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"Geometric morphometric approaches to facial shape and trait attribution"

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Supervisor/Supervisor: ao. Univ.-Prof. Mag. Dr. Katrin Schäfer
To Katrin Schaefer,
and my friends & family

who supported me along the way.
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1. General introduction

This thesis was designed to approach some enduring challenges in face research with geometric morphometric methods. These challenges include the determination of facial shape and features that lead to a certain trait attribution and to link these features back to biological processes (e.g., growth, ageing, sex hormones) and bodily characteristics (e.g., muscle strength, body fat) as well as behaviors. The detection and quantification of these interrelations not only promote our understanding of current social interactions in humans, but are also a prerequisite for meaningful interpretations in the light of evolution. A thorough assessment of these interrelations, however, has only become feasible with progress in morphometric methods.

Geometric morphometrics (GMM) is a fairly recent innovation in quantitative morphometrics (Adams, Rohlf, & Slice, 2004; Weber & Bookstein, 2011). Like earlier approaches it combines the quantification of shape and form with statistical analyses. These are aimed at describing patterns of shape variation within and between groups as well as the covariation of shape with other variables such as age, ecological parameters as well as social and endocrinological factors. GMM also has some unprecedented qualities, namely mathematical superiority, increased statistical power and ease of visualization of the results (Rohlf & Marcus, 1993).

The novel aspects of GMM relevant to my work are:

1. The shape information is captured in the form of Cartesian coordinates of measurement points (so-called landmarks), instead of distances, angles and ratios. This way—for the first time—the relative spatial (geometric) relationships among measurement points are preserved throughout the analyses, which led Rohlf and Marcus to name this approach “geometric morphometrics” in 1993 and to call it “a revolution in morphometrics” (Rohlf & Marcus, 1993).

Landmarks are homologous points across the specimens. They are defined as discrete juxtapositions of tissues, maxima of curvature or extremal points. Sliding semilandmarks, in turn, are parts of a curve or surface. In two-dimensional data (as used in this thesis), semilandmarks are equally spaced along an outline curve, such as the jaw outline. They are allowed to slide between the adjacent landmarks so as to minimize overall “bending energy” before being projected back to the curve (Bookstein, 1997; Mitteroecker & Gunz, 2009). Alternatively, sliding to minimize Procrustes distances would also be possible (Slice, 2007), but was not used in this thesis. Thereafter, semilandmarks are processed like the other landmarks.

Bending energy is a measure of shape change from one landmark configuration to another. The term has its roots in the mechanics of a flat, infinitely thin metal plate, which serves as a model to smoothly interpolate shape changes between two landmark configurations (Bookstein et al., 1999). The same thin-plate spline (TPS) algorithm is applied to produce the so-called deformation grids, which represent the infinitely thin metal plate graphically and relate to the third great advancement of GMM—the potential to visualize statistical results as shapes (see below).
2. Non-shape information of the landmark configurations, including overall size, is removed prior to statistical analyses. If relevant to the research question, overall size can be brought back into the analysis as a single variable termed centroid size (CS). The state-of-the-art procedure for extracting the shape information is a generalized Procrustes analysis (GPA; also called Procrustes superimposition or Procrustes fit) of the raw landmark coordinates (Figure 1). In this process, the centroid of each landmark configuration is translated to the origin of the coordinate system. Then, all configurations are scaled to a centroid size of 1. CS is defined as the square root of the sum of squared deviations of all landmark coordinates of a configuration to the centroid of the same configuration. Then all landmark configurations are rotated iteratively towards their average until the sum of within-landmark variance is minimized. Convergence is usually attained after a few iterations (Mitteroecker & Gunz, 2009). The resulting shape coordinates (Figure 1, right) are then subject to statistical analyses such as shape regression and partial least squares analysis (see below for details). This first step in each GMM analysis also allows estimating a mean shape.

Figure 1. Generalized Procrustes analysis (GPA).
After digitization, all landmark configurations (left panel) are centered, scaled and rotated. This standardization process is based on a least-squares criterion. The resulting coordinates are called Procrustes coordinates or shape coordinates (right panel). They capture shape information invariant to position, isometric size and orientation of the original specimen (or its pictorial representation). Only thereafter can the coordinate values be used for statistical analyses, and differences in these values reflect differences in configuration shapes. Size information is preserved as a separate variable—centroid size (CS)—and might be analyzed individually.
3. As the geometry of the measurements, i.e. the landmarks, is preserved throughout the analysis, statistical results can be visualized as shapes. Furthermore, the above-mentioned TPS deformation grid depicts shape changes between two landmark configurations and makes them readily interpretable (Weber & Bookstein, 2011 for mathematical details). The start configuration or template is thereby superimposed by a grid with quadratic units (Figure 2, left). Then the TPS interpolation function is applied to its vertices. With that, the shape difference to the end configuration or target is modeled as a deformation of this grid (Figure 2, right). When shape differences are subtle, they can be extrapolated to ease pattern recognition and interpretation (Mitteroecker & Gunz, 2009).

Another way to visualize the statistically predicted configurations of two-dimensional data is to unwarp the image of each specimen towards the target and then to average these unwarped pictures pixel by pixel (Rohlf, 2004). Targets for any kind of visualization can be, for example, group means, shapes predicted by a regression or a partial-least squares analysis.

Figure 2. Thin-plate spline deformation grids.
The mechanical properties of an infinitely-thin metal plate are used to model the difference in shape between a template configuration (left) and a target configuration (right) with maximum smoothness (minimal bending). This interpolation function is graphically represented by a grid with uniform quadratic units on the template (such as the sample average) that is deformed towards the target configuration (e.g. plus two standard deviations of mean physical strength). In this example, only the position of the landmark in the middle changed, corresponding to a vertical compression of the grid in the upper half and a relative vertical elongation of the grid units in the lower part (right panel).

4. Shape estimates of multiple predictor variables can be compared statistically and visually (Rohlf & Marcus, 1993). This allows refined hypotheses testing regarding sexual selection, impression formation and face overgeneralization. The latter can occur not only from faces to objects, but also to other human faces (e.g., babyface overgeneralization; Zebrowitz & Montepare, 2008).
The progress in biological shape analysis is tightly linked to physical anthropology (Slice, 2007 for a review). More than fifteen years have passed since geometric morphometrics was first applied to and further developed in osteological analyses (e.g., O’Higgins & Strand Viðarsdóttir, 1999) and the reconstruction of early hominine fossils (Bookstein et al., 1999; O’Higgins, 2000). In 2004, Adams and Rohlf documented the steep increase of publications that involve geometric morphometrics since the early 1990s. One year later, in 2005, Schaefer and colleagues published the first articles that combined geometric morphometrics with rating studies of facial frontal portraits and with hormonal data (Schaefer et al., 2006; Schaefer, Fink, Mitteroecker, Neave, & Bookstein, 2005). Valenzano and colleagues (2006), in turn, focused on facial attractiveness of lateral profiles. Their work identified shape patterns predicted by certain ratings, and the synthesis began: Evolutionary psychology has posed questions like “what makes a face look unattractive–attractive/feminine–masculine/submissive–dominant?” and has tried to link the ratings scales among themselves and to evolutionary principles such as mate choice and intrasexual competition. Physical anthropology has measured skulls to investigate the nature of human sexual dimorphism. Before those articles, the link of ratings to actual (measurable) biological and morphological characteristics, when not completely neglected, had been highly constrained in interpretation due to the methods used in assessing shape and form. These first bridging articles between evolutionary psychology and anthropology are now more than five years old and a review article in 2009 marvelously summarized the advantages and potentials of such a GMM-based “psychomorphospace” (Schaefer, Mitteroecker, Fink, & Bookstein, 2009). Our article on trait attribution to cars was published in 2008 (see Chapter 2.4). It was, however, only in 2010 that reports of other research groups using GMM in face research on living humans became public (Kleisner, Kočnar, Rubešová, & Flegr, 2010; Scott, Pound, Stephen, Clark, & Penton-Voak, 2010). At the same time, we further promoted this approach in several conference posters and talks (e.g., Windhager, Bookstein, Grammer, Thorstensen, & Schaefer, 2009; Windhager & Schaefer, 2010; Windhager, Slice, Bookstein et al., 2008). I am currently looking forward to following how this fruitful synthesis of methods and disciplines will continue and to doing my share in the future.

Before getting into detail on the articles that constitute this thesis, I would like to more closely address the concept and realization of the psychomorphospace (Schaefer et al., 2009) in the course of a typical analysis. The psychomorphospace is both the core and the common factor in the single chapters in this thesis. This GMM-based concept permits “to relate the effects of biological processes on form to perceptions of the same processes” (Schaefer et al., 2009, p. 98) in the same data space (Figure 3).
Figure 3. Concept of the psychomorphospace.

Geometric morphometrics (GMM) is a powerful tool for the systematic assessment and statistical analysis of facial shape in relation to both biological qualities (left) and person attributes (right). The shape estimates of the various predictor variables can be compared statistically and visually. This adaptation of GMM methodology yields a framework in which rigorous testing is possible. Organismal form can thereby serve as intermediate in a causal chain linking biology and perception. The deformation grids in this figure stem from the analyses presented in Chapter 2.2.

It considers covariances of features depicted from naturally occurring shape variation as opposed to ratings of averages. This preserves not only the variability of stimuli in a rating experiment, but also allows the comparison with morphological correlates of biological processes in the same data set. One way to link shape with both perception and biological factors is partial-least squares (PLS) analysis. The corresponding path model is given in Figure 4 (top row).

Clearly, it is also possible to associate shape with a single predictor (Figure 4, bottom row on the left) and to visualize the corresponding shape pattern, either as deformation grid or as morph (Figure 4, bottom row on the right). Note that this morph is not based on the original photographs as in many traditional studies, but on original photographs that are unwarped towards a landmark configuration that is itself the result of a statistical analysis. Accordingly, the amount of contribution of an underlying factor is known. These visualization tools also work in the context of the PLS analysis as outlined in Chapters 2.2 and 2.4.
Figure 4. Geometric morphometric methods.

First, facial shape is parameterized by the Procrustes shape coordinates of a large set of landmarks and semilandmarks (left panels). These shape variables can be related with another block of variables such as physical measurements and trait attribution by a two-block partial least squares (PLS) analysis (Bookstein et al., 2003; Rohlf & Corti, 2000). PLS provides a pair of linear combinations or latent variables (one for facial shape and one for the other variables) for which the covariance between them is a maximum (upper panel). The multivariate pattern of covariances can thus be described effectively as a single dimension. In a shape regression (bottom row, left), a linear regression function is calculated for every shape coordinate, so that shape variation is individually predicted by one (or more) variables. The statistical significance of PLS dimensions and shape regressions is assessed by permutation tests (Good, 2000; Mitteroecker & Bookstein, 2007). Thin-plate spline deformation grids as well as image averaging and unwarping can be used to visualize the results as shapes (bottom row, right: both visualizing the same landmark configuration).

Yet, not only the methodological approach is common to the following chapters, but also the general context of facial shape variation and its link to person perception. The first two articles deal with contemporary human faces, whereas the last three chapters cover the overgeneralization from faces to objects, namely car fronts.

Humans seem to be face experts as soon as they are born (Zebrowitz & Montepare, 2008), and reading faces is part of their lives from then on. It helps to decide who to approach and who to avoid, who to ask for help and who to marry. Within an instant, people can accurately infer age, sex and intentions (Bruce et al., 1993; Willis & Todorov, 2006), and this is not without a biological basis. This topic has fascinated psychologists, painters, political leaders, anthropologists and writers—just to name a few—for hundreds of years. Nonetheless, pinning these attributions down to specific facial forms and features has proven difficult and sometimes impossible. As Johann Caspar Lavater put it in 1866, thinking about the circumstances under which physiognomy (i.e. judging...
human character, physical and psychological condition from facial features) could be science:

“The question will stand simply thus: whether it be possible to explain the undeniable striking differences which exist between human faces and forms, not by obscure and confused conceptions, but by certain character, signs and expressions? Whether these signs can communicate the strength and weakness, health and sickness of the body; the folly and wisdom, the magnanimity and meanness, the virtue and vice of the mind. This is the only thing to be decided; and he who, instead of investigating the question, should continue to claim against it, must either be deficient in the love of truth, or in logical reasoning.” (p. 2).

Narrowing the research question down to a central thesis topic

The geometric morphometric toolkit in general, and the concept of the psychomorphospace in particular, were used to investigate (i) which morphological features underlie the attribution of a person characteristic such as dominance (or submissiveness) when faces of unknown persons are seen and (ii) how these features relate to facial characteristics of other physical and social qualities (strength, prenatal hormone exposure, masculinity,…).

Dominance is one of two fundamental dimensions in human impression formation (Kervyn, Yzerbyt, & Judd, 2010; Todorov, Said, Engell, & Oosterhof, 2008) and is strongly associated with age and sex. In general, men are regarded as more dominant than women, and older people as more dominant than younger ones (Ashmore & Tumia, 1980; Chiao, Bowman, & Gill, 2008; Karafin, Tranel, & Adolphs, 2004). At the same time, there is also large variation of perceived dominance within individuals of the same age and sex (Neave, Laing, Fink, & Manning, 2003; Quist, Watkins, Smith, DeBruine, & Jones, 2011). While there is considerable evidence for stereotypical trait perception (Ashmore & Tumia, 1980; Hess, Adams Jr., & Kleck, 2005; Zebrowitz et al., 2012), studies dealing with biological and physical causes and consequences are still scarce. Moreover, the corresponding facial cues and their relationship to other qualities were barely scrutinized, often due to less powerful morphometric approaches (Holland, 2009).

The first article in this thesis (Chapter 2.2) compared adult male facial features eliciting dominance attributions, termed male facial dominance, to facial indicators of potential biological correlates (e.g., physical strength, body fat) and to those of other social inference (perceived attractiveness, perceived masculinity).

Previous studies indicated that prenatal testosterone exposure is a candidate for endocrinological predisposition of facial dominance (Neave et al., 2003; Schaefer et al., 2009). Yet, it remained unclear whether these facial characteristics are developed during sexual maturation or at least in part before puberty. The second article (Chapter 2.3) thus aimed to quantify the relationship between prenatal testosterone exposure (approximated through the second-to-fourth digit ratio) and facial shape in young boys. It was hypothesized that a lower digit ratio (higher prenatal testosterone exposure) was
associated with increased facial robusticity—a shape pattern typically perceived as dominant and masculine in adult men (Johnston, 2006; Schaefer et al., 2009).

The next two articles (Chapters 2.4 and 2.5) tested whether trait attributions to people are generalized to objects with similar to face-like geometrical properties such as car fronts. If social perception is applied to car fronts, the same pattern of trait attribution, i.e. the same fundamental dimensions of impression formation (dominance/competence and trustworthiness/warmth: Cuddy, Glick, & Beninger, 2011; Todorov et al., 2008) are to be expected. Likewise, similar proportions and shape features as in faces should cue to perceived dominance, masculinity, and other personality traits and emotions. Finally, eye movement recordings (Chapter 2.6) were used to confirm the specific analogies of single elements of a car front to explicit facial features. As such, this study answered questions like the following: Are headlights of cars equivalent to eyes in faces? Furthermore, it extended the questionnaire data on parallels of car and face perception towards the preconscious level of information processing.
2. Empirical work

2.1 Indication of my own contribution

Table 1. List of my contribution to the five research articles that constitute the empirical work of this thesis. The list of activities is adapted from Winston (1985).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Paper strength</th>
<th>Paper digit ratio</th>
<th>Paper cars Austria</th>
<th>Paper cars Ethiopia</th>
<th>Paper cars eyetracking</th>
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<tr>
<td>Conceptualizing and refining research ideas</td>
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<td>Literature search</td>
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<td>Creating research design</td>
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<tr>
<td>Instrument selection</td>
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<tr>
<td>Instrument construction/questionnaire design</td>
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<tr>
<td>Selection of statistical tests/analyses</td>
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<td>Performing statistical analyses and computations</td>
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<td>Drawing the figures</td>
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<tr>
<td>Collection and preparation of data (gathering, entering)</td>
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<tr>
<td>Interpretation of statistical analyses</td>
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<td>First draft of manuscript</td>
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Contribution:
- major single, × major together with at least one coauthor, (X) minor, – no or non-significant
2.2 Geometric morphometrics of male facial shape in relation to physical strength and perceived attractiveness, dominance, and masculinity (published in the *American Journal of Human Biology*)


Journal Citation Report (ISI) Impact factor 2011: 2.267
Anthropology: Rank 9/79, Q1

![Estimated facial shape of a physically strong man.](image)
Original Research Article

Geometric Morphometrics of Male Facial Shape in Relation to Physical Strength and Perceived Attractiveness, Dominance, and Masculinity

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Objectives: Evolutionary psychologists claim that women have adaptive preferences for specific male physical traits. Physical strength may be one of those traits, because recent research suggests that women rate faces of physically strong men as more masculine, dominant, and attractive. Yet, previous research has been limited in its ability to statistically map specific male facial shapes and features to corresponding physical measures (e.g., strength) and ratings (e.g., attractiveness).

Methods: The association of handgrip strength (together with measures of shoulder width, body height, and body fat) and women’s ratings of male faces (concerning dominance, masculinity, and attractiveness) were studied in a sample of 26 Caucasian men (aged 18–32 years). Geometric morphometrics was used to statistically assess the covariation of male facial shape with these measures. Statistical results were visualized with thin-plate spline deformation grids along with image unwarping and image averaging.

Results: Handgrip strength together with shoulder width, body fat, dominance, and masculinity loaded positively on the first dimension of covariation with facial shape (explaining 72.6%, P < 0.05). These measures were related to rounder faces with wider eyebrows and a prominent jaw outline while highly attractive and taller men had longer, narrower jaws and wider fuller lips.

Conclusions: Male physical strength was more strongly associated with changes in face shape that relate to perceived masculinity and dominance than to attractiveness. Our study adds to the growing evidence that attractiveness and dominance/masculinity may reflect different aspects of male mate quality. Am. J. Hum. Biol. 23:805–814, 2011. © 2011 Wiley Periodicals, Inc.

INTRODUCTION

Sexual selection theory predicts that females gain a heritable benefit for their offspring by mating with ornamental males of better phenotypic and genetic quality (Anderson, 1994). In humans, it is thought that such quality is signaled through certain morphological characteristics, such as facial masculinity in men (Pound et al., 2006; Scheib et al., 1999; Swaddle and Reijerson, 2002). Facial masculinity is influenced by androgen action, that is, the presence of sex steroids (principally, testosterone [T] and its metabolites), which lead to the development and expression of facial characteristics that are typically male (Bardin and Catterall, 1981; Schaefer et al., 2005; Verdonck et al., 1999). Although facial growth in women ceases around age 14, men’s growth continues—increasing facial sexual dimorphism (Bulgynia et al., 2006; Ursi et al., 1995). Adult men generally have longer chins than women, wider jaws, lips, and noses, more pronounced supra-orbital tori, and thicker eyebrows (Burton et al., 1993; Ferrario et al., 1998; Fink et al., 2005; Gangestad and Thornhill, 2003). Empirical studies on the visual perception of men’s faces have reported a positive association between T and perceived masculinity (Penton-Voak and Chen, 2004) and attractiveness (Roney et al., 2006); but see Neave et al. (2003)). This has led to the suggestion that women are sensitive to facial cues associated with T and that they use these cues to judge male attractiveness (Roney et al., 2006).

One anthropometric feature that may be related to masculinity and dominance is physical strength, because of its association with T (e.g., Auyeung et al., 2011; Bhasin et al., 2001). Even after controlling for body height and weight, men—on average—are stronger than women (Miller et al., 1993; Mulsman and Brouwer, 2005), and T plays a key role in this robust sex difference, as it has potent effects on the musculoskeletal system (Evans, 2004; Neave, 2008).

Fink et al. (2007) hypothesized that women can assess male physical strength from facial features and consider them in their evaluation of mate quality. To test this hypothesis, they measured men’s handgrip strength (a measure of overall physical strength, Rantanen et al. (1999) and Wind et al. (2010)) and asked females to rate the facial images of these men on dominance, masculinity, and attractiveness scales. Grip strength correlated significantly and positively with all three rated attributes, that is, faces of physically stronger men were perceived as being more dominant, masculine, and attractive. Further support for this association comes from Sell et al. (2009), who found that participants were able to accurately judge men’s physical strength and fighting ability from their facial and bodily photographs. Although these data provide corroborating evidence that women can assess men’s physical strength from faces and bodies, neither study...
used morphometric methods to investigate facial features associated with strength.

Therefore, in the present study, we statistically assessed men’s facial shape in relation to hand grip strength and to women’s perception of dominance, masculinity, and attractiveness by using geometric morphometric (GMM) toolkit (Bookstein, 1991; Mitteorecker and Gunz, 2009). Body height, shoulder width, and body fat proportion were included as possible confounding variables in the analyses, as they have been reported to correlate with strength and/or face shape (Fink et al., 2007; Gallup et al., 2007; Sánchez et al., 2009; Sell et al., 2009). Finally, we investigated and visualized how these measures individually predicted male facial shape.

MATERIALS AND METHODS

Male facial photographs and anthropometric measures

Participants were male Caucasians recruited from the student population in Goettingen, Germany. Digital face images in frontal view with a neutral expression were collected in the course of a larger project on male physical appearance (for a previous report, see Fink et al. (2007)). The Frankfurt horizontal plane (Farkas, 1994a) was used as reference for head positioning, with the camera set at eye height. Of the initial sample, six men were discarded from the GMM analysis, because variation in the orientation of the head would have biased landmark coordinate data and subsequent visualizations. The remaining sample of 26 men ranged from 18 to 32 years in age (mean = 24.00, SD = 3.67). Handgrip strength was measured with a hand dynamometer (Jamar, Sammons Preston) in kilograms force (kgf). For each hand, participants were instructed to squeeze the dynamometer with maximum strength. The observed mean and range of grip strength in our sample is similar to published data for another German sample (Guenther et al., 2008). The calculated average of right and left hand measures was used for further analyses and uncorrelated with age (Pearson r = 0.037, P = 0.858). Mean and maximum grip strength (over left and right hands) were strongly correlated (Pearson r = 0.968, P < 0.001).

In addition, body height (in cm) and the percentage of body fat were measured (Tanita TBF-300 body composition analyzer).

Female face ratings

Seventy-nine women—mainly students from the undergraduate and graduate population of the University of Goettingen, Germany, aged 19–32 years (mean age = 23.33; SD = 2.73)—rated the appearance of each face on dominance, masculinity, and attractiveness scales (data obtained from Fink et al. (2007)). Faces were displayed in random order on a computer screen and judged on a seven-point Likert scale (1 = extremely subordinate/feminine/unattractive, 7 = extremely dominant/masculine/attractive). All women reported not to have seen any of the men before. Inter-rater reliability was high with a Cronbach’s α of 0.96 for dominance, masculinity, and attractiveness attributions, respectively. Thus, all further analyses were based on the mean ratings for each stimulus (which showed a reasonable amount of variation for all three attributes, Table 2).

Facial landmarks

Thirty-eight fixed somatometric landmarks and 32 semi-landmarks were used to capture the shape of each face (Fig. 1a, Table 1). They were defined following Kolar and Salter (1997) and Farkas (1994b). Semi-landmarks are points sampled along curves that are allowed to slide along these curves until overall “bending energy” is minimized. They can then be treated as classical landmarks in further analyses (Bookstein, 1997; Bookstein et al., 1999).

The digitizing process included equal spacing of semi-landmarks along each curve as starting positions for the sliding and was realized in tpsDig2 (Ver. 2.12; Rohlf, 2008a).

Statistical analyses

As opposed to traditional morphometric approaches, GMM is based on two-dimensional Cartesian coordinates of the landmarks and semi-landmarks [for recent reviews of GMM methods see Mitteroecker and Gunz (2009) and Slice (2007)]. One major advantage of this approach is that the association of any kind of form (male faces in our case) with other measures is calculated while preserving the geometry of landmark configurations. Thus, the results of statistical analyses can be visualized as forms, which are more readily interpretable than tables of numbers alone.

After a generalized Procrustes superimposition analysis (GPA; Rohlf and Slice, 1990) to standardize location, orientation, and scale of the facial configurations, the semi-landmarks were slid as to minimize the amount of bending energy between each configuration and the Procrustes average of all the specimens in an iterative process (in tpsRelw 1.46; Rohlf, 2008b). The aligned configurations were then “symmetrized” (i.e., each landmark configuration was averaged with its relabeled reflection, Mitteroecker and Gunz (2009)). The resulting shape coordinates (Fig. 1b) served as the basis for subsequent analyses. A two-block partial least squares (PLS) analysis was conducted on the shape coordinates and the trait variables. PLS yields linear combinations that optimally (in a least-squares sense) describe the covariances among two sets of variables (Rohlf and Corti, 2000; Streissguth et al., 1993). The statistical significance was evaluated by permutation tests (Good, 2000). Furthermore, we calculated multivariate regressions of shape coordinates onto each physical and appearance variable (shape regressions with single predictors) and report the uncorrected P-values. In an exploratory approach like this present, we think that it is not straightforward to decide upon how many variables should be corrected for the family-wise error. This way, we allow the reader an unbiased judgment.

Thin-plate spline (TPS) deformation grids (Bookstein, 1991) were used to visualize the association between facial shape and the traits. The “consensus” configuration (i.e., the average configuration of the 26 male faces) served as a template for all visualizations. Cubic splines were used to connect outline landmarks, thus enhancing face recognition. Additionally, the predicted configurations that result from the shape regressions were also visualized using the original photographs. The photograph of each man was “unwarped” to the target configuration, so that the originally digitized landmarks coincided with the landmarks of the specified target configuration (in our case, the pre-
dicted shape for a specific value of the predictor variable in the shape regression). These unwarped images were then averaged resulting in a single facial image per target shape (in tpsSuper 1.14; Rohlf, 2004).

Analyses and visualizations were conducted in SPSS 15, tpsRelw 1.46 (Rohlf, 2008b), Mathematica 6, tpsPLS 1.18 (Rohlf, 2005a), tpsRegr 1.31 (Rohlf, 2005b), and tpsSuper 1.14 (Rohlf, 2004).

RESULTS

We identified the covariation of face shape with handgrip strength, somatometric measures, and female ratings using (a) a multifactorial approach (PLS analysis) and (b) by running regression analyses with single predictors (shape regressions). Sample descriptives are reported in Table 2.

Partial least squares analysis

Partial least squares analysis identifies linear combinations of variables that optimally (following a least-squares criterion) describe the covariation among two sets of variables. One set comprised the shape coordinates of the 26 male faces, while the other comprised handgrip strength, somatometric measures (body fat, body height, and shoulder width), and perception measures (dominance, masculinity, and attractiveness). The first pair (shape + traits) of PLS axes accounted for 72.6% of squared covariation, the second pair added 17.9%, and the third pair added 4.8%. Only the first dimension of covariation was statistically significant after 9,999 permutations ($P = 0.023$).

Figure 2 visualizes the first two axes for the block of trait variables (see the electronic Supporting Information for a rotating three-dimensional scatter plot of the trait variable loadings). The biplot depicts the 26 male faces as points and the trait variables as vectors. The direction of the vectors indicates that dominance and masculinity associations were based on highly similar facial characteristics that differed slightly from facial shapes of men with high handgrip strength. Morphological correlates of handgrip strength also differed from those of body fat. Body height and attractiveness vectors diverged from the other four vectors. The divergence of attractiveness from the dominance and masculinity vectors resemble the pattern of bivariate correlation coefficients of these variables. Perceived dominance and masculinity were highly positively correlated (Pearson $r = 0.91$, $P < 0.001$), whereas the correlations between intersexually perceived attractiveness and these two variables were positive but moderate (dominance: Pearson $r = 0.44$, $P < 0.05$; masculinity: Pearson $r = 0.54$, $P < 0.01$).

The first pair (shape + traits) of PLS axes accounted for 72.6% of the squared covariation and gives a low-dimensional representation of the association between facial shape and the measured traits (Fig. 3). The contributions of the individual trait variables (strength, somatometric measures, and appearance) were visualized in a profile plot (Fig. 3, upper panels). The coefficients of standardized variables for the first dimension were—in decreasing order: body fat (0.57), shoulder width (0.45), handgrip strength (0.38), dominance (0.36), masculinity (0.36), body height ($-0.20$), and attractiveness ($-0.18$). The deformation grid for each “profile” ($\pm 2$ SD) is given below. The left profile ($-2$ SD) could be considered “slender,” whereas the right ($+2$ SD) might be summarized as “heaviest.” The morphological correlate of “slender” is an elongated face as indicated by the vertically stretched grid. Local grid deformations suggested that “slender” faces had more angular jaw lines ending in pointer chins than “heaviest” faces.
TABLE 1. Landmark definitions and operationalization following Kolar and Salter (1997) and Parkas (1994b)

<table>
<thead>
<tr>
<th>Landmark (LM) definitions and operationalization for frontal photographs of faces approximating the Frankfurt horizontal plane</th>
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<tbody>
<tr>
<td>Forehead</td>
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<tr>
<td>Nose</td>
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<tr>
<td>Mouth</td>
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<td>Jaw line</td>
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<tr>
<td>Jaw line</td>
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</table>

Although digitized for the left and the right side of the face according to the same definitions, only those on the right side are described verbally in the table to enhance visibility of the landmarks and labels in Figure 1. Names of traditional anthropometric measurement points are in small capitals, sliding semi-landmarks in italics. "LM" describes bilateral measurement points; "M" marks landmarks on, or close to, the facial midline (= midaxis, a line through nasion, subnasale, and menton, Parkas (1994b)), that thus have no right- or left-hand counterpart.

TABLE 2. Descriptive statistics of physical and perception variables (n = 20 men)

<table>
<thead>
<tr>
<th>Physical</th>
<th>Handgrip strength (kg)</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body fat (%)</td>
<td>8.4</td>
<td>54.00</td>
<td>60.00</td>
<td>54.00</td>
<td>7.99</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>170.0</td>
<td>180.0</td>
<td>179.73</td>
<td>4.98</td>
<td></td>
</tr>
<tr>
<td>Body width (cm)</td>
<td>40.0</td>
<td>50.5</td>
<td>44.31</td>
<td>2.38</td>
<td></td>
</tr>
<tr>
<td>Perception</td>
<td>Attractiveness</td>
<td>1.46</td>
<td>4.44</td>
<td>2.41</td>
<td>.78</td>
</tr>
<tr>
<td>Dominance</td>
<td>2.03</td>
<td>6.02</td>
<td>3.42</td>
<td>.73</td>
<td></td>
</tr>
<tr>
<td>Masculinity</td>
<td>2.45</td>
<td>6.02</td>
<td>3.82</td>
<td>.75</td>
<td></td>
</tr>
</tbody>
</table>

Generally, the grid for a "heaviest" man (Fig. 3, right) is horizontally compressed, which indicates that the overall face shape is round. This compression is especially pronounced in the lower face with a jaw outline that is rounder than that of a slender profile. The grid is horizontally stretched in the region between eyebrows and eyes, the lips are thinner, and the eyes and the nose are smaller.

Shape regressions

Morphological correlates of each physical and rating measure were further investigated, separately, using multivariate regressions of the shape variables on each trait (shape regressions). The target configurations in Figures 4 and 5 are ± 3 SD of each variable from the consensus estimate of the same variable. The shape estimate of plus three standard deviations was also used as the target configuration for the image unwarping and image averaging (Fig. 6).

The facial correlates of handgrip strength and percentage of body fat are visualized in Figures 4 and 6. The deformation grids show that with increasing strength and body fat proportion face shape changes into a rounder face with a lower forehead. The grid is horizontally stretched in the region between the eyebrows and eyes with rising strength but not with higher body fat. Although the relative size of the eyes remains constant in the shape regression onto strength, it decreases with increasing body fat.
proportion. There is a broadening of the lower face in both shape regressions, yet the particular rounding of the chin is a characteristic of high body fat but not of high strength. In the opposite direction, this trend depicts a jaw that becomes more angular with lower body fat proportion (Figure 4, left). In both shape regressions, the relative prominence of the eyebrows, nose, and lips is reduced with high values of the predictor variable. The shape regression onto handgrip strength explained 6.8% of the variance ($P = 0.091, 1,000$ permutations), those onto body fat 13.7% ($P = 0.003, 1,000$ permutations).

The association of male facial shape and appearance (as rated by women) is shown in Figures 5 and 6. In accordance with results from the PLS analysis and bivariate correlations, the shape regressions for perceived dominance and masculinity hardly differed, whereas the pattern of shape changes associated with attractiveness differed from both (Figs. 5 and 6). Because shape estimates of the subordinate/dominant and feminine/masculine scales were almost identical, we give a single verbal description for both dimensions. The left column (Fig. 5) depicts the deformation from the sample average facial shape to a male face that female raters perceived as more subordinate and feminine than average. The corresponding grid is vertically stretched, an effect that is especially pronounced in the lower face, indicating an elongated face. The lower jaw and the chin are relatively narrow. The vertical compression of the grid in the lip region suggests fuller lips. The eyes are larger and the nose appears longer than those of a masculine and dominant looking male face. The eyebrows are thinner and further apart.

![Fig. 3. Visualization of covariation of male facial shape with handgrip strength, somatometric variables, and intersexual perception (in italics). The left grid shows the shape change from the origin (contributions of all trait variables are zero) minus 2 standard deviations along the first pair of PLS axes. This corresponds to the face of a man who is relatively tall and rated as attractive by women, whereas his body fat proportion is relatively low as is his handgrip strength (strength), shoulder width (shoulder w.), attributed dominance (dom.), and masculinity (masc.) as indicated by the top left panel. The standardized score for each variable is plotted as vertical line extending from a horizontal axis that corresponds to the mean. Contrary, the grid on the right (plus two standard deviations along the first pair of PLS axes) visualizes the deformation towards the face of a man with a relatively higher body fat proportion, shoulder width, and handgrip strength, but lower body height. For the perception variables, displacement vectors (top right) further show a positive contribution of perceived masculinity and dominance and a negative loading of attractiveness.](image-url)
Fig. 4. Male facial shape changes with strength and body fat. The shape change from the average male face to minus and plus three standard deviations of mean left- and right-handgrip strength (upper panel) and body fat proportion (lower panel) is visualized ($n = 26$). Equivalent numeric expressions are given below each picture. The thin-plate spline deformation grids show differences in facial shape determined by these two biological variables, especially in the jaw line, the eyes, and mid-face between the eyebrows.

Hence, masculine and dominant looking male faces are characterized by a wider and more prominent lower jaw and comparably shorter noses and smaller eyes than the average man. The horizontally compressed grid in the lip region shows smaller lips (Fig. 5 on the right, Fig. 6) in comparison with less masculine and less dominant rated faces. The shape regression onto dominance explained 8.0% of the variance ($P = 0.060$, 1,000 permutations), the one onto masculinity 7.3%.

Different shape characteristics were found for the morphological correlates of perceived attractiveness (bottom row in Fig. 5, on the right in Fig. 6). The deformation of the average face into an unattractive face leads to a rounding of the lower face, a vertical stretching of the grid in the chin region, and a horizontal compression in the region of the eyes and eyebrows. The region of the mouth became comparably smaller as did the mid-face. On the other hand, the predicted configuration of an attractive male face is characterized by a vertical stretching in the region of the eyebrows, eyes, and mid-face. The horizontal stretching of the lip region suggests a wider mouth. The jaw line is more angular than in the unattractive male face and the chin more pointed. The shape regression explained 3.3% of the variance.

Table 3 summarizes the face shape changes associated with increasing handgrip strength, body fat proportion, perceived dominance, masculinity, and attractiveness. This qualitative comparison of the different associations with male facial shape and facial features is based on the individual shape regressions visualized in Figs. 4–6.

Fig. 5. Thin-plate spline deformation grids of shape regressions onto perceived dominance, masculinity and attractiveness. The male average face is deformed to minus and plus three standard deviations of each variable ($n = 26$). The corresponding numerical values are given below the deformation grids. Facial shapes and features signaling dominance and masculinity in men are highly similar and deviate from the ones that lead to increased attractiveness attributions by women.

**DISCUSSION**

This study explored the relationship of male handgrip strength and female ratings of male faces to the specific characteristics of male face shapes by utilizing GMM. We found that handgrip strength, a proxy for total body strength (Rantanen et al., 1999; Wind et al., 2010), was associated with a robust face yielding a rounded outline, wide eyebrows, and a well-curved jaw line. This face looked similar to one associated with a high body fat proportion but not with either high or low body height. Moreover, faces of physically strong men were more similar to faces women perceived as dominant and masculine than to those they rated as highly attractive. Instead, attractive male faces appeared to be more closely linked with body height. Thus, attractive and dominant/masculine face shapes appear to be dissociable despite positive correlations of strength, dominance, masculinity, and attractiveness.
Previous research has established a link between physical, morphological, and perceptual characteristics. For instance, adult male physical strength can reliably be judged by women viewing faces alone (Sell et al., 2009), and faces of physically strong men are perceived as dominant, masculine and attractive (Fink et al., 2007). Along this line, Gallup et al. (2010) reported positive correlations of handgrip strength with socially dominant and aggressive behavior as rated by unacquainted persons.

The present study elaborates these findings by focusing on face shape, thus assessing anthropometric and perceptual covariation. Our data show that both physically strong men and those that women perceive as masculine and dominant had a broad middle and lower face, a short nose, and thin lips. This similarity of masculinity and dominance-related facial features converges with previous findings by Schaefer et al. (2009). These authors assessed the facial shape corresponding to high and low prenatatal T levels (via 2D:4D ratio) and described a strong similarity to facial features related to women’s dominance and masculinity ratings. Hinck et al. (2006) found that men with a lower 2D:4D ratio had greater physical fitness and propose a proximate link between these variables via the amount of exercise the men engaged in. Thus, our result of a widened region between the eyebrows with increasing physical strength might be attributable to a thickening of the Procerus muscle, which is involved in flaring nostrils (van Lunteren and Stroh, 1988) and increased air-intake during physically demanding activity.

Our study's face shape regressions, using single predictor variables, indicated that dominance and masculinity attributions shared some communalities with, but also differed from those features that corresponded to physical strength: strong men were characterized by a widened region between the eyebrows and eyes (i.e., the eyes were further apart), thinner and higher eyebrows, larger eyes with a rounder shape of the visible iris, a narrower mouth, and a less prominent chin relative to the rest of the lower face. These results are in line with Wade et al. (2004), who found that Caucasian women rated those drawings of “prototypical” male African American faces as more dominant, masculine, and strong. These drawings show facial characteristics that resemble those corresponding to shape regressions upon these traits in our study. Research using digitally manipulated male faces also supports our results by indicating that females rated males with an increased facial height and a prominent lower jaw as more dominant, but not as more attractive (Swaddle and Reierson, 2002). Keating (1985) reported that smaller eyes and thinner lips increased dominance ratings, while manipulations of jaw shape and brow thickness did not affect them. The difference between this and our results, at least in part, may be due to different methodologies used to study the link of face shape and perception. In the Keating study, people's perception was studied in response to single feature manipulations, whereas this present study is concerned with the shape-perception link by considering the face as a single geo-
metric whole. Despite the power of the GMM methodology, a sample of 26 subjects inevitably limits the conclusions that can be drawn. Although the PLS model, that yields our main result, is significant (and unaffected by family-wise error), among the shape regressions, merely the one onto body fat proportion is statistically significant (even after adjusting the significance level for multiple pairwise comparisons). The lack of significance here is most likely due to sample size. The shape patterns for dominance, masculinity, and attractiveness, however, closely resemble those found for a British sample (Schafer et al., 2009). Thus, the deformation grids including the one for physical strength can be assumed to show a morphological signal rather than statistical noise. Yet, only follow-up studies based on a larger sample will be able to confirm that smaller variations, such as the widening between the eyebrows for stronger men, are not an artifact.

With regard to the relationship of physical strength with face shape and body morphology, the evolutionary psychology literature is remarkably scarce, although anthropological and medical studies suggest a strong interrelation. In a qualitative comparison study, Donofrio (2000) reported that a high amount of facial fat is often linked to a high body fat proportion. More recently, Coetzee et al. (2009) showed that subjects were able to accurately categorize individuals as under- or overweight based on frontal facial photographs. The present study highlights specific similarities and differences between facial configurations associated with high body fat and faces of strong men. Although both share a prominent jaw, the shape of the jaw line is much rounder in men with a high percentage of body fat than in strong individuals. This may be due to the size difference of massester muscle, which is known (together with temporal muscles for jaw closing) to correlate positively not only with weight but also with muscular strength of the upper and lower limb (Raadsheer et al., 2004). A thicker (and stronger) massester could also explain the above mentioned difference in jaw line shape between strong and masculine/dominant faces.

Although the shape of eyebrows, nose, and mouth were very similar in faces of men with high amounts of body fat and strong men, the visible part of the iris was not. One reason for this might be that in individuals with high body fat proportion a large part of the iris is covered due to an increased fat storage in the upper and lower lids as well as in the eyebrow pads (Rohrich and Pessa, 2007). Additionally, we found the region between the eyebrows to be much wider and more prominent in the shape estimate for strong men when compared with those with a high body fat proportion, which might be attributable to the thickening of the Procerus muscle in individuals who do physical exercise and strength training (van Lunteren and Strobl, 1988).

Studies investigating the association of physical strength and body mass-index (BMI) report equivocal results. In a large longitudinal sample of German men, Guenther and colleagues (2008) found a positive correlation of body height and weight with handgrip strength, but not with BMI. Ertem et al. (2003) did not find a correlation between BMI and hand grip strength measures in Turkish men, neither did Archer and Thanzami (2009) in Indian Mizzos. In contrast, Koley and Yadav (2009) reported a positive association of handgrip strength and BMI in Indian cricket players and controls. Yet, a positive correlation of percentage of body fat with handgrip strength was detected in cricketers only.

Previous research has suggested a link between strength and attractiveness. In a cross-cultural study, women rated an average (or mesomorphic) masculine body shape indicative of greater muscle mass as very attractive, whereas a disproportionately high body fat proportion (endomorphic) as least attractive (Dixon, 2009). Furthermore, Frederick and Haselton (2007) found support for an inverted U-shaped association between masculinity and attractiveness, according to which moderate muscular body types were most attractive. In line with Hönekopp et al. (2007), who found physical fitness to be positively associated with body but not with facial attractiveness in men, our PLS analyses showed that the pattern of morphological features related to high perceived attractiveness is not closely related to any pattern predicted by another variable under investigation. We replicated these results using shape regressions. Although strong and attractive men share relatively large eyes, the prominence of eyebrows was only observed in masculine/dominant and not in strong men. The attractive facial shape is comparably longer and more dolichocephalic than in very strong, dominant, and masculine-rated men. When perceived attractiveness is high, the lower jaw is narrower and not square and especially the lower lip is wider and fuller. Thus, our results parallel those of Schaefer et al. (2009) and are in line with Cunningham et al. (1990), who concluded that a combination of both mature and so-called neonate features make a male face attractive. The latter reported that prominent cheek bones, chin area, and eyebrow thickness as well as large eyes, and small noses correlated positively with attractiveness. Indeed, the degree of perceived facial babyishness is positively correlated with the attribution of honesty, warmth, and sincerity—attributions typically associated with femininity and submissiveness (Ashmore and Tumia, 1980)—even within attractive faces (Berry, 1991). These findings add to the growing evidence that attractiveness and dominance/masculinity may reflect different aspects of male mate quality.

Embedded in the evolutionary psychology framework, Puts (2010) elaborated on the idea that the human male’s anatomy and behavior may largely be explained in terms of intrasexual selection, more specifically, by contest competition. He argues that excluding competitors by force or threatening force precedes and, thus, widely overrides other mechanisms in sexual selection such as mate choice and sperm competition. According to Sell and colleagues’ (2009) formidable hypothesis, fighting ability, which is closely linked to resource-holding potential, is a highly pertinent factor in mate selection. The authors suggest that facial features perceived as masculine and dominant are cues of physical strength and hence formidable, which should be desirable for women. In support of this, Pilet and Stulp (2010) reported a negative association of (handgrip) strength and childlessness in male retirees of a large European sample from 12 countries. Although attractiveness is moderately positively correlated with strength, perceived masculinity, and dominance, our study showed that these variables contribute differently (in direction and magnitude) to the first dimension of covariation with facial shape. Future studies will be needed before one can conclude that it is physical strength.
that mediates the relationship of attractiveness and masculinity and dominance [as proposed by Bell et al. (2009)] rather than testosterone per se.

In conclusion, physical strength and facial appearance, particularly of men, has been of interest to human biologists and evolutionary psychologists, because they are assumed to signal aspects of male quality. However, no study has yet provided a convincing decomposition with regard to the mediating facial features (i.e., which shapes and features are associated with high body strength or body fat, and which of these in turn trigger certain trait attributions), mainly because of methodological constraints on statistical shape assessment and shape estimation. In addressing this issue, we used two different approaches, one multifactorial (two-block PLS) and one using single predictor variables (shape regressions) to identify morphological correlates of (handgrip) strength, body fat proportion, and women’s perception of dominance, masculinity, and attractiveness in adult male faces. TPS deformation grids as well as image unwarping and image averaging provide a comprehensive visualization of the associated facial shapes. The main finding of this study is that despite positive correlations between male physical strength and perceived dominance, masculinity, and attractiveness, there are common but also distinct facial features associated with these variables. We believe that a thorough statistical assessment of facial shape—which has only recently become available utilizing GMM—is a valuable approach to refined hypothesis testing in sexual selection.

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LITERATURE CITED


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2.3 Second-to-fourth digit ratio and facial shape in boys: the lower the digit ratio, the more robust the face (published in the Proceedings of the Royal Society B: Biological Sciences)


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Second-to-fourth digit ratio and facial shape in boys: the lower the digit ratio, the more robust the face

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During human ontogeny, testosterone has powerful organizational and activational effects on the male organism. This has led to the hypothesis that the prenatal environment (as studied through the second-to-fourth digit ratio, 2D:4D) is not only associated with robust adult male faces that are perceived as dominant and masculine, but also that there is an activational step during puberty. To test the latter, we collected digit ratios and frontal photographs of right-handed Caucasian boys (aged 4–11 years) along with age, body height and body weight. Using geometric morphometrics, we show a significant relationship between facial shape and 2D:4D before the onset of puberty (explaining 14.5% of shape variation; p = 0.014 after 10,000 permutations; n = 17). Regression analyses depict the same shape patterns as in adults, namely that the lower the 2D : 4D, the smaller and shorter the forehead, the thicker the eyebrows, the wider and shorter the nose, and the larger the lower face. Our findings add to previous evidence that certain adult male facial characteristics that elicit attributions of masculinity and dominance are determined very early in ontogeny. This has implications for future studies in various fields ranging from social perception to life-history strategies.

Keywords: children; digit ratio; dominance; facial shape; geometric morphometrics; testosterone

1. INTRODUCTION

Human second-to-fourth digit ratio (2D : 4D)—the relative length of index to ring finger—and facial shape are covered separately in a rapidly increasing number of research articles (the 2D : 4D ratio alone was the topic of at least 306 publications until early 2009 [1], and is now covered in more than 60 articles per year [2]). This popularity might reflect their association with manifold traits, ranging from sex and gender to physical qualities, appearance and behaviour. Yet their direct link has so far been studied in adults only [3–5]. This is the first study to expand the evidence towards children.

(a) Second-to-fourth digit ratio: a proxy for prenatal testosterone

The Homeobox genes Hox a and d play an important role in the differentiation of the vertebrate urogenital system and also control digit development [6]. The postnatal 2D : 4D ratio correlates negatively with high levels of foetal testosterone (in relation to foetal oestradial levels) in the earlier measured amniotic fluid [7,8]. Accordingly, the ratio serves as a retrospective marker of the level of circulating androgens in utero, along with the individual’s sensitivity to these hormones [9]. Further lines of evidence, such as sexual dimorphism and specific diseases, support a negative association of 2D : 4D with prenatal testosterone exposure (summarized by Hönékopf & Thierfelder [10] and McIntyre [11]; but see Berenbaum et al. [12]). Even though this ratio increases with age, the rank order of 2D : 4D remains relatively stable until early adulthood [13,14].

(b) Prenatal and postnatal testosterone and adult facial shape

Male postnatal testosterone levels decrease until they have the same range as female plasma concentrations at two to three weeks of age [15]. Despite a secretory peak at one to three months in male infants, testosterone levels then remain equally low—actually lowest in life—in boys and girls until puberty. After the onset of puberty (at 8.5–13 years in girls [16]; at 9.5–13.5 years in boys [17]), the sex difference increases rapidly owing to a steep rise of testosterone levels in male adolescents. This rise contributes to the extended body and facial growth in males [18] and adult sexual dimorphism [19,20]. Yet adult circulating and prenatal testosterone seem to operate differently on male facial shape [5], and both of them differ from adult sexual dimorphism in faces [3,4].

Early androgen action (as estimated by 2D : 4D) seems to increase the contrast between upper and lower face in adults (with a prominent jaw, ‘robusticity’ [4,21]), whereas high adult circulating testosterone is associated with a uniform elongation of the face [5,21]. The lack of correlation between 2D : 4D and adult salivary testosterone was recently published for men and women [22,23]. The relationship between 2D : 4D and testosterone, however, is mediated by individual androgen sensitivity (cf. [24] for androgen receptor gene variation in relation to 2D : 4D).
Figure 1. (a) Facial measurement points and (b) resulting shape coordinates. (a) The set of 70 predefined landmarks (digitized in \texttt{tpsDio2} [27]) on two-dimensional photographs of frontal faces. All X symbolize fixed somatometric landmarks, while white circles mark sliding semilandmarks on curves. (b) Landmark configurations after Procrustes superimposition, used for statistical shape analyses.

Although the digit ratio is correlated with adult facial shape of both sexes by similar patterns, the effect was found to be about three times greater in men than in women, and non-significant for the latter [4]. Using a morphometrically more limited approach, however, Burris et al. [3] found no association between male 2D:4D and four facial measures, but confirmed the negative correlation of the ratio with nose width in females, as reported by Fink et al. [4].

(c) Second-to-fourth digit ratio and facial shape in boys: hypotheses and predictions

Neave et al. [25] hypothesized that high intra-uterine testosterone levels have an ‘organizational’ effect on male facial features; this effect is activated during puberty and results in masculine and dominant characteristics in adulthood. In the current work, we tested this hypothesis by studying the faces of male children. No association of their facial shape with 2D:4D (as a proxy for prenatal testosterone) would support the notion of this activation at puberty at the earliest. Conversely, a significant link between 2D:4D and facial shape would weaken the argument of a puberty impact and modify the hypothesis. Then, the same shape patterns as in adults (described by Fink et al. [4]) would be expected.

2. MATERIAL AND METHODS

We measured the length of the second and the fourth digit of the right hand of boys, took standardized frontal photographs and recorded age, body height and weight.

(a) Participants

The final dataset comprised Caucasian boys aged 4–11 years (7.8 ± 2.2) from Upper Austria. The sample was distributed equally over this age range (age groups: 3–5, 6–8 and 9–11 years; \( \chi^2 = 2.235, \text{d.f.} = 2, p = 0.327, n = 17 \)). All 17 boys were right-handed and their frontal photographs met the standardization criteria listed below. Only participants without previous injuries to the fingers of their right hand were included. All children joined the study voluntarily and their parents signed a declaration of consent.

(b) Second-to-fourth digit ratio

The length of the second and fourth digit of the right hand was measured directly with a vernier calliper, from the ventral-most proximal crease to the tip of the gently stretched finger. Each length was measured three times. The ratio between the mean lengths of the second and the fourth digit was then calculated for each person.

(c) Facial photographs and measurement points

Frontal photographs were taken with a digital reflex camera (Canon EOS 300D) and a 116 mm lens. To standardize the photographs, all children were advised to look straight into the camera with neutral facial expression, to remove their glasses or any facial adornment and to tie their hair back. The camera was positioned at eye height 3.5 m away from the face. Studio lights helped standardize the light conditions. The children’s heads were adjusted according to the Frankfort Horizontal Plane [26]. Photographs not meeting the standardization criteria (e.g. with laterally turned or smiling faces) were excluded.

A set of 70 soft tissue measurement points (somatometric landmarks and semilandmarks) were manually digitized as two-dimensional coordinates in \texttt{tpsDio2} [27] to capture facial shape (figure 1a). We used the landmark scheme by Windhager et al. [28] except for one landmark: the so-called lower lip point was not fixed in the present study, but allowed to slide between chinon and labrale inferius.
Semilandmarks are measurement points that have no morphologically defined exact position (white circles in figure 1a). They were digitized equally spaced along curves that themselves are homologous among individuals (e.g. the jaw line). Semilandmarks are allowed to slide between the adjacent landmarks so as to minimize overall bending energy before being projected back to the curve [29,30]. After sliding, they are treated like fixed somatometric landmarks in subsequent analyses.

(a) Shape analysis
As a slight turning of the face (to the left or right) is sometimes inevitable when working with young children, we first 'symmetrized' the faces to minimize the effect of head turning on face shape. Symmetrically slid semilandmarks were computed by sliding each face against the average symmetric shape [31]; the digitized landmark configurations were aligned in a generalised Procrustes superimposition [32], then the average shape was computed (by averaging all $x$ and $y$ coordinates landmark by landmark) and 'symmetrized' [30]. A landmark configuration is symmetrized by reflecting it, relabelling the landmarks of the reflection (so that, for example, the left alae origin in the reflection gets the same landmark number as in the original) and computing the average between original and reflection after another Procrustes superimposition. After sliding the semilandmarks to this average symmetric shape, we also symmetrized the individual faces.

The resulting shape coordinates (figure 1b) were then subjected to principal component analysis (PCA; termed relative warp analysis for shape coordinates) to assess the shape variation in the sample (electronic supplementary material, figure S1). A shape regression (a multivariate regression of shape coordinates onto an independent variable) was used to test the association of facial shape and digit ratio. A Monte Carlo permutation test [33] was used as the test statistic. The results of significant ($p < 0.05$) shape regressions were visualized by thin-plate spline (TPS) deformation grids [34]. These depict shape changes from the average configuration to faces that are predicted for higher and lower digit ratios. Outline landmarks were connected with cubic splines to ease interpretation. The specific facial configurations were also visualized using the original photographs. For this, the photograph of each boy was 'unwarped' to the predicted configuration, so that the originally digitized landmarks then coincided with those of the target configuration. These unwrapped pictures were averaged pixel by pixel (in TPSSUPER v. 1.14 [35]), yielding a single picture for each configuration. Finally, a separate figure shows the mean and predicted facial configurations superimposed to render shape differences more visible. Outline landmarks were again connected with cubic splines.

Analyses and visualizations were carried out in Mathematica v. 6 (symmetrizing, TPS grids, superimposed configurations), S+ (symmetric sliding), TPSREL V. 1.46 [36] (relative warps analysis), TPSRIG v. 1.36 [37] (shape regressions), TPSSUPER v. 1.14 [35] (image unwarping and averaging) and SPSS v. 15 (bivariate correlations, relative warp plots). Figures were edited with Adobe Illustrator CS3.

3. RESULTS
The second-to-fourth digit ratios of the 17 boys ranged from 0.91 to 1.01 (0.98 ± 0.03). The shape regression (i.e. the association of facial shape with the digit ratio) explained 14.5 per cent of shape variation in our sample and is statistically significant ($p = 0.0139$ after 10 000 permutations). Facial shapes associated with high and low digit ratios are visualized as shape changes from the sample average (figure 2). Size differences in the local deformations are relative to other regions. This is because absolute size (i.e. centroid size) has been standardized during Procrustes superimposition. Facial shapes associated with high digit ratios (figure 2, left panels) are characterized by a relatively large forehead, long and slim eyebrows, comparatively large eyes with a round shape of the visible iris, and a relatively long distance of the eyes to the alae origins. The deformation grid in the nose area indicates a vertical stretching of the nose as well as a relatively short distance to the mouth. The cheeks are narrower, the jaw outline is less broad and the chin more pointed than predicted for faces corresponding with boys with lower digit ratios (figure 2 right panels). These faces, in contrast, have a relatively smaller and shorter forehead. The eyebrows are thicker and further apart from the smaller eyes. The distance between the eyes is comparably large. The flaring parts of the nostrils are relatively wide and short. The grids point to a prominent lower jaw that is laterally and vertically extended compared with boys with higher digit ratios. The shape differences become especially clear when all five configurations of figure 2 (±1 s.d. of digit ratio, ±2 s.d. and average) are plotted superimposed (i.e. in the same coordinate system; figure 3). The forehead and the lower face apparently bear the largest signal associated with 2D : 4D. Procrustes superimposed raw coordinates (with semilandmarks slid towards the non-symmetrized sample average) yielded the same results for the shape regression upon 2D : 4D.

To test if body height, body weight or age mediated the observed relationship between anatomical traits and digit ratio, we correlated these measures with the 2D : 4D ratio. There was no significant correlation between 2D : 4D ratio and age ($r = -0.068, p = 0.795, n = 17$), body mass index ($r = 0.271, p = 0.281, n = 17$), body height ($r = -0.295, p = 0.251, n = 17$) or body weight ($r = -0.329, p = 0.198, n = 17$). Also, the depicted association between facial shape and digit ratio (figure 2) was found to persist when regression vectors for body mass index, body height and body weight were projected out [38–40] individually.

4. DISCUSSION
Our results show a clear association between the second-to-fourth digit ratio and facial shape in boys as young as 4–11 years old. The observed shape pattern mirrors previous results for adult men [4,5]. It cannot be definitively ruled out that any of the boys had entered puberty. Nonetheless, as the digit ratio was uncorrelated with age in our sample, this does not alter the validity of our main conclusion: the well-reported facial robustness associated with low 2D : 4D (i.e. high prenatal testosterone exposure) can be observed years before puberty. This supports the speculation of Neave et al. [25] that there is an 'organizational' relationship between (i) facial dominance and masculinity, and (ii) the prenatal hormonal environment, but our finding also shows a pubertal onset of its activation. Another
Figure 2. Visualization of the shape regression upon 2D:4D ratio in boys' faces. While the upper panels show thin-plate spline deformation grids from the sample average to predicted facial shapes for several digit ratios, the lower panels visualize the same facial shapes through image unwarping and image averaging. The middle column (with the undeformed grid in upper row) corresponds with the average landmark configuration and the average digit ratio for boys. The faces immediately left and right of the central face show +2 s.d. and −2 s.d., respectively, and the faces at far left and far right show +4 s.d. and −4 s.d., respectively, compared with the average 2D:4D ratio. Ratios higher than the average 1.09 (+4 s.d.) and 1.04 (+2 s.d.), the faces on the right to lower ones 0.93 (−2 s.d.) and 0.87 (−4 s.d.). Digit ratio accounted for 14.5% of the shape variation. Note that values ± 4 s.d. are outside the observed range.

hint at the more direct pathway is that the facial shape pattern of adult salivary testosterone differs from the one of 2D:4D in men with the shape pattern for perceived masculinity/dominance closely resembling the latter [5]. Moreover, Koehler et al. [41] could not identify any significant relationship between 2D:4D and perceived body and facial masculinity or testosterone volume in adult men. The lack of correlation between prenatal and actual testosterone levels was true both for facial shape and, for example, display behaviour [42]. Finally, Bulgina et al. [43] concluded, from their analysis of the Denver Growth Study’s radiographs, that the cranial shape of three-year-olds is highly correlated with the individual adult shape. Accordingly, the adult pattern of interindividual difference might already be established within the first few years of life.

Of course, this does not preclude that much facial shape change results from male adolescent hormone secretion and longer growth in men. Note that castration before or after puberty also has different effects on the male organism [44]. Despite the considerable increase in sexual dimorphism after puberty (including secondary sexual characteristics, such as beards and brows [45,46]), our results show that intramale facial shape variation owing to differences in prenatal testosterone exposure is already present in childhood. One description might be that ‘the effects of [postnatal or adult] circulating hormones are superimposed on changes induced perinatally’ ([47], p. 49). Future studies might, however, compare the magnitude of shape difference associated with 2D:4D before and after puberty to clarify the role of sexual maturity. Likewise, dissecting causation and mediation of variables associated with the relationship between facial shape and 2D:4D would be an important direction for future research. Such an approach might provide valuable clues to the mechanism behind prenatal testosterone’s effects on face shape in children and in adults.

Males are more variable than females in a variety of traits, presumably because the former exhibit a greater range of context-dependent reproductive strategies [48]. This greater variability includes 2D:4D [49], determined in a very narrow window during ontogeny [8]. The foetal testosterone level, in turn, is positively correlated with foetal cortisol, maternal cortisol and maternal testosterone [50]. This relates to the ‘maternal dominance hypothesis’ and empirical work of Valerie Grant and colleagues, who suggested that dominant female primates (including humans) produce more male offspring: the high testosterone levels of these females apparently play a role [51,52]. Taken together, the variation in male digit ratio might thus reflect a preparation for different life-history strategies depending on social status and environmental context (e.g. chronic stress). Specifically, we hypothesize dominant and/or stressed mothers to have children with higher prenatal testosterone exposure. Such children might behave more competitively from childhood onwards. Y chromosome-linked factors, however, might also contribute to family resemblance in digit ratio [53].

Consequently, we would expect that not only the facial correlates of prenatal testosterone (as approximated...
through 2D : 4D are highly similar between children and adults, but also physical correlates, trait attribution and social interactions. The number of studies explicitly testing these associations in children is rare, but boys with lower digit ratios yield faster results when other factors, such as age, body mass index, and maturity, controlled $r = 0.15$ [54]. Another helpful source is the research on the social consequences of babies' facial features. Our facial shape pattern associated with low prenatal testosterone exposure (high 2D : 4D values) closely resembles baby schema simulations in infant faces (as in Gockler et al. [55]). Follow-up studies will show whether boys with higher digit ratios are also perceived as cuter, less strong, less alert and less intelligent than less 'baby-faced' children [56]. Thus, they might also receive more help and more babyish talk [57,58], of course mediated by the age of the recipient. Children with low digit ratios, in contrast, might be regarded as more masculine and dominant. Furthermore, physical correlates with 2D : 4D found in adult men (such as physical fitness and competitive ability [59]) might also already present in children and help to acquire resources in a peer or sibling context. High disposition dominance in the form of a low 2D : 4D seems ultimately positively related to male reproductive success [60]. It remains to be investigated how hormonal predisposition interacts with differential social treatment in shaping children's behaviour. A dominant mother might, for example, be more interactive with and tougher on her offspring [61]. Altogether, the link between children's facial features and 2D : 4D raises a novel set of questions: are boys with high prenatal testosterone exposure already perceived as more dominant and masculine by children and adults? Do they acquire more resources in competition with peers, and what are their strategies? To what extent does this model apply to girls?

We thank Fred L. Bookstein, Philipp Gunz and Philipp Mitteroecker for computations and Mathematica code, Michael Stachowitsch and two anonymous reviewers for valuable comments, as well as all the children, parents and teachers for their participation.

REFERENCES


15 Forest, M. G. 1979 Plasma androgens (testosterone and 4-androstenedione) and 17-hydroxyprogesterone in the neonatal, prepubertal and peripubertal periods in the


Electronic supplementary material to be retrieved from:
http://rspb.royalsocietypublishing.org/content/suppl/2012/02/08/rspb.2011.2351.DC1.html

Second-to-fourth digit ratio and facial shape in boys: the lower the digit ratio, the more robust the face

Data Supplement

Files in this Data Supplement:

Facial shape variation within the sample - The low amounts of explained variance along the first three dimensions indicated a homogeneous distribution. Also the plot of the first two dimensions showed no conspicuous outliers that might have derogated subsequent analyses.

The relative warps analysis depicts the main directions of facial shape variation within a sample in the first few relative warps (RWs). RW 1 explained 33% of the variance in facial shape, RW 2 accounted for 21%, and RW 3 for 12% (N = 17).
2.4 Face to face: the perception of automotive designs (published in Human Nature, cover feature)


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Anthropology: Rank 11/61, Q1; Social Sciences, Biomedical: Rank 9/29, Q2
Face to Face
The Perception of Automotive Designs

Sonja Windhager · Dennis E. Slice · Katrin Schaefer · Elisabeth Oberzaucher · Truls Thorstensen · Karl Grammer

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Abstract Over evolutionary time, humans have developed a selective sensitivity to features in the human face that convey information on sex, age, emotions, and intentions. This ability might not only be applied to our conspecifics nowadays, but also to other living objects (i.e., animals) and even to artificial structures, such as cars. To investigate this possibility, we asked people to report the characteristics, emotions, personality traits, and attitudes they attribute to car fronts, and we used geometric morphometrics (GM) and multivariate statistical methods to determine and visualize the corresponding shape information. Automotive features and proportions are found to covary with trait perception in a manner similar to that found with human faces. Emerging analogies are discussed. This study should have implications for both our understanding of our prehistoric psyche and its interrelation with the modern world.

Keywords Automobiles · Faces · Geometric morphometrics · Human perception · Maturity · Trait allocation

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The patterns of culture that we create and consume, although not adaptations in themselves, might reveal about human evolutionary psychology as much as or more than the most carefully planned psychological experiments (Buss 2004:410).

Humans seem to have a general perceptual strategy that leads to the phenomena of animism and anthropomorphism. Animism is the attribution of life to the non-living, whereas anthropomorphism is the interpretation of non-human beings and things in human terms (Guthrie 1993). This hyperactive agent-detection device has evolved because the adaptive advantage of detecting every agent is much higher than the costs of being mistaken (Bulbulia 2004). In this way, our brain will try to interpret even its non-social environment as primarily social—because of the adaptive advantage to find and gather information from faces, which is necessary to detect personal identity, possible kin relationships, personality and facial expressions, and action tendencies (Cosmides and Tooby 1992). As a result, we are tempted to see faces everywhere, even in clouds, stones, and cars (Guthrie 1993).

The human face is a complex multi-signal system from which we can infer a great deal of information at no more than a glance—in other words, after only 100 ms of exposure (Willis and Todorov 2006). Such information refers to age, sex, attitudes, personality traits, and emotions.

Body proportions play an important role. Since structures grow proportionally more and for a longer period of time the further they are from the neurocranium (Enlow and Hans 1996), babies and young children have relatively large eyes and large, protruding foreheads as compared with adults, constituting the so-called Kindchenschema (Lorenz 1943). Furthermore, babyish characteristics in adult faces influence perception of personal traits (Keating et al. 2003). Facial shape also differs between the sexes, with males having the more pronounced lower faces owing to extended growth (Fink et al. 2005; Ursi et al. 1993). Humans attribute dominance to faces characterized by a prominent chin, heavy brow ridges, and a muscular face (see Buss 2004 for a review; Grammer and Thornhill 1994).

Indeed, facial features, including structural elements as well as static facial expressions, may influence one’s perception of another person’s personality (see Argyle 2002 for a review). For the personality, five cross-culturally valid factors (agreeableness, conscientiousness, extroversion, neuroticism, and openness/culture) are often applied (McCrae and Costa 1997). Personality and facial expressions are found to interrelate in that extroversion, agreeableness, and culture significantly correlate with smiling (Kenny et al. 1992). Important components in facial expressions of emotions include the eyebrows, eyelids, and mouth. Their movements form the global pattern of such widely recognized expressions as happiness, sadness, surprise, disgust, anger, and fear (Ekman 1999).

In summary, people draw many inferences from a stranger’s face. Owing to the evolutionary significance of decoding facial signals, humans seem to have developed a selective sensitivity to the relevant features and configurations, even if presented in rather abstract ways (Thayer and Schiff 1969, as cited in Argyle 2002). We predict that such information is also encoded and perceived in car fronts, which is supported by Desmet et al. (2000). The idea that cars have faces has been proposed by both researchers (e.g., Coss 2003; Erk et al. 2002) and product designers (Kerssenbrock
The tendency to interpret car fronts as faces could be the result of an error management strategy—which has evolved in order not to miss any information about faces, as outlined above. Such a tendency, if it exists, can be independent of the way the processing itself is done because the result is independent of the way it is reached. With evidence that such interpretation or direct processing occurs, the approach can be extended to the interpretation of car fronts as facelike, and then the same information could be extracted as it would be from faces themselves. This would be an indirect proof of the hypothesis.

We therefore expect ratings of car fronts to vary with aspects of their geometry in a manner consistent with that in faces.

We will quantify and visualize the link between perception and the geometry of a car front and its constituent parts. For this purpose, we emphasize geometric morphometric (GM) methods. In contrast to classic morphometric approaches, GM is not based on distances, angles, or ratios, but on the 2- or 3D coordinates of “landmarks” (see Bookstein [1991]). A standardization process, the generalized Procrustes analysis (GPA), allows the investigation of shape independent of differences in the scale, orientation, and location of the specimens (Rohlf and Slice 1990). The resulting shape coordinates can then be used for further analyses, such as multivariate regression or partial least squares (PLS) analysis. Results of such analyses are again landmark coordinates and/or their linear combinations. The technique of thin-plate splines, as introduced in the context of GM by Bookstein (1991), provides the interpolation of differences at landmarks. The resulting deformation grids enable us to assess intuitively what might otherwise be disguised in large tables of numbers. Besides the possibility of visualizing the results, the ability to show a significant regression model of trait perception on car form comparable to that found on human facial shape would be strong support for the hypothesis.

If people indeed interpret the object world socially as a by-product of an evolutionary adaptation, we expect to be able to reconstruct changes in the proportions and morphology of car fronts that covary with the perception of traits analogous to those of human faces. Furthermore, we explore which shapes of car fronts people like.

In summary, our hypotheses are: First, car fronts possess cues from which we infer such characteristics as maturity, gender, attitudes, emotions, and personality. If this is the case, people will show high interrater agreement. Second, shape contributes to the variation of attributions among cars.

**Material and Methods**

**Participants**

Twenty males and 20 females between 19 and 33 years of age (mean=24.53, SD=3.013) participated in the experiment, and each received 10 euro compensation. All were respondents to a university advertisement and were of Central European descent.
Stimuli

We used high-resolution 3D computer models (digital mockups) of 38 cars, representing 26 manufacturers (brands). They were accurate reconstructions of actual car models from 2004 to 2006 edited via 3ds Max® (Autodesk 2006). We scaled the cars to their original size and positioned a virtual camera with a 20 mm lens at a point 12 m from and half the height of the respective car. Lighting was standardized using a virtual sun. All cars were colored silver and license plates erased, although brand logos were retained. Finally, we rendered pictures at 640 × 480 pixels.

Procedure

On a computer monitor, cars were displayed in random order for the raters. Each participant rated each car on 19 traits (see below) using an onscreen slider that produced results from 0 (unipolar: not at all, bipolar: a lot of one extreme) to 100 (unipolar: a lot, bipolar: a lot of the other extreme). Subjects were subsequently shown printed images of all the cars in random order, one at a time, and were asked to mark on a continuous 10 cm line the extent to which they perceived this car to have a face and whether they associate the car front with a human face, an animal face, or no face at all. Finally, they were asked to mark facial features (eyes, nose, mouth, ears) on the picture when and where they perceived them.

Statistical Analyses and Geometric Morphometrics

Individual traits were assessed for consistency using Cronbach’s alpha. Traits scoring ≥0.75 were retained. Average values for each trait per car were subjected to a principal components analysis (PCA) based on the covariance matrix. Geometric

<table>
<thead>
<tr>
<th>Landmarks</th>
<th>Definition</th>
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<tbody>
<tr>
<td>1–4</td>
<td>Corners of the windshield</td>
</tr>
<tr>
<td>5–6</td>
<td>Center of the rearview mirrors, left and right</td>
</tr>
<tr>
<td>7, 9</td>
<td>Extremes of the outer/inner edges of the left headlight (from the position of the viewer)</td>
</tr>
<tr>
<td>8, 10</td>
<td>Extremes of the top/lower edges of the left headlight (from the position of the viewer)</td>
</tr>
<tr>
<td>11,13</td>
<td>Extremes of the outer/inner edges of the right headlight (from the position of the viewer)</td>
</tr>
<tr>
<td>12,14</td>
<td>Extremes of the top/lower edges of the right headlight (from the position of the viewer)</td>
</tr>
<tr>
<td>15–16</td>
<td>Broadest part of the grille; i.e., points of greatest lateral extension</td>
</tr>
<tr>
<td>17–18</td>
<td>Highest and lowest point of the grille at the midline (defined by the bilateral symmetry of the car)</td>
</tr>
<tr>
<td>19–20</td>
<td>Broadest part of the additional air intake slots (inner part); i.e., points of greatest lateral extension</td>
</tr>
<tr>
<td>21–22</td>
<td>Highest and lowest point of the additional air intake slots (inner part) on the midline</td>
</tr>
<tr>
<td>23–24</td>
<td>Broadest part of additional lateral structures of additional air-intake slots and/or additional lights</td>
</tr>
<tr>
<td>25–26</td>
<td>Intersection of front tires and car body closest to the midline</td>
</tr>
<tr>
<td>27–28</td>
<td>Outside corner of the tread of the left/right tires</td>
</tr>
<tr>
<td>29–30</td>
<td>Greatest lateral extension of the car</td>
</tr>
<tr>
<td>31–32</td>
<td>Inside corner of the tread of the left/right tires</td>
</tr>
<tr>
<td>33–34</td>
<td>Middle of the top/lower edges of the windshield</td>
</tr>
</tbody>
</table>
morphometrics was used to explore the relationship between car shape and trait scores. For this, we defined 34 landmarks (Table 1, Fig. 1). The bilateral symmetry of the car defined the midline. “Highest” and “lowest” points were determined parallel to this axis, and “greatest lateral extensions” perpendicular to the midline.

The sets of landmarks, digitized in tpsDig (Rohlf 2005a), were superimposed using GPA (Rohlf and Slice 1990). The resulting shape coordinates were then regressed onto car scores on individual PC axes and onto the mean “liking” score. The relationship between shape and perception was further explored using partial least squares (PLS) analysis (Rohlf and Corti 2000; Streissguth et al. 1993). For all such analyses, we used thin-plate splines for the visualization of the results.

Analyses and visualizations were carried out in R (PCA and general statistics), SPSS 12 (Cronbach’s alpha), tpsRegr (Rohlf 2005c), and tpsPLS (Rohlf 2005b).

Results

Interrater Agreement

The Cronbach’s alpha values show high consistency in the ratings (Table 2). Alpha values for five traits fell below the modestly conservative criterion of 0.75. These traits were excluded from further analyses.

Principal Components Analysis (PCA)

A PCA of the average scores per car showed the first principal component (PC) to account for 83% of total variation, the second for nearly 10%, while the others add less than 3% each. This suggests variation in the perception of car characteristics is essentially one- or two-dimensional.

When we take coefficients with absolute values above 0.27 (the constant value of coefficients for an isometric vector in this 13-variable case), positive scores on PC1 indicate cars perceived as adult, dominant, arrogant, angry, masculine, and hostile, with the reverse being true for cars with negative scores (Table 3). We will refer to this axis as “power.” The second PC shows positive coefficients for content (i.e.,
satisfied), happy, open, submissive-dominant, child-adult, and agreeable, and negative coefficients for afraid and angry (Table 3). We call this axis “sociability.” Scores of individual cars are plotted in Fig. 2.

The PCA provides insight into the patterns of covariance of traits across different makes and models of automobiles, but it does not directly address the corresponding shape information. That is the subject of the following analyses.

Shape Regressions

The multivariate, multiple regression of the GPA shape coordinates onto the first two PCs explained 17% of total shape variation (randomization test: \(P=0.001\)). Separate regressions onto PC1 and PC2 explained 13.3% and 3.8%, respectively, with \(P-\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>PC1</th>
<th>PC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child-Adult</td>
<td>0.48</td>
<td>0.27</td>
</tr>
<tr>
<td>Male-Female</td>
<td>−0.32</td>
<td>−0.18</td>
</tr>
<tr>
<td>Friendly–Hostile</td>
<td>0.32</td>
<td>−0.24</td>
</tr>
<tr>
<td>Submissive–Dominant</td>
<td>0.38</td>
<td>0.29</td>
</tr>
<tr>
<td>Angry</td>
<td>0.32</td>
<td>−0.28</td>
</tr>
<tr>
<td>Afraid</td>
<td>−0.24</td>
<td>−0.29</td>
</tr>
<tr>
<td>Happy</td>
<td>−0.15</td>
<td>0.44</td>
</tr>
<tr>
<td>Surprised</td>
<td>−0.17</td>
<td>0.03</td>
</tr>
<tr>
<td>Open</td>
<td>−0.14</td>
<td>0.35</td>
</tr>
<tr>
<td>Agreeable</td>
<td>−0.18</td>
<td>0.27</td>
</tr>
<tr>
<td>Content</td>
<td>−0.05</td>
<td>0.45</td>
</tr>
<tr>
<td>Arrogant</td>
<td>0.38</td>
<td>−0.02</td>
</tr>
<tr>
<td>Aroused</td>
<td>0.13</td>
<td>−0.02</td>
</tr>
</tbody>
</table>

Values in italics indicate major contributions of this variable to the PC groupings.
Fig. 2 Position of individual cars on PC1 “power” and PC2 “sociability”. The variation in the perception of car characteristics is essentially one-dimensional

Fig. 3 Regression of shape onto PC1 “power” (top) and PC2 “sociability” (bottom)—predicted shapes (±3 SDs). The grids are deformed in the direction of decreasing (left) and increasing (right) power and sociability, respectively
values of 0.001 and 0.185. Predicted shapes are visualized for PC1 and PC2 for scores ±3 standard deviations of the trait variation on the associated axis (Fig. 3).

Cars of high “power” are relatively lower/wider and/or have more slitlike and/or laterally angled headlights and/or a wider, but less high, air intake. The spline reveals a vertical extension of the grille. Conversely, there is a vertical stretching with decreasing “power.” The windshield in these cars is relatively larger. Headlight shapes are also rather distinctive, shifting closer to the car’s midline. The grille is narrower, and the region between the grille and air intake is extended. The greatest lateral extension of the additional structures is shorter and closer to the actual air intake, which is expressed by the “pulling in” of the grid.

On PC2, in the direction of increasing “sociability,” there is some degree of widening and shortening of the car and an apparent shifting of the lateral-most points upward with respect to the headlights. The grille is enlarged and positioned relatively higher with respect to the headlights. The greatest lateral extension of the inner part of the air intake is shifted upwards. On the other hand, cars with large negative loadings have air intake slots whose greatest lateral extension is relatively lower, suggesting a rectangular rather than trapezoidal air intake; the outer parts point even further down.

Partial Least Squares Analysis

Partial least squares (PLS) analysis (Rohlf and Corti 2000; Streissguth et al. 1993) constructs mutually orthogonal sets of linear combinations of each set of variables (shape and trait averages) that covary the most between the two sets. The first pair of PLS axes accounted for 93% of the total cross-correlation (randomization test: P<0.001), the second PLS axes for less than 4% (P=0.999).

Fig. 4 Shape-trait PLS analysis. The plots visualize ±2 SDs along the first pair of PLS axes. Displacements represent magnitudes of the individual traits associated with the related spline plot and can be read from left to right as: child–adult (1), male–female (2), friendly–hostile (3), submissive–dominant (4), angry (5), afraid (6), happy (7), surprised (8), open (9), agreeable (10), content (11), arrogant (12) and aroused (13)
Combining geometric morphometrics with PLS analysis allows the visualization of the relationships (Fig. 4). The “displacement bar” at the top of each plot pair can be interpreted as the individual contribution of each trait to the combination of traits most correlated with shape. Thus, the car pictured on the left represents a childlike, female, friendly, submissive, not angry, afraid, happy, surprised, open, agreeable, not arrogant, and/or unaroused car. It gives a compact impression. The windshield becomes more prominent, the grille narrower. The extreme upper and lower edges of the headlights are close to the middle of the car. Additional lateral structures are close to the inner part of the air intake. The centers of the rearview mirrors are shifted upward. Just the opposite is true for cars that are rated as adult, male, hostile, dominant, angry, unafraid, unhappy, unsurprised, closed, disagreeable, arrogant, and/or aroused (Fig. 4, right).

**Raters’ Preferences for Car Shapes**

We regressed GPA-constructed shape variables onto the single variable “liking” (coded 0 to 100, average 40, range 20–55), explaining 11.5% of shape variation (1,000 permutations: \( P = 0.001 \)). Predicted geometries are given in Fig. 5. The cars that are “liked” are predicted to have a wide stance, a narrow windshield, and/or widely spaced, narrow headlights. The lateral-most points of the air intake are

**Fig. 5** Predicted shapes of cars for “liking” values of 0 (left), 40 (center—the average with the undeformed grid), and 80 (right)

**Fig. 6** Subjects’ association of a face with the car. More than 60% of our subjects indicate seeing a face in at least 70% of the cars presented
shifted upwards, the grille is extended vertically. These attributes are very similar to those of “power” and, in fact, the association between “liking” and PC1 scores is significant (Kendall’s tau=0.312, P=0.006).

Raters’ Perception of Facial Features in Cars

As shown in Fig. 6, 32.5% of our subjects associated a human or an animal face with at least 90% of the cars. People were also asked to mark facial features in each car whenever and wherever they thought appropriate. All 40 subjects considered all 38 cars (N=1,518, as two were missing). They marked eyes in 75.2%, a mouth in 62.6%, a nose in 54.3%, and ears in 38.1% of the cases. Generally, the headlights were marked as eyes. The nose tended to be the grille or the emblem; the additional air intake slots, the mouth.

Discussion

Error management theory states that asymmetries in the recurrent costs of errors in inference can lead to the evolution of biases, even when these biases result in greater rates of inferential error (Haselton and Buss 2000). An overperception error in terms of processing artifacts as agents does no harm at all, whereas a single real encounter lacking that inference could be lethal. This effect probably forces us to interpret our world primarily in social terms. In this study we show that people act consistently with this assumption and that GM can be used as a valid tool for the reconstruction of such perceptive biases.

In our study, people generally agreed in their ratings. Thus, there must be some kind of consistent information that is being perceived in car fronts. However, a few traits lacked such agreement (disgusted, extroverted, sad, neurotic, and conscientious), possibly for several reasons. In humans, judgments of conscientiousness seem to be linked to dress style and extroversion to attractiveness (Albright et al. 1988)—qualities that might not be communicated in cars. Second, some traits are difficult to judge even in our conspecifics, such as disgust (Hess and Blairy 2001) and neuroticism (Borkenau and Liebler 1992).

The rating of car fronts was found to vary mainly along a single dimension which we identified as “power,” explaining 83% of trait variation. Perceived maturity had the greatest contribution to this vector, followed by the interpersonal attitudes of dominance, arrogance, anger, and hostility. A further component of high impact was masculinity.

Since we were not only interested in the perceptions per se but also in the corresponding car shapes, we performed shape regressions as well as a PLS analysis. The latter gives the shape that best matches a linear combination of the traits under consideration. The existence of a significant regression as well as a significant pair of PLS axes are further strong support for the consistent interpretation of car shape. Both approaches showed a highly similar pattern of covariation of shape and trait allocation and point to configurational analogies between car fronts and (human) faces.

On the large scale, the grids illustrate a shape change toward a larger windshield and a smaller car body in the direction of low “power.” This resembles the classic human (and, in the broader sense, mammalian) growth allometry pattern, with
infants having a relatively larger neurocranium and a smaller face than adults. Facial growth ceases in females at the age of 14 while males continue growing beyond the age of 18 (Ursi et al. 1993). There is no vertical elongation in the grid representing mature, masculine cars as seen in the growing human face, but presumably the raters were able to assess more of the 3D form than was finally captured by the 2D landmarks. In almost all cars scoring high in “power,” the hood is elongated horizontally and at least resembles the protruding adult lower face. These proportion shifts reflect what Pittenger et al. (1979) found when applying the cardioidal strain algorithm—a mathematical transformation simulating growth—to drawings of Volkswagen Beetle fronts and asking the participants for relative age attributions. Interestingly, the cardioidal strain transformation does not seem to model aging in all objects (cf. the remarks on armchairs and shoes in Mark et al. 1988). The pronounced lower car body relative to the windshield area further resembles the prominent chin reported for dominant-looking people (Buss 2004). We actually found that ratings for dominance, arrogance, anger, and hostility increase with “adulthood” and “masculinity.” Since the perception of biological forms is interlinked with the association of certain attitudes and behavioral stereotypes, we suggest that perceived age and sex drive the first PC (“power”). We are not aware of studies that explicitly test the representation difference for infants versus adults (it might be too obvious to test anyway), but we know that one attributes childlike traits to baby-faced people of all ages, perceiving them as less dominant and less strong (Keating et al. 2003). Likewise, along this same trajectory, women relative to men are perceived as soft and submissive (Ashmore and Tumia 1980). Masculinized male (and female) faces, on the other hand, obtain higher ratings in perceived dominance, masculinity, and age (Perrett et al. 1998).

As opposed to the large-scale changes described above, we will now discuss the more local deformations. Headlights become more angular in the direction of increasing “power” and appear to parallel what Brannigan and Humphries (1972) described as an angry frown (having the eyebrows drawn down, particularly at the inner ends). Thus, the association of hostility and arrogance is not surprising. Schematic faces with lowered eyebrows are also chosen as the more dominant ones (Keating et al. 1977). Massive eyebrow ridges are a testosterone-mediated masculine trait in the human face (Schaefer et al. 2005). The bigger grille might reflect the larger noses of men as compared with women (Enlow and Hans 1996).

Conversely, cars perceived as childlike, submissive, not arrogant, not angry, female, and friendly are characterized by headlights that have their upper edge maximum relatively closer to the midline, which looks similar to Brannigan and Humphries’s (1972) sad frown (eyebrows being drawn down at their outer ends) or sad eyebrow raise. It might reflect the inner brow raise frequently present in happy, sad, and fear expressions (Kohler et al. 2004). These are also exactly those attributes scoring high in the PLS analysis corresponding to a visualization of shape with the same headlight properties.

The second PC of our perception ratings “sociability” deviates from the first in that happiness, openness, and agreeableness have major contributions. These attributes are generally found to be amplified when people judge smiling persons (Otta et al. 1996) and remind of the warmth dimension assumed (along with competence) to be a universal dimension of social cognition (Fiske et al. 2007).
Shape regression, though not significant, shows a relative upward shifting of the lateral-most points of the air intake with increasing “sociability.” In this way, the car gives us a big smile.

The better our subjects liked a car, the closer it matched the shape characteristics corresponding to high values of “power” (PC1). Thus, people seem to like mature, dominant, masculine, arrogant, angry-looking cars. Shape regressions for the sexes considered separately (not included in this paper) look alike. In interpreting this finding, it is important to bear in mind that liking is a multifaceted concept. We can like somebody as a spouse, a one-night stand, a friend, an ally, etc. With regard to cars, this list might extend even further. It could well be that we favor a car not because we see an interaction partner but as a means of communication and maybe even manipulation. Atzwanger (1995) has shown that specific car designs do affect the lane-changing behavior of other drivers. Giving a mature, dominant, masculine, arrogant, and angry impression might therefore be desirable in the daily battles on the roads (crowded intersections, traffic jams). Undoubtedly, what I “like” and what I “buy” are not necessarily the same things. However, such design considerations might facilitate the decision between otherwise equal opportunities.

On the other hand, we cannot rule out potentially intervening variables. Cars of high “power” also tend to be the more expensive, prestigious, high quality, of greater engine capacity, and probably also safer. But we can make inferences about two related aspects that could have mediated in impression formation: owner and brand stereotypes. We do not deny interdependencies, but one has to be cautious when considering the direction of causation. Do we judge the car the way we do because of our (maybe stereotyped) impression of its owner, or did the owner decide to buy this car because it communicates the desired characteristics? Did brand attributes override the perceived attributes of the car front being presented, or is BMW (for example) regarded as a dominant, male, etc., brand because the company has always built cars that have such a (facial) expression? Furthermore, the possibility that brand personality attributions have affected the characteristics rating can be dismissed. The Volkswagen New Beetle, Golf, and Passat are actually spread along the first principal component (PC 1), although they belong to the same brand. Also the two Citroëns, which are rather close to each other in price and engine capacity, are far apart along PC 1 (Fig. 2).

The idea of cars having faces is not new. This association can be found in scientific textbooks, as in Enlow and Hans (1996) and Coss (2003), in films (e.g., Walt Disney’s “Cars” [2006]), and in car descriptions on TV and in auto magazines. They refer to “almond eyes” (of a Citroën DS; Schirman 2006), Kindenhenschma (Kerssenbrock 2005), or a smile (Juergens 2003). Catalogues of automobile accessories offer headlight covers (“eyebrows”), to give the car an “evil look” (Juergens 2003). Also, the results of this study suggest that humans are prone to see faces in cars. Not only did people consistently attribute characteristics to specific car shapes, they also agreed on the degree of “faciness” (Fig. 6, Table 2). Other indirect evidence is that, when asked, more than 60% of our subjects indicated seeing a face in at least 70% of the car fronts presented. Moreover, they marked eyes in 75%, a mouth in 63%, a nose in 54%, and ears in 38% of the cases. Eyes were marked at headlights in 98.4% of the eye-markings, which is consistent with the findings of
Erk et al. (2002). We are aware of not being able to distinguish whether our subjects have always perceived facial features in cars or whether they did so only because we asked them to look for them. However, support is evident in the striking importance of eyes, as found for real faces in eye-tracking studies (e.g., Henderson et al. 2001). Moreover, we recently conducted an eyetracking study ourselves and found a significance of headlights (and eyes) in attracting our gaze, even when subjects were asked to look for the mouth, the nose, or the ears (Windhager et al., submitted). Another hint comes from fMRI research. Erk et al. (2002) suggest that our brain processes cars in a similar way to faces because the cars activate the fusiform face area (but cf. Gauthier et al. 2000). The methodology of our study does not allow conclusions on the underlying processing mechanisms or the degree of overlap between face and non-face processing, but it could provide a starting point for the formulation of specific hypotheses to be tested with functional magnetic resonance imaging (fMRI) and electroencephalography (EEG).

It was a challenge to work with built structures because the single parts can be placed rather deliberately. Furthermore, there might be shape information that we have not captured through our landmarks but that still influences perception. Additional lateral structures are perceived as belonging to the mouth in some cases but not in others, thus constraining the interpretation. Moreover, the analyses treat all landmarks equally, but some might dominate particular analyses or guide perception—for example, the shape of the headlights might be more important in determining the rating than the size of the grille.

Let us now speculate on the reasons for cars’ appearance. It might be that we want our cars to express what we are or what we would like to be. On the other hand, their shapes might be a result of functional constraints—for example, the faster the car, the smaller (the more tilted) the windshield, and the “adult” resemblance might just be a coincidence.

This study was a first step to link the shape of car fronts and their constituent parts to trait attribution. Many questions remain. People might associate cars with an animal rather than a human face. The horizontal compression depicted in grids visualizing a dominant, aggressive car could give the impression of a crouching predator ready to attack. Preliminary investigation of sex differences suggests that there is a general pattern of automotive perception. The prospect for future research is to have a closer look at the sexes and at size, a characteristic we excluded from the present analyses. Furthermore, incorporating subjects who lack experience with our cars, brands, and media would allow even stronger conclusions.

With respect to practical applications, a tool for automobile designers to style cars according to a desired image could be derived. How the perception of car fronts affects our daily life (i.e., driving or pedestrian behavior) remains to be investigated. Does one change lanes and give way sooner when an “aggressive” car appears in the rearview mirror?

Conclusion

The aim of the present study was to investigate whether people tend to perceive the world primarily in a social way. We wanted to see whether people ascribe certain
traits to cars as they do to human faces, and if it is possible to extract the underlying shape information. Our main result was that people actually ascribe characteristics concordantly for most of the dimensions analyzed. The perception of car fronts was found to vary mainly along a single dimension comprising maturity, sex, and interpersonal attitudes, whereas emotions and personality traits pale in comparison. Applying geometric morphometrics, we show that distinct features in the car fronts correspond to different trait attributions. Thus, humans possibly interpret even inanimate structures in biological terms, which could have implications for driving and pedestrian behavior.

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2.5 “Cars have their own faces”: cross-cultural ratings of car shapes in biological (stereotypical) terms (published in *Evolution and Human Behavior*)


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*Rating study in Ethiopia in 2008.* © K. Schaefer, S. Windhager
“Cars have their own faces”: cross-cultural ratings of car shapes in biological (stereotypical) terms

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Original Article

Abstract

It was recently shown that Austrians associate car front geometry with traits in a way that could be related to face shape geometry mapping to those same overall suites of traits. Yet, possible confounding effects of familiarity with the car models, media coverage and entertainment could not be ruled out. In order to address this, the current study uses a cross-cultural comparison. Adult subjects in two countries (Austria and Ethiopia, n=129) were asked to rate person characteristics of 46 standardized front views of automobiles on various trait scales. These two countries differ substantially with regard to their experience with car models and brands, as well as car marketing and media coverage. Geometric morphometrics was then used to assess the shape information underlying trait attribution. Car shapes for perceived maturity, maleness and dominance were highly similar in both countries, with patterns comparable to shape changes during facial growth in humans: Relative sizes of the forehead and windshield decrease with age/growth, eyes and headlights both become more slit-like, noses and grilles bigger, lips and air-intakes are wider. Austrian participants further attributed various degrees of some interpersonal attitudes and emotions, whereas neither Austrians nor Ethiopians congruently ascribed personalities. Morphological correlates of personal characteristics are discussed, as are person perception and its overgeneralization to inanimate objects. Cross-cultural similarities and differences are addressed, as well as implications for car styling, follow-up studies on driving and pedestrian behavior, and fundamental dimensions in inference from (human) faces.

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Keywords: Behavioral anthropology; Geometric morphometrics; Cross-cultural overgeneralization; Facial shape

1. Introduction

Recently, Windhager et al. (2008) showed that people in Austria attribute person-like traits to cars based on the shape of cars and their constituent parts in a way that mirrors these attributions to people and animals. Yet, the authors were not able to rule out possible influences of familiarity with these car models, with automobile advertisements, brand stereotypes, anthropomorphic cars in movies and the like. The current study extends this work to a cross-cultural perspective with Ethiopia as a reference country. In Ethiopian rural areas, participants are not exposed to either the brands or car models under study or even any kind of car marketing and advertisement. Quite the opposite holds true for most parts of Europe, the United States and large industrial centers around the world.

Human and animal faces convey much essential information in contexts ranging from predation to social interaction. Organisms gain much from being right (e.g., identification of predator, prey, conspecifics) and lose little when accidentally treating a nonagent as an agent. As an example, taking a bear for a stone might be lethal, whereas the opposite does not harm. This asymmetry in the costs of errors might have led to a perception bias (error management theory; Guthrie, 1993; Montepare & Zebrowitz, 1998; Nettle, 2004). Increasing sensitivity to the relevant
features and configurations in the course of evolution might have resulted in contemporary mechanisms for the interpretation of faces that are activated not only by real faces and their photographs, but also by abstract representations (schematic faces: e.g., Keating, Mazur, & Segal, 1977; Senior et al., 1999) and that might extend even to cartoon figures (cf. Pittenger, Shaw, & Mark, 1979). This may be a version of Sperber’s (1994) process of extending an “actual” (evolutionarily salient) domain into a “proper” (cognitively conformal) domain.

Applying the rules of person perception to shapes with the same general structure as a face or body has been shown by the systematic manipulation of a Volkswagen (VW) Beetle cartoon (Pittenger et al., 1979). The same algorithm applied to other objects such as shoes and armchairs did not lead to comparable trait attributions (Mark, Shaw, & Pittenger, 1988). Thus, a certain degree of schema congruity seems to be a prerequisite for the overgeneralization from faces to objects (Aggarwal & McGill, 2007). The level of congruity is the extent to which features of an entity match those of a category schema, in our case (human or mammal) faces. Both cars and faces are bilaterally symmetric to a vertical axis with a visually separated upper part (forehead, windshield), an ellipsoid on each side of the main body (eyes, headlights) and two extensions (ears, side-view mirrors), as well as two features in the midline one above the other (nose, grille, mouth/additional air-intake).

The analogy between automobiles and facial shape is already suggested (and depicted) in Coss (2003) and in Enlow’s (1975) textbook on facial growth. Intuitively assessed similarities confront us every day in car advertisements, news coverage and entertainment media (e.g., Disney Pixar’s “Cars” or Disney’s VW Beetle “Herbie” movies) — exploiting our tendency to anthropomorphize nonhuman agents the more similar they are to human physical appearance and motion (Morewedge, Preston, & Wegner, 2007; Waytz, Epley, & Cacioppo, 2010).

Given the evolutionary significance of a correct interpretation of another’s biological state and intention, it is apparent that morphological distinctions are the ones that drive age attribution (Montepare & Zebrowitz, 1998, for a review) and sex discrimination (Brown & Perrett, 1993), as well as the attribution of femininity, masculinity (Bruce et al., 1993) and associated traits such as strength, submissiveness and dominance (e.g., Grammer & Thornhill, 1994; Todorov, Said, Engell, & Oosterhof, 2008). Children have a relatively larger forehead, thin and arched brows, larger eyes, shorter noses as well as a smaller mid and lower face compared to adults (Bulgyina, Mitteroecker, & Aiello, 2006; Enlow & Hans, 1996; Trenouth & Joshi, 2006), and most adult facial sexual dimorphism involves the same features that constitute the difference between children and adults (Schaefer, Mitteroecker, Gunz, Bernhard, & Bookstein, 2004; Weston, Friday, & Liô, 2007). There is recent and fairly convincing evidence that perceptions of age and perceptions of masculinity relate to very similar features in the face (Boothroyd et al., 2005). Todorov and collaborators (2008) describe dominance alongside trustworthiness as one of two dimensions in the spontaneous characterization of faces. The link of social dominance and (perceived) physical body size has just been empirically confirmed (Marsh, Yu, Schechter, & Blair, 2009). Williams and colleagues (1999) found that women relative to men are regarded as soft and submissive (Ashmore & Tumia, 1980; Hess, Adams, & Kleeck, 2005) in a pancultural study including 25 nations. Artificially masculinized male and female faces are perceived to be more dominant, masculine and older (Perrett et al., 1998). Guthrie (1970) even speculates that the protruding male chin in the human species was selected as a sexual signal and thus exceeds the functional necessity of food processing.

Ecological theory (summarized in Montepare & Zebrowitz, 1998) provides a useful theoretical framework for the investigation of accurate perception and behavior as well as for overgeneralization as an evolutionarily beneficial strategy. The three relevant tenets are as follows: (1) Social perceptions serve biologically and socially adaptive functions. Although this favors the expectation of increased accuracy, it does not preclude errors, especially if there might be a greater advantage in overdetection (cf. error management theory; Guthrie, 1993; Montepare & Zebrowitz, 1998; Nettle, 2004). (2) Social judgments are informed by perceptible stimulus qualities, and overgeneralization effects will occur when qualities typical of one context occur in another. (3) People’s physical qualities reveal affordances, which are the opportunities for acting or interacting, and are linked to behavioral tendencies.

Pittenger and colleagues (1979) modeled a drawing of a VW Beetle front and a cartoon version including painted facial features in line with a mathematical simulation of growth — the cardiodial strain algorithm — and asked undergraduates of an American university for relative age attributions. The ratings were found to correlate positively with expectations from the modeling. Windhager et al. (2008) extended this approach in Austria by the use of natural-looking, existing car models, a broader list of rated traits (including sex, interpersonal attitudes, emotions and personality) and the actual measurement of car shape and its constituent parts. If there is a biologically based overgeneralization from faces to cars, then the biomorphic aspects of such a visual stimulus should be broadly recognized even if the actual object is not. We are saying that to be recognized as a face may well be a biologically based affordance of cars. Cross-cultural agreement would therefore be a prerequisite for supporting theoretical assumptions such as schema congruity and error management theory. Thus, the primary purpose of the present study was to test whether this shape–trait correspondence generalizes across cultures (and especially to a culture that is not exposed to car marketing, has little exposure to the film industry, etc., such as found in regions of Ethiopia).
Generalizability requires confirmation that:

- the correlation between Austrian and Ethiopian mean ratings is high, and
- the predicted car shapes for a specific trait attribution are similar.

From Pittenger et al. (1979) and from the structure of the first principal component of trait attribution and the corresponding car shape of the Windhager et al. 2008 study, we predict that (1) at least the biomorphic aspects of maturity, sex and interpersonal attitudes should generalize cross-culturally with (2) perceived maturity showing the strongest signal and (3) that maturity, sex and dominance attributions have a single factor in common. If there is such a single factor, car shapes estimated from these three qualities will be similar for the three scales and the two countries.

2. Materials and methods

2.1. Participants

The current study was based on three data sets (Austria, presstudy Ethiopia 2008 and comparative sample Ethiopia 2009). Their characteristics are summarized in Table 1. The Austrian sample was different from the study published in 2008 (Windhager et al., 2008). Data were collected in the capital of Austria, Vienna, and in rural villages and surrounding areas 30 to 45 km from the capital of Ethiopia, Addis Ababa (in 2008: Dukem, Holeta Genet, Laga Tafo and Sululta; in 2009: Holeta Genet, Sululta and two sites in Debre Zeit). Participants in Austria were recruited through online advertisements and in Ethiopia through local assistants. In Ethiopia, taking both years together, 11 of 89 participants reported having a driver's license and 6 claimed to own a car. The abrupt rise in the amount of compensation from 2008 to 2009 (Table 1) was necessary due to high inflation.

2.2. Stimuli

As in the preceding study, all pictures stem from computer renderings of high-resolution, realistic 3D digital models. The major advantage of this stimulus source is that materials, light and positioning can be better standardized than in any real-life situation (in 3ds Max from Autodesk Media & Entertainment, San Rafael, CA, USA). The digital mockups were scaled to the size of the original cars and colored silver, and the license plates were erased (Fig. 1). For a realistic appearance, materials such as car paint, chrome, rubber and glass as well as shadows were added. A virtual sun was placed at a 45° angle right in front of the car. A virtual camera with a 200-mm lens was positioned on the midline in front of the car at 12-m distance and half the height of the car (illustrated in Fig. 1).

We engaged in such standardization efforts because we were interested in the response to the shape of the car front and its constituent parts. All other differences such as reflections, optical distortions (through different lenses and distances), slight differences in positioning of the car to the camera or different colors of the car body might obscure the signal and hinder the interpretation. We used the stimuli of the previous study and added eight new ones. A detailed list of the models (all from 2004 to 2007) from 26 different brands is given in Appendix A.

2.3. Questionnaire and procedure

Each participant was asked to rate each car on 19 trait scales before the next car was presented. All 46 cars were presented in random order for each person. As the human face is a multisignal system from which humans can immediately infer information on age, sex, attitudes, personality traits and emotions, we wanted to cover this variety of possible inferences when testing trait attributions to car fronts. All rating scales were continuous and ranged from 0 to 100 (values and ticks not visible). The first four were bipolar [the biological features: child–adult and male–female; the two main dimensions of interpersonal relationships (Argyle, 2002): friendly–hostile and submissive–dominant]. In order to prevent artifacts from a possible

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side bias, the direction of the “sex” scale, with “male” (0) on the left and “female” (100) on the right side, was not in line with the other scales (in the sense of a social signal where perceptions of adulthood, maleness and dominance go together). We reversed this scale prior to data analyses to present the results more intuitively. The other scales were unipolar, ranging from “not at all” to “a lot/very much”. These remaining 15 items were (in the order on the questionnaire): the six so-called basic emotions (Ekman, 1999) — sad, angry, afraid, happy, disgusted, surprised; the five cross-culturally valid personality factors (McCrae & Costa, 1997) — open, extroverted, agreeable, conscientious, neurotic; two items that resulted from discussions with the automotive industry — contented, arrogant; as well as “aroused” to account for the dimensional approach to emotions by Russell (e.g., Russell, 1997) and, finally, “I like the car”. Cross-cultural comparisons were of averages for each dimension by car and country. Subjects who were acquainted with the use of a computer mouse worked on a computer interface (all participants in Austria, 17% in 2008 and 19% in 2009 in Ethiopia); the others responded on a paper-and-pencil version. The color printouts of the cars, in the latter case, were presented vertically to match the presentation of the screen.

In Austria, we used the following instructions (translation from German): “This is a simple rating experiment. Please describe your impression of the shown car front by moving the slider to the left or the right”. The experimenter stayed with the subject until the first ratings were completed to ensure that the task and the interface were understood. In the

Fig. 1. Preparation of the standardized car stimuli. Customary true-to-detail digital mockups of car models from 2004 to 2007 of 26 brands (example in the upper left panel (A)) were edited in 3ds Max (Autodesk Media & Entertainment, San Rafael, CA, USA) to face a virtual camera (in blue) at half the height of the car exactly frontally (B and C). A virtual sun (in yellow) produces symmetric reflections and shadows on the material to give the car a realistic appearance. The lower right picture (D) shows the camera view after rendering. These are the pictures that were presented in the rating experiment.
prestudy Ethiopia 2008, we used the following introductory sentences in English and Amharic, the official language of Ethiopia: “Please tell us: How does this car look? There is no right or wrong answer, just your opinion counts!” As 71% of participants in 2008 reported Oromo as their mother tongue, we decided to add translations into this language. We also felt the need for a more detailed introduction. The revised version for 2009 was: “You will see different car fronts. This study is not about function of the car or whether you would like to have it or not, but only about how you think it looks. Please do not try to be polite, but mark your personal, honest impression.” The items on the 19 scales were presented in German in Austria, in Amharic and English in Ethiopia 2008 and in Amharic, English and Oromo in Ethiopia 2009. Each questionnaire was translated back and forth by three Ethiopian native speakers fluent in at least two Ethiopian languages, English and/or German. Much personal communication took place to ensure that not only the items but also the concepts behind them translate well into the other languages. The follow-up questionnaires included demographic questions as well as questions on car ownership, car use and “dream” cars. Finally, our subjects were debriefed, paid and thanked for their cooperation.

2.4. Excluded and missing data

Each participant was asked to rate 46 car fronts on 18 traits and their degree of liking. From the Austrian sample, we had to omit data from two men for reasons of obvious problems with the rating scheme. Furthermore, the ratings of four cars from another subject were not considered because all values were defaulted. In the Ethiopian sample of 2008, we excluded the data of three men and two women using paper and pencil because their seriousness or comprehension of the task was questionable from visual inspection (e.g., zigzag patterns across the page instead of rating the pictures). Furthermore, in nine cases, all ratings of one car by a single subject could not be taken into account due to missing data. Of the remaining 32,167 data entries (meaning the rating of one subject on one scale for one car), 173 were missing (0.5%) and omitted. In the 2009 Ethiopian sample, one woman left after rating 22 cars. From the remaining 36,252 data points, 327 were missing data (0.9%) because subjects left the scale of a certain variable blank, made two markings on the same scale or forgot to rate a specific car, and the like. Again, such suspect or missing data were omitted from subsequent analyses.

2.5. Statistical analyses and geometric morphometrics

Pearson correlation coefficients, bivariate linear regressions, plots and significance tests, and descriptive statistics were computed in SPSS 15. All tests were two-tailed. Pearson correlation coefficients equal to or larger than 0.3 are statistically significant at the .05 level for our sample size of 46 automobiles.

A geometric morphometrics approach was used to link the ratings to car shape. Recent reviews of these methods can be found in Mitteroecker and Gunz (2009) and, in connection with perception data, in Schaefer and colleagues (2009). The great advantage of geometric morphometrics is that the results of statistical analyses are in terms of coordinates so that corresponding shapes can be visualized. The form of each car was captured by the two-dimensional Cartesian coordinates of 34 landmarks that were described in detail in the preceding publication (Windhager et al., 2008). Shape information invariant to scale and position was extracted by Generalized Procrustes Analysis (Rohlf & Slice, 1990). The superimposed configurations were then entered as dependent variables in a multivariate regression with the averaged rated trait scores as the independent variable (“shape regression”). The estimated shape changes from the average car to a car that is rated as more childlike, adult, female, male, etc. were visualized through deformation grids based on the thin-plate spline interpolation function (Bookstein, 1991). For illustrative purposes, outline landmarks were connected with straight lines. Permutation tests based on 1000 permutations were used as the test statistic (Good, 2000). In terms of computer programs: landmark coordinates were digitized in tpsDig2 Version 2.12 (Rohlf, 2008), shape regressions and permutation tests were computed in tpsRegr Version 1.36 (Rohlf, 2009), and thin-plate spline deformation grids were generated using Mathematica 6. All figures were edited in Adobe Illustrator CS3.

3. Results

3.1. Cross-cultural comparisons: correlations

Magnitudes of Pearson correlation coefficients were used to assess the strength of association between the Austrian and Ethiopian mean ratings per car for each trait. The sample size equals the total number of stimuli, i.e., 46, for all subsequent analyses. With the Ethiopian prestudy data from 2008, we obtained a strong positive correlation of 0.75 for the child–adult dimension (see also Windhager et al., 2009), whereas all other coefficients fell below 0.36.

When the Austrian and the Ethiopian sample of 2009 were considered, we observed strong, significant positive correlations not only for child–adult (r=0.85) but also for female–male (r=0.75) and submissive–dominant (r=0.84) ratings. All p values were below 2.7×10⁻³ so that we abandoned explicit Bonferroni adjustments. The correlation coefficients for the other scales remained below 0.57 (arrogant, see Fig. 3), followed by 0.43 (afraid) and 0.36 (sad), raising an issue that is considered later. Scatterplots visualizing the association of Austrian and Ethiopian 2009 mean ratings for child–adult, female–male and submissive–dominant are presented in Fig. 2. Taking the Austrian subjects as the reference sample, we found coefficients of determination (R²) of 0.72, 0.56 and 0.71, respectively. As
Fig. 2. Intercultural consistency in the attribution of child–adult, female–male and submissive–dominant ratings to car fronts. The three panels show the scatterplots and linear regression lines for the Austrian and the 2009 Ethiopian sample. The regressions were significant at the .001 level, as were the correlations (see main text). The numbers label the single car fronts, which are listed in Appendix A (n=46). This figure not only shows intercultural consistency, but also hints at the close relation of the three scales, which is illustrated by highly similar relative positions of single cars in all three plots.
the labels in Fig. 2, which identify the single car models, suggest, the intercorrelations between these three dimensions were high.

Within the Austrian sample, every pairwise comparison had a correlation coefficient of more than 0.96. In the 2009 comparative Ethiopian sample, the correlation coefficients ranged from 0.68 (female–male compared to submissive–dominant) to 0.81 (child–adult compared to female–male). All $p$ values were below $2.2 \times 10^{-7}$.

The correlation coefficients for the other dimensions were again rather low when the Austrian sample and the Ethiopian sample of 2009 were considered. Basically, all items could be allocated to one of two types. Plotting the Austrian car ratings against the Ethiopians' for each trait separately, one type was characterized by a relatively small circular scatter. We use “neurotic” as an example in Fig. 3. This pattern was also observed for agreeable, conscientious, content, disgusted, extroverted, sad and surprised.

The second type is where the Austrians utilized a much broader range than the Ethiopians. This pattern is illustrated with the item “arrogant” in Fig. 3 (right panel). All cars were rated as rather arrogant in Ethiopia, whereas we found various degrees of attributed arrogance for the same cars in Austria. A similar pattern was identified for afraid, angry, aroused, happy, friendly–hostile and open. The average Ethiopian ratings across all cars for these items were 62.5 (arrogant), 45.6 (afraid), 42.5 (angry), 44.5 (aroused), 66.6 (happy), 36.4 (friendly–hostile) and 65.6 (open) for the items of this second type of low correlation.

Possible intervening variables such as familiarity with questionnaires (which was investigated in the follow-up questionnaire) and the use of a paper-and-pencil version failed to explain these cross-cultural differences.

3.2. The association of trait attribution and car shape

Shape regressions were calculated to investigate the relationship of the shape of a car front and its constituent parts (headlights, windshield, etc.) with the three scales that showed the greatest cross-cultural consistency: attributed maturity, sex and dominance. For the assessment of shape–trait correspondence and for reasons of clarity, we used the Ethiopian ratings of 2009 and the Austrian data. In all six shape regressions (three items by two countries), none of the 1000 permutations achieved a better (lower Goodall $F$ values) result than the real data (thus, $p<.001$) in each case. To optimize the depiction of the overall shape pattern that corresponded to different trait attributions, we deformed the average car to ±2 standard deviations (S.D.) of the appearance variable for the Austrian ratings and to ±2.5 S.D. of the Ethiopian scores of the 2009 sample. As the deformations of the average car towards an estimated car that would be rated as child, female or submissive are hardly visually distinguishable from each other and between the two countries, we describe this common pattern of shape change all at once. With regard to global differences, we found a vertical stretching in cars of low attributed maturity and dominance, but high femininity (Figs. 4–6 on the left).

![Fig. 3](image-url) Fig. 3. Two phenomena of low correlation coefficients. Some variables were characterized by a low range of the averaged ratings in both countries and a circular scatter; i.e., all 46 cars were rated similarly along those specific scales (exemplified with “neurotic” in the left panel). The unipolar scales are read from zero (not at all) to 100 (a lot/very much). The second category was described by an elliptical scatter.
Fig. 4. The shapes of car fronts that were rated as “child” and “adult” in Austria and Ethiopia. The upper panels visualize the shape regressions onto the Austrian perception data; the lower ones, those upon the Ethiopian 2009 attributions on the child-adult scale (n=56 car fronts). The undeformed grid with quadratic squares in the middle in this and the next two figures corresponds to the average car shape of the sample. The configurations and deformation grids depict a highly similar pattern for both countries and correspond to ±2 S.D. for the Austrian and ±2.5 S.D. for the Ethiopian sample from the estimate of the average car.

as opposed to a general compression in cars of high maturity, masculinity and dominance (Figs. 4–6 on the right) in both countries. Concerning local features, the grids show a deformation towards a relatively larger windshield in the direction of low maturity, high femininity and low dominance. Cars that led to associations of adulthood, maleness and dominance were characterized by a relatively smaller windshield. As we standardized size during

Fig. 5. Estimated car shapes for increased femininity and masculinity attributions in Austria and Ethiopia. The geometry of the average car was deformed in the directions of increased perceived femininity (on the left) and increased masculinity (on the right) for both Austrian ratings (upper panels) and Ethiopian ratings of 2009 (lower panels). The major shape changes were in the relative height-to-width ratio of the car, the relative size of the windshield, the shape of the headlights, the height of the grille and the width of the additional air-intake slots.
Procrustes superimposition, we can only talk about relative differences here. The grille becomes relatively wider and taller with increasing attributed age, maleness and dominance. Also, the headlights differed in shape. The extreme upper and lower edges of the headlights were close to the middle of the car in a vehicle that was likely to be rated as childlike, feminine and submissive, whereas the headlights were extended laterally and were more slit-like in the estimated geometry of a vehicle with an adult, male, dominant appearance. The additional air-intake became wider and thinner with increasing attributed maturity, masculinity and dominance. To repeat, the pattern looked the same for Austrian and Ethiopian ratings (cf. upper and lower panels in Figs. 4–6).

4. Discussion

Our approach of combining rating studies with geometric morphometrics did not make any a priori psychological assumptions on the similarity of faces (or bodies) and car fronts. Actually, the results of the analyses (i.e., the thin-plate spline deformation grids) could have associated any shape change with the car ratings. Our findings — local (e.g., angled vs. round headlights, relatively smaller vs. taller and larger grille, narrow vs. wider additional air-intake) and global (e.g., proportion of windshield to the rest of the car body) shape differences according with changing impressions from child to adult, female to male and submissive to dominant — unearthed the striking similarities between car and face perception. There is much anecdotal evidence on the parallelism of car fronts and (human) faces, yet whether car fronts actually activate brain circuits for face processing or whether our findings stem from a different kind of generalization such as the (rational) judgment of proportions will have to be the subject of follow-up studies.

The current study replicated the pattern of trait attribution to car fronts from Windhager and colleagues (2008) with another Austrian sample of people in their twenties. Furthermore, and more importantly, we added a cross-cultural perspective by collecting data in regions of Ethiopia, where the car models and brands were unknown and car marketing does not exist. There, street transportation is dominated by small trucks, off-road vehicles, some taxi buses, horses and carts, donkeys and people carrying their goods.

4.1. Cross-cultural similarities: inference of allometry

Even though street scenery could not be more different, we found a high cross-cultural consistency in child–adult, female–male and submissive–dominant attributions to cars, with correlation coefficients of 0.75 to 0.85. Thus, these two peoples may have drawn on a common psychological mechanism. As there is hardly any no car marketing in Ethiopia, our results likely are due to the properties of the car. The estimated shape patterns, which hardly vary at all (Figs. 4–6), reflect one underlying dimension of facial proportion. We cannot completely rule out carryover effects from the order of
items, but we tried to minimize them by counterbalancing the sex stereotypes in the directions of our rating scales. Moreover, friendly–hostile as the third scale on the questionnaire (between male–female and submissive–dominant) did not reflect the observed patterns for the other three items. Therefore, we believe the biomorphic aspects of the stimuli to be a likelier explanation of our results than potential carryover effects. The most likely candidate for this single dimension is allometry (i.e., the change of facial shape along with proportions during growth) and the corresponding social cues we reviewed briefly in the introduction. A relatively large forehead compared to a short lower face and large eyes leads to increased babyishness attributions and perceived need for protective aid in humans (Alley, 1981; Alley, 1983). The attribution of femininity to the same morphological features might relate to the extended growth period in men (Schaefer et al., 2004; Weston et al., 2007). Along the same lines, rating studies generally confirm the positive association of perceived masculinity, dominance and age in human faces (e.g., Boothroyd et al., 2005; Hess, Adams, Grammer, & Kleck, 2009; Perrett et al., 1998). The observed pattern of overgeneralization to car fronts in this study adds support to the notion that these traits are a single biological dimension of inference from facial form. Of course, we cannot say how often this percept would arise unevoked.

Our study supersedes the findings of Pitenger et al. (1979) by using Cartesian coordinate landmark data instead of a model of proportional gradients referring to just a center and an outline curve that does not allow the detection of regional effects (e.g., headlight shape). Even though our figures and the overall proportions of windshield-to-car body might look similar to those presented by Pitenger et al., the geometry of the child–adult gradient that we found is, in fact, different: their geometry was cardioidal, but ours turned out to be axial.

4.2. Another kind of cross-cultural agreement

We also observed a second, completely different category of cross-cultural agreement: low rating variance in cars around the middle of certain scales (illustrated on the left in Fig. 3). A possible source for this phenomenon is a lack of signal value of these traits in more abstract representations such as cars, and consequently low interrater agreement within each culture. Many studies have shown that some of these traits are hard to judge even in humans (e.g., for neuroticism: Borkenau & Liebler, 1992; disgust: Hess & Blairy, 2001) or seem to correlate with other qualities that our silver cars do not have, such as extroversion being related to attractiveness and conscientiousness to dress style (Albright, Kenny, & Malloy, 1988). Our earlier study (Windhager et al., 2008) also found low interrater agreement for perceived conscientiousness, disgust, extroversion, neuroticism and sadness in car fronts.

4.3. Cross-cultural differences in trait attribution to car fronts

There were differences between Austrian and Ethiopian ratings in items that deal with (emotional) valence (with the exception of openness). There was high differentiation between cars in the Austrian mean ratings, while in Ethiopia, all cars were judged as rather "arrogant" (perhaps in a positive sense), "happy", "friendly" and "open". One possible reason is that Ethiopians are very polite and rather restrained in sharing their personal opinion of somebody, especially if it is negative. A second reason might be that interactions with real cars in Ethiopia are generally only positive (transport of water, animals, goods, etc.). Or, third, the more elaborated introduction to the rating task in 2009 still did not overcome the tendency to judge cars in general instead of particular car models (that all cars were judged as "arrogant" in Ethiopia, Fig. 3, favors this conclusion).

Fourth, these traits may not be readily perceived in cars but need the emphasis of marketing strategies. To a few Ethiopian subjects, all the cars looked alike, a phenomenon similar to other-race and other-age effects with regard to human faces and their modulation by experience (e.g., Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008). For "afraid", "angry" and "aroused", the mean ratings ranged around the middle of the scale, perhaps owing to low agreement between the participants. Also, Ethiopian subjects in general tended to use simple subdivisions of the scale (half, one third, two thirds).

4.4. Prospects for future research

The more detailed introduction and explanation of the rating scale in 2009 extended cross-cultural agreement from just child–adult to include male–female and submissive–dominant. The availability of an Oromo translation might also have contributed to this development.

Cross-cultural comparisons would further benefit from an extension of methodologies to assess different levels of perception and cognition. It would help to repeat the eye tracking study of Windhager and colleagues (2010) with an Ethiopian sample and to further investigate the preconscious processing of car fronts by electroencephalography or functional magnetic resonance imaging (cf. Erk, Spitzer, Wunderlich, Galley, & Walter, 2002). Also, the addition of data from more countries and cultures (Henrich, Heine, & Norenzayan, 2010) would certainly help to distinguish between human universals and effects of marketing or advertisement.

The similarities of car and face perception described here might influence driving, pedestrian behavior and the design of car fronts. Do we change lanes sooner when an adult, dominant car appears in the rear-view mirror? Do children perceive cars as agents with eyes (headlights) and therefore assume they see them anyway when they try to cross the street?
4.5. Conclusions

Investigating the relationship between car front shape and personal trait attribution, we obtained very similar results in two different countries, Austria and Ethiopia, on child–adult, female–male and submissive–dominant scales. This finding cannot be interpreted as a result of marketing, brand or owner stereotypes. It likely reflects the perception and interpretation of proportions that shift between child and adult. Car fronts today might address evolutionary mechanisms originally designed for the perception of faces. There are implications of a bias for driving and pedestrian behavior, and for the automotive industry.

We end with the anecdote that inspired the title of this article. Our very first Ethiopian participant in 2008, completing the questionnaire on the side of a dusty road amidst cattle led to the river for drinking, commented on a question as to whether he generally associates a human face, an animal face or no face with cars: “I do not know what to answer. Cars have their own faces!”

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Appendix A

List of the car models under study. The numbers correspond to the data labels in Fig. 2.

1. Alfa 147
2. Audi A6
3. BMW 3
4. BMW 5
5. BMW 645ci
6. Chrysler 300C
7. Chrysler Crossfire
8. Citroen C2
9. Citroen C4
10. Daihatsu Cuore
11. Fiat Stilo
12. Ford Focus
13. Honda Civic
14. Kia Picanto
15. Lexus GS
16. Maybach
17. Mazda 6
18. Mercedes A
19. Mercedes C
20. Mercedes E
21. Mercedes SLK
22. Mini Cooper
23. Mitsubishi Colt
24. Nissan New Micra
25. Opel Astra
26. Opel Signum
27. Peugeot 307
28. Peugeot 1007 Rc
29. Renault Modus
30. Saab 9-5
31. Seat Toledo
32. Smart Passion
33. Suzuki Swift
34. Toyota Prius
35. Toyota Yaris
36. VW Golf
37. VW New Beetle
38. VW Passat
39. Citroen C1
40. Peugeot 107
41. Toyota Aygo
42. Ford Galaxy
43. Seat Alhambra
44. VW Sharan
45. VW Touran 2005
46. VW Touran 2007

References


2.6 Laying eyes on headlights: eye movements suggest facial features in cars (published in Collegium Antropologicum)


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Data collection using an eyetracker. © S. Windhager
Laying Eyes on Headlights: Eye Movements Suggest Facial Features in Cars

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ABSTRACT

H umans’ proneness to see faces even in inanimate structures such as cars has long been noticed, yet empirical evidence is scarce. To examine this tendency of anthropomorphism, participants were asked to compare specific features (such as the eyes) of a face and a car front presented next to each other. Eye movement patterns indicated on which visual information participants relied to solve the task and clearly revealed the perception of facial features in cars, such as headlights as eyes or grille as nose. Most importantly, a predominance of headlights was found in attracting and guiding people’s gaze irrespective of the feature they were asked to compare – equivalent to the role of the eyes during face perception. This response to abstract configurations is interpreted as an adaptive bias of the respective inherent mechanism for face perception and is evolutionarily reasonable with regard to a “better safe than sorry” strategy.

Key words: cars, automobiles, eye movements, faces, facial features, gaze patterns, human perception

Introduction

The human tendency of animism and anthropomorphism, i.e. interpreting even the non-living as living and in human terms, has long been noticed¹. This propensity is revealed, for example, when we look out of the window and see faces in the clouds and is assumed to be triggered by spatial relationships of single features. But how could such a perceptual bias have evolved and persisted?

The answer is: “better safe than sorry!” That is, we gain much from being right (e.g., identifying another human, predator, prey) in vague reality and lose little when accidentally treating a non-agent as an agent, e.g. a stone as a bear². Such asymmetries in the recurrent costs of errors in inference can lead to the evolution of biases even when these biases result in greater rates of inferential error³, and favor the persistence of a hypersensitive agent detection system⁴. But there is more to it than mere detection of presence.

Faces in particular convey much additional information such as the focus of the other’s attention through head and gaze direction, sex and age, and attitudes⁵ and are therefore worth our special attention. This focus of attention is reflected by fixations obtained by eye movement recording. During face perception, the duration of a fixation (i.e., periods of relative gaze stability) as well as the number of fixations that are exhibited on a specific region is highest on the eyes, nose and mouth – in descending order⁶. This pattern is the same for familiar and unfamiliar faces as well as upright and inverse oriented pictures⁷. Even in scrambled faces, people look at eyes and nose first. In summary, when exposed to faces, processing is highly determined with eyes having a special significance. Functional magnetic resonance imaging showed that face processing leads to an activation of the fusiform gyrus in the temporal lobe⁸, the so-called fusiform face area. Importantly, this area is also found to be activated in laypersons⁹, not just in car experts¹⁰, when being presented with automobiles.

In other contexts, i.e. physical attractiveness, social dominance and exclusion, Maner and colleagues already demonstrated the measure of visual attention in
general, and eye tracking in particular, to be a valid tool in the reconstruction of (evolved) perceptual biases. In the current study, we developed a specific task to explore whether people actually perceive facial features in artifacts, more specifically in cars: A face and a car front were presented next to each other and participants were asked whether these two “have the same eyes” (or, nose, mouth, or ears in other trials). By monitoring the eye movements, it can be determined on which visual information a participant relies on to solve the task. Only if the car’s constituent parts do have an underlying facial signal quality, there will be an increased number of fixations on a specific region of the car front when the subject is asked to compare, e.g., the eyes, of the face and the car.

Materials and Methods

Participants

Twenty-five male and twenty-five female participants were recruited via advertisement in Austria. Their age ranged from 19 to 36 years (M=24.5, SD=3.6). They received 10 € compensation and were not allowed to have participated in previous studies using the same stimulus material. One woman had to be excluded from the analyses due to technical problems during eye movement recording.

Procedure

To realize the comparison of four different features, stimulus material was grouped in four blocks. Each block was introduced with the question (translated from German): “Do the face and the car front have the same [eyes | nose | mouth | ears]?” whereby in each block participants were asked to compare a specific feature. The participants were further instructed to develop a general impression and not to answer each question individually. Participants were allowed to take a break between the four blocks for as long as they wished. To ensure that the initial fixation position was not on the experimental stimuli, each trial started with the presentation of a fixation cross in the upper left corner of the screen for 1,000 ms. Similarly, the stimuli were presented for 4,000 ms. This duration is commonly used in visual search paradigms including faces. Quality of eye tracking calibration was verified prior to every trial. Ten pseudo-random sequences of the stimulus material were realized by varying the sequence of the blocks (i.e., the specific features asked to compare) as well as the order of stimuli within the blocks. The pairing of the faces and car fronts was held constant for all sequences, i.e., a specific face was always paired with the same car.

Stimuli

Each experimental stimulus was made up of two different objects: A human face with a neutral expression and a front picture of a car. Human faces were standardized frontal pictures of 19 men and 19 women of various ages. Participants were instructed to directly face the camera, which was positioned at eye height, and to approximate the Frankfort Horizontal (meaning ears and bottoms of eye sockets at the same level as described by Farkas), None of the participants wore glasses, jewelry, tattoos or make up. Constant studio lighting, a 200 mm lens on a digital camera and a distance of 3 m were used to minimize optical distortions. Seventy-two pre-defined somatometric landmarks (adapted from Farkas) were then marked on each facial photograph for the standardization of position, orientation and size of the facial stimuli. This iterative standardization process based on a least squares criterion was conducted in the computer program Facial Explorer (see Rikowski and Grammer for a detailed description of the procedure). Pictures were also standardized with regard to white balance, contrast and brightness, and finally superimposed by a blurred white ellipse (in Photoshop CS) to disguise contextual information such as hair style and clothing as well as to avoid any visual edges during presentation. The resulting pictures were of 830x532 pixels.

The car fronts were high resolution 3D computer models (Digital MockUps) of 38 existing car models from 2004 to 2006, comprising 26 brands, and were edited with 3ds Max (Autodesk Media & Entertainment, San Rafael, USA). All cars were colored silver and scaled to their original size. Materials such as chrome, gum, and glass as well as shadows were taken into account to give the cars a realistic appearance. License plates were erased and standardized lightening was realized by a virtual sun at a 45° angle right in front of the car. A virtual camera with a 200 mm lens was positioned in the midline at 12 m distance and at half of the height of the respective car. The frontal images of the cars were of 640x497 pixels. To realize the experimental stimuli, a face and a car front were randomly assigned and placed next to each other with the car on the right side.

Apparatus

Eye movements were recorded from the left eye using a video based iView X Hi-Speed tracking column (SensoMotoric Instruments, Germany) with a sampling rate of 250 Hz. Participants were seated in a distance of ~50 cm to a 19” CRT monitor connected to an IBM compatible desktop computer. Stimulus presentation was controlled by Presentation (Neurobehavioral Systems, CA, USA).

Analysis of eye movements and gaze direction

Between rapid eye movements with high velocities above 500° per second (so-called saccades), our eyes remain relatively still (i.e., a fixation). During these fixations, our visual system takes up new information. The amount of information extracted from an area of interest is reflected by the number of fixations exhibited on this specific area of interest. In the current study, we calculated the center of gravity for the headlight, the grille, the additional air intake and the side-view mirrors based on the two-dimensional Cartesian coordinates of their landmarks as defined by Windhager and colleagues for
each car. The average of all x-coordinates of a feature’s landmarks equals the x-coordinate of its center of gravity, and likewise with the y-coordinates. For the faces themselves, the center points of the pupils, -pronasale-, -stomion- and -tragion- were used as analogous centers.

Then each fixation was assigned to the feature with the next closest center. There was one value per paired feature, i.e. the numbers of fixations for left and right headlights and side-view mirrors, and eyes and ears respectively, were summed up. The analyses were of average numbers of fixations per feature from either car or face.

**Statistics**

Repeated measurement ANOVAs were conducted in SPSS 11 for each task to compare the numbers of fixations on different regions. If the criterion of statistical significance (p≤0.05) was met, pair-wise t-tests together with Bonferroni adjustments were applied as post-hoc tests. All tests were two-tailed and Cohen’s d was given as effect size measure.

**Results**

**Visualization**

For the visualization of fixation patterns, heatplots were generated on the basis of the spatially smoothed total fixation time of every individual pixel and were superimposed on the stimulus material – thus reflecting the degree of attention received by the single parts: The brighter the color, the higher the total fixation time on this region. In the example depicted in Figure 1, the heatplot indicates when subjects were asked whether the face and the car front had the same eyes, the focus of attention was on the eyes of the face and the headlights of the car.

![Fig. 1. Heatplot visualizing spatially smoothed total fixation times in response to the question "Do the face and the car front have the same eyes?".](image)

**Statistical analysis**

Separately for the four different tasks (i.e., the comparison of eyes, nose, mouth, or ears) the numbers of fixations exhibited on a feature were submitted to a 2×4 repeated measurement ANOVA with object-type (face vs. car) and fixated feature (eyes [headlights], nose [grille], mouth [additional air intake], and ears [side-view mirrors]) as within-subject factors.

To categorize fixations as belonging to a certain feature, centers of gravity of the single features were identified individually for each stimulus. In a second step, for each individual fixation, the spatial distances of the fixation to the centers of gravity were determined separately for each participant and stimulus. Subsequently, each fixation was categorized as belonging to the feature with the shortest corresponding distance; the resulting means and standard errors of the means are given in Table 1 and plotted in Figure 2.

Analysis revealed that the main effect of object-type was not significant for the comparison of eyes and the comparison of the nose, F<1, but for the comparison of

**TABLE 1**

MEAN NUMBERS OF FIXATIONS (UPPER ROW) AND STANDARD ERRORS OF THE MEANS (SEM, LOWER ROW) FOR THE VARIOUS REGIONS OF THE CAR FRONT AND THE HUMAN FACE SPITITTED BY TASK

<table>
<thead>
<tr>
<th></th>
<th>... eyes?</th>
<th>... nose?</th>
<th>... mouth?</th>
<th>... ears?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cars</td>
<td>Faces</td>
<td>Cars</td>
<td>Faces</td>
</tr>
<tr>
<td>Headlights/eyes</td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
</tr>
<tr>
<td>SEM</td>
<td>4.02</td>
<td>4.67</td>
<td>2.64</td>
<td>3.07*</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>0.13</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
<td>Grille/nose</td>
<td>1.86*</td>
<td>1.27*</td>
<td>2.92</td>
<td>2.20</td>
</tr>
<tr>
<td>SEM</td>
<td>0.08</td>
<td>0.06</td>
<td>0.09</td>
<td>0.09</td>
</tr>
<tr>
<td>Air intake/mouth</td>
<td>0.56*</td>
<td>0.88*</td>
<td>1.04*</td>
<td>1.07*</td>
</tr>
<tr>
<td>SEM</td>
<td>0.09</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
</tr>
<tr>
<td>Side-view mirrors/ears</td>
<td>1.51*</td>
<td>1.32*</td>
<td>1.32*</td>
<td>1.28*</td>
</tr>
<tr>
<td>SEM</td>
<td>0.11</td>
<td>0.06</td>
<td>0.11</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Significant mean differences between targeted feature (in bold face) and other regions on the car or face respectively are marked with an asterisk (*n= 49 subjects). The corresponding effect sizes are given in Table 2.

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the mouth, F(1.48) = 14.99; p < 0.001, and ears, F(1.48) = 4.87; p = 0.03. The main effect of feature and the object-type by feature interaction were significant for all four tasks, all Fs > 5.68, all ps < 0.001. The individual statistics for all four tasks are provided in the Appendix.

Of theoretical relevance in the present analysis is, whether the eye movement patterns exhibited on faces and cars correspond, more specifically, whether: (A) similarities in the overall pattern of eye movements in faces and cars can be observed, and (B), whether the specific feature that had to be compared in the different tasks (e.g., the nose) resulted in a higher number of fixations on a specific feature in the car – thereby establishing a link between facial features and the corresponding features in cars. For that reason, separately for object-type and task, pair-wise comparisons between the respective target-feature of the task (e.g., the eyes) and the remaining three features (e.g., the nose, mouth, and ears) were performed by means of paired-samples t-tests. To prevent the accumulation of α-errors and preserve the overall significance level of 0.05, a medium-conservative Bonferroni α-adjustment was applied by dividing the overall significance level by the number of individual tests. The corresponding effect sizes (Cohen’s d) are reported in Table 2.

An inspection of Table 1 and 2 reveals two major findings. First of all, the eyes and the headlights always – no matter what feature was asked to compare – received as many or even more fixations than the target-feature that actually had to be compared. As can be seen in the first row of Table 2, effect sizes for the comparison of the eyes/headlights with the other features were not significant or even negative. The number of fixations even increased by further 36% for the eyes and 33% for the headlights when the participants were explicitly asked to compare the eyes; as obvious in Figure 2, eyes and headlights outweighed all the other features by far (factor 3.5 for the eyes and factor 2 for the headlights as compared to other features of the respective object). A second finding of theoretical relevance is revealed by the second, third, and fourth row of Table 1. If asked to compare the eyes, nose, or ears, the resulting eye movement patterns for faces and cars were highly similar: The target-feature was always looked at more often than the remaining features, leaving eyes and headlights aside in the latter two tasks. If asked to compare the nose, the mean number of fixations was more than twice as high for the grill as for the other features, i.e., the air intake and the side-view mirrors (see Figure 2). Similarly, numbers of fixations were more than doubled for the side-view mirrors and the ears when participants had to compare the ears. Interestingly, when asked to compare the mouth, our subjects – as apparent in Figure 2 – predominantly fixated on the mouth of the face, however, during the examination of the car, the grill and the air intake competed for the role as ‘mouth’.

### TABLE 2

<table>
<thead>
<tr>
<th></th>
<th>... eyes?</th>
<th>... nose?</th>
<th>... mouth?</th>
<th>... ears?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do the face and the car front have the same ...</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cars</td>
<td>Faces</td>
<td>Cars</td>
<td>Faces</td>
</tr>
<tr>
<td>Headlights/eyes</td>
<td>0</td>
<td>0</td>
<td>0.42</td>
<td>-1.21*</td>
</tr>
<tr>
<td>Grille/nose</td>
<td>2.94*</td>
<td>4.85*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Air intake/mouth</td>
<td>4.58*</td>
<td>5.24*</td>
<td>3.08*</td>
<td>2.04*</td>
</tr>
<tr>
<td>Side-view mirrors/ears</td>
<td>3.03*</td>
<td>4.70*</td>
<td>2.25*</td>
<td>1.52*</td>
</tr>
</tbody>
</table>

Significant comparisons are marked (*)

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Discussion

In the present study, we could show that analogies of faces are actually perceived in non-living objects, namely cars. People consistently directed their gaze from the facial feature to a specific region of the car front when asked to compare eyes, nose, mouth, and ears between a face and a car. Gaze patterns revealed headlight to be considered as eyes, the grille as the nose, either the grille or the additional air intake as the mouth as well as the side-view mirrors as ears.

Yet, the most striking finding of the present study is that the number of fixations was found to be greatest on the headlight in every single condition (and further increased, when people were asked whether the face and the car front had the same eyes). So people predominately fixated the eyes and also the headlight, although they were asked to look for something else. The significance of eyes in face perception is consistent with the existing literature. Although the eye region covers just 21% of the face, it receives a (disproportionately) large percentage of gaze fixation, i.e. attention. Two reasons are discussed in the current literature: On the proximate level, it is the most salient physical property of the human eye such as the extraordinary high contrast between white sclera and black pupil, horizontal elongation and the symmetric positioning that foster detection and can operate as indicator of the current alignment of a face; and on the ultimate level, the co-evolution of physical property and social signal in face detection and attention orientation up to facial expressions. Such gaze-signal enhancement might have been crucial for increased cooperative and mutualistic behaviors (e.g. group hunting, scavenging) in human evolution. The finding that the same attention bias exists for the headlights of a car strengthens the claim for a face appearance of cars and the existence of an overperception error. Besides, this analogy between eyes and headlight highlights also the task independent automaticity of an evolved perceptual bias.

Thus, humans like many species are highly sensitive to such patterns no matter how abstract they are, cf. also the eyespots on many butterfly species. In a recent paper, we could even show — using a combination of a rating study with geometric morphometrics — that human characteristics such as maturity, sex and interindividual attitudes can be reliably inferred from car fronts and that the corresponding shapes mirror proportion shifts and feature changes known from human faces. Additional neurophysiological studies will be necessary to further investigate the similarities of face and car perception as anticipated by Erk and colleagues. Another promising direction for future research will be the systematic alteration of the car stimuli in the way faces, were tested in the past (inverted, whole-part, thached-rized) and.

In summary, we conclude that people can interpret car fronts not only as face-like, but furthermore that the automatic information seeking behavior during the perception of car fronts is based on anthropomorphic assumptions of the beholder — as reflected by eye movements. This favors the claim that animism and anthropomorphism are part of our every-day life. Such a likewise perceptual as cognitive bias might have evolved through the ongoing selective pressure to detect every agent close-by and might not only affect design decisions nowadays.

Acknowledgements

We thank our participants, Florian Karolyi for assistance during data collection, Louise Viola for help with the manuscript and two anonymous reviewers for valuable comments. This work was supported by a research grant from EFES Unternehmensberatung GmbH and the FWF Grant P18910 to H. Leder and C.-C. Carbon.

REFERENCES

САНТАК

Лики скилица да видимо лица чак и на неизвршима структурама попут автомобила већ је давно замењена, наке емпиријских доказа је мало. Како бисмо испитали ову тенденцију ка антропоморфизму, испитивима је дано да супореде специфична оближња лица (попул оцију) и предњи дио автомобила, постављени један до другога. Обрасти покрета оцију су показали на оне визуалне информације које испитивци осланјају на резонансе задатак и укачили на перцепцију фацијалних оближња код автомобила – например предњих свjetala као оцију и реешке као носа. Што је најважније, утврђено је доминантност предњих свjetала, с обзиром да су она привлачила поглед неовисно о оближњима која су требали супоредити – једнако као што су служио и оцима код перцепција лика. Овај хипотеза на апстрактне конфигурације је интерпретирана као адаптивно својство инертног механизма за перцепцију лица и еволуцијски је важно као дио стратегија «сигурно је сигурно».

Appendix

DETAILED TEST STATISTICS OF THE REPEATED MEASUREMENTS ANOVAS (49 SUBJECTS) FOR THE TASK-SPECIFIC ANALYSES WITH OBJECT-TYPE AND FEATURE AS WITHIN-SUBJECT FACTORS

<table>
<thead>
<tr>
<th>Factor (df,df)</th>
<th>Do the face and the car front have the same ...</th>
<th>... eyes?</th>
<th>... nose?</th>
<th>... mouth?</th>
<th>... ears?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>p</td>
<td>F</td>
<td>p</td>
<td>F</td>
</tr>
<tr>
<td>Object-type (1,48)</td>
<td>0.37</td>
<td>0.38</td>
<td>0.99</td>
<td>0.33</td>
<td>14.99</td>
</tr>
<tr>
<td>Feature (3,144)</td>
<td>514.25</td>
<td>&lt;0.001</td>
<td>197.85</td>
<td>&lt;0.001</td>
<td>5.68</td>
</tr>
<tr>
<td>Object-type by feature (3,144)</td>
<td>21.33</td>
<td>&lt;0.001</td>
<td>18.68</td>
<td>&lt;0.001</td>
<td>7.15</td>
</tr>
</tbody>
</table>
3. Concluding discussion

This work took advantage of the latest developments in modern shape analysis in order to trace person perception at zero-acquaintance back to biological roots and fundamental shapes. Accordingly, the thesis extended the methodologies currently used in face research and showed a way to answer long pending questions. These include, for example, how much facial shape change (and in which regions exactly) corresponds to a doubled hormone level, twice the physical strength, or to a far more dominant or masculine face. Which facial features exactly determine a certain rating of appearance? Does face perception generalize to car fronts and which features lead to a certain trait attribution?

Although the first articles at the intersection of anthropometry and psychometry were published in 2006 by Schaefer and colleagues as well as Valenzano and coworkers, the face research community has just begun to appreciate the power of these geometric morphometric methods. This thesis not only adds new findings to specific hypotheses, but also exemplifies how these can be systematically tested. The growing understanding of the potential impact for the field is also shown in three anonymous reviews on the article presented in Chapter 2.2:

“It adds to a new and exciting literature on characteristics of the face and what they mean. … The use of geometric morphometrics to study the features of the face that indicate strength and attractiveness is both new and exciting. It adds to previous research that has established relationships between ratings of faces and actual physical characteristics but has failed to identify those characteristics. Importantly, this paper will publicize these methods which will be of use to other researchers in this area. … This area of research is interesting and topical. There are a number of labs currently working on these sorts of studies whose research would be positively impacted by the methods and data in the paper.”

“This study uses facial morphometrics to examine morphological correlates of perceived attractiveness, dominance and masculinity as seen by adult women. The study adds to our knowledge of this topic, particularly regarding the specific facial characteristics associated with biologically important social reactions. … The topic is of widespread interest and part of a very active research area. Their approach, i.e., geometric morphometrics, has been underutilized in this area.”

“In all, the paper makes a very good case for its primary conclusion: that physical strength and attractiveness in the face are not the same construct. I find the data and arguments on that point thoroughly convincing. In addition to this basic point, the paper contains many data points that are useful for researchers in the area,”

The papers of this thesis have also been of interest for other lines of face research. Both psychologists (e.g., Delgado, 2009; Miesler, Leder, & Herrmann, 2011; Wade & Tatler 2010) and marketing experts (e.g., Landwehr, McGill, & Herrmann, 2011; Lastovicka &
Sirianni, 2011) have already cited the papers from 2008 and 2010 (Chapters 2.4 and 2.6) in their work.

“The findings of Windhager et al. (2008) make us speculate that humans perceive both the features and configuration of a face in a face-like object.” (Ichikawa, Kanazawa, & Yamaguchi, 2011, p. 500)

In extension of our work, Ichikawa and colleagues tested 27 other man-made products and three natural objects for the existence of the facial features and facial expression. The highest ranked objects included mostly round wall-plugs, which supports, in my opinion, the prerequisite of schema congruity for an overgeneralization from faces to objects. As I discussed in the most recent car paper (Chapter 2.5, Introduction Section), it seems that not only the existence of schema congruity is relevant for trait attribution, but also the degree of congruity.

“Second, the current research employed only computerized avatars rather than actual interaction partners. ... Finally, although the computer is preprogrammed, there is good reason to believe that participants treat such stimuli as social stimuli. First, the mere presence of eyes on a target or characteristics that resemