. It can be expected that the nature of the categorization tasks would be different in these cases. This does not explain why Trujillo et al. found average faces as being more attractive than nonaverage faces whereas here it was shown that distance to the center of the space did not affect female face attractiveness. The answer to this lies within the process of averaging. Trujillo et al.'s method of averaging may make faces that are much closer to the center of a face-space than would occur in a natural set of faces. This is borne out by the fact that Trujillo et al.'s average faces where even more attractive than the normal attractive faces. In the current experiment only natural faces (and without hair) were used and among these faces (even though they were shown to vary according to their distance to the center of a space) there was not sufficient variation to capture an attractiveness advantage for those close to the center. The conclusion is therefore, that if one artificially increases averageness then it is possible to increase attractiveness but for a set of naturally occurring female faces there is no significant correlation between attractiveness and distance to the center of the face-space. There is an ever-increasing trend to use artificially constructed faces in psychological research, but the current research shows that there is still an important role for real faces. This also reinforces the importance of effective controls when artificially manipulating faces to prevent perceptual biases (see also, Jones, 2018b; Windhager, Bookstein, Mueller, Zunner, Kirchengast, & Schaefer, 2018).

For female faces, the data show that increasing femininity always increases attractiveness. As female faces become more feminine, they become more attractive and further, due to the positive monotonically increasing quadratic curve, the correlation between femininity and attractiveness becomes stronger as femininity increases. In the real world, a common way to make a female face more attractive is by the use of cosmetics. These cosmetics are often employed to enhance the face's femininity (Russell, 2009). For example, exaggerating lips thickness with Collagen injections help female faces to be more feminine and thus more attractive (see for example Dastoor, Misch, & Wang, 2007), even though it makes them less average.

The linear correlations between the attractiveness, masculinity/femininity ratings, and distinctiveness and between the MDSs distances from the center were almost similar for both the DRMDS and the SRMDS. The only difference was between masculinity and the MDSs distances when the correlation between masculinity and the distance from the DRMDS center was significant and the correlation with the distance from the SRMDS was not significant. Another similar difference was found for the non-linear quadratic correlation where the quadratic correlation between the distance from the DRMDS center and attractiveness was significant and the quadratic correlation between the distance from the SRMDS center and attractiveness was not significant. This emphasis the claim that the two spaces can have some overlap. Moreover, the DRMDS that was built using specify a-priori dimensions is little more accurate relating to the center of the MDS, not surprisingly, because it was built using the deviation from the MDS origin. Thus, it enables get more detailed relations between attractiveness, masculinity and the distance from the center of the MDS, specifically for male faces.

General Discussion

The current findings offer insights into the nature of MDS models of face-space and how they can be actualized. Further, these actualized MDS models were used to explore the nature of attractiveness and distinctiveness for male and female faces and how masculinity and femininity play differing roles in overall attractiveness ratings. Lastly, the nature of the types of dimensions that are specifically related to male and female attractiveness are compared.

MDS representations of face-space can be effective and can be constructed from similarity ratings or from dimensions. Here, two face-spaces were built using different procedures, based on different ideas, but keeping the main concepts of face-space. Similarities were found between the properties of these two spaces, therefore strengthening the validity of the original face-space metaphor. Those similarities emphasize the advantage of the model; it can be built by different procedures, but either way the models provide insights into to perception of faces whether it is facial memory or facial attractiveness.

Analysis of attractiveness within these MDSs found that male facial attractiveness is different to female facial attractiveness. For male faces, attractiveness is related to the center of the MDS model and to the face distinctiveness. For female faces, attractiveness was not related to those characteristics but rather attractiveness related to femininity. In fact, femininity had a curvilinear relationship with attractiveness such that there was no peak level of femininity for female attractiveness. Hence, female face attractiveness was mostly predicted by femininity and, within the typical range of faces, increased femininity is always considered more attractive. In contrast, however, male faces attractiveness was mostly predicted by averageness. Further, male faces attractiveness related to masculinity with a negative non-monotonic quadratic curve. Male faces that are highly masculine or are extremely non-masculine are less attractive - again, it is more attractive to be average even on the masculinity scale.

The current research explored only subjective measures of faces. It is possible to physically measure features to obtain objective measures of facial dimensions including sexually dimorphic features. Future research could explore the link between an objectively derived MDS and the face-spaces reported here.

In conclusion, irrespective of how the face-space metaphor is implemented, it is able to provide insights into visual facial properties such as distinctiveness and attractiveness. Distinctive faces do appear to be further from the center of MDS versions of face-space than typical faces. The location of the more attractive faces is dependent, however, on the gender of the faces being assessed and averageness, or proximity to the center of the face-space, is not always best for female faces.

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Figure 1. An example of faces of male (left) and female (right).

Table 1. The correlations between the SRMDS dimensions and the DRMDS dimensions for each of the two genders.

	SRMDS dimensions			
DRMDS dimensions	**1**	**2**	**3**	**4**
Male faces				
Size factor	-.02	.26**	.20*	.21*
Shape factor	.05	.03	.24*	.12
Color factor	.68***	.01	-.08	-.02
Complexion factor	.08	-.19	.14	.10
Eyes factor	.06	-.55***	-.05	-.01
Nose factor	.13	.21*	-.13	-.02
Mouth factor	.44***	.02	-.14	.03
Female faces				
Size factor	-.18	-.12	-.24*	.04
Shape factor	.08	.57***	-.20*	.15
Color factor	.79***	-.16	.03	.14
Complexion factor	.28**	-.17	-.02	-.03
Eyes factor	.53***	.09	.03	.06
Nose factor	.09	-.18	-.09	.16
Mouth factor	.12	.14	.08	.01

* p<.05 ** p<.01 *** p<.001

Table 2. Correlations between attractiveness, masculinity/femininity rating and distinctiveness

Variables	Attractiveness	Masc / Fem
Male faces		
Attractiveness		
Masculinity	.14	
Distinctiveness	-.27**	-.04
Female faces		
Attractiveness		
Femininity	.70***	
Distinctiveness	.10	.18

* p<.05 ** p<.01 *** p<.001

Table 3. The correlations between attractiveness, masculinity/femininity (Masc/Fem), distinctiveness with distances in the two MDS models and values on the dimensions.

Variables	**Attractiveness**	**Masc / Fem**	**Distinctiveness**
Male faces			
Distance SRMDS	-.22*	-.17	.47***
Dimension 1	-.24*	.30**	-.32**
Dimension 2	.05	.12	-.17
Dimension 3	.18	.08	-.10
Dimension 4	.11	.23*	.16
Distance DRMDS	-.27**	-.24*	.49***
Size factor	.09	.17	.01
Shape factor	.19	.04	.23*
Color factor	-.31**	.45***	-.27**
Complexion factor	-.30**	.20*	.29**
Eyes factor	-.06	-.16	.03
Nose factor	.08	.01	-.30**
Mouth factor	-.17	.22*	-.04
Female faces			
Distance SRMDS	-.09	-.04	.47***
Dimension 1	-.41***	-.13	-.36***
Dimension 2	.24*	.26**	.17
Dimension 3	.04	-.01	.02
Dimension 4	.00	-.19	-.07
Distance DRMDS	-.02	.07	.52***
Size factor	.01	-.14	-.14
Shape factor	.16	.04	-.03
Color factor	-.45***	-.21*	-.43***
Complexion factor	-.57***	-.33***	.18
Eyes factor	-.09	.21*	-.07
Nose factor	-.15	-.28*	-.23*
Mouth factor	.22*	.06	-.03

* p<.05 ** p<.01 *** p<.001

Table 4. Predicting faces attractiveness linearly and quadratically by the distance from the center of the MDS, distinctiveness and masculinity/femininity (B - coefficient used for the predicting equation; **β** - the standardized value of the coefficient).

	Male faces			Female faces		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Distance SRMDS	-1.117*	0.436	-0.251*	-0.400	0.552	-0.074
Distance SRMDS^2	-7.280*	3.281	-0.217*	3.437	3.343	0.105
R^2	0.093			0.019		
F(2,97)	4.99**			0.93		
Distance DRMDS	-0.088*	0.034	-0.271*	-0.014	0.054	-0.027
Distance DRMDS^2	0.002	0.015	0.014	0.014	0.030	0.048
R^2	0.071			0.003		
F(2,97)	3.70*			0.12		
Distinctiveness	-0.248*	0.098	-0.267*	0.086	0.135	0.064
Distinctiveness^2	-0.003	0.110	-0.003	0.434	0.224	0.195
R^2	0.072			0.046		
F(2,97)	3.76*			2.35		
Masculinity/ Femininity	0.003	0.060	0.005	0.524***	0.054	0.690***
Masculinity/ Femininity^2	-0.146*	0.057	-0.285*	0.119*	0.054	0.156*
R^2	0.083			0.518		
F(2,97)	4.36*			52.21***		

* p<.05 ** p<.01 *** p<.001

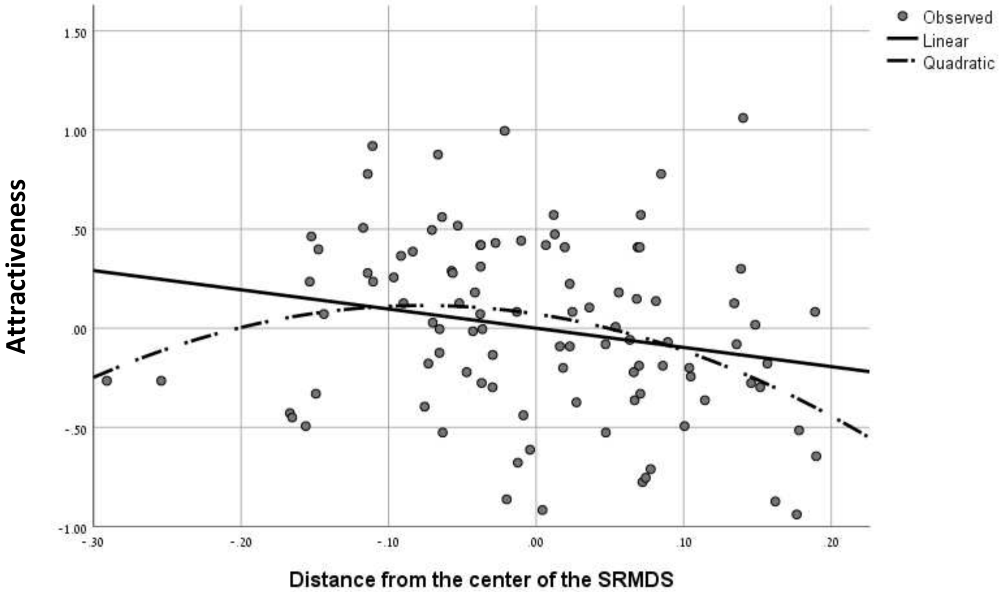

Figure 2. Predicting male-face attractiveness by the distance from the center of the SRMDS linearly and quadratically.

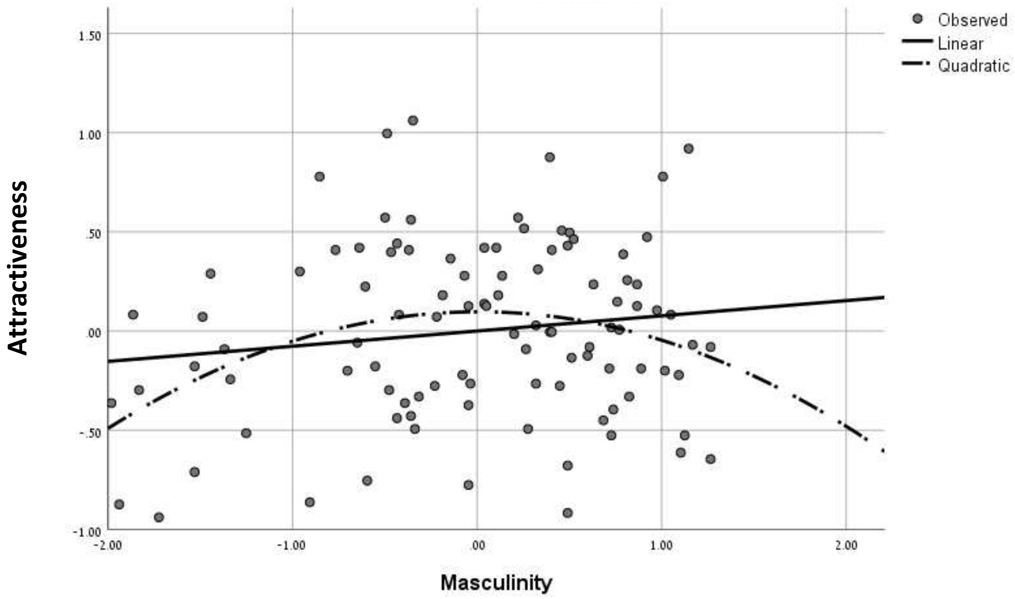

Figure 3. Predicting male-face attractiveness by masculinity linearly and quadratically.

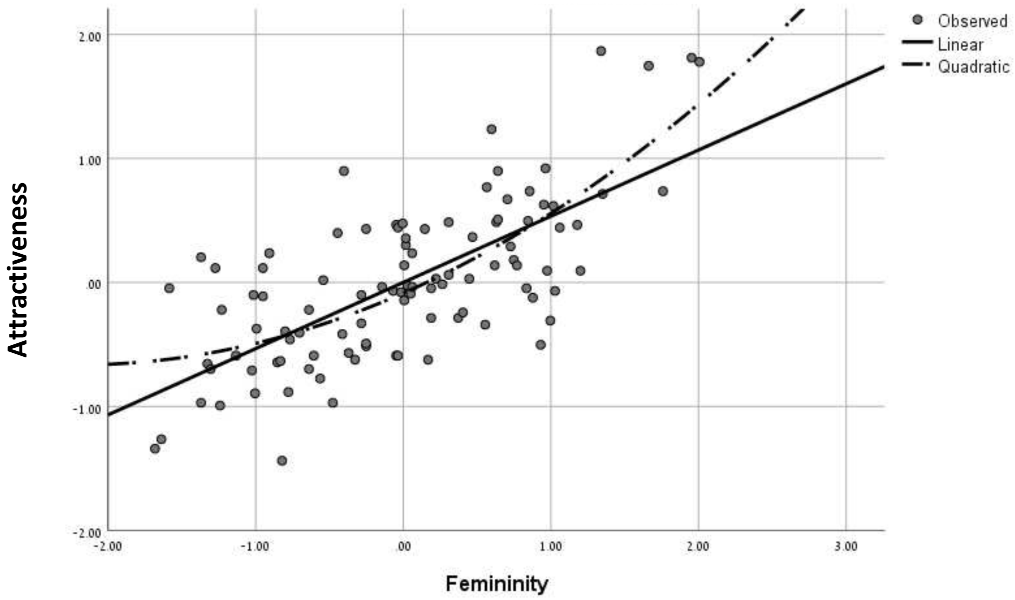

Figure 4. Predicting female-face attractiveness by femininity linearly and quadratically.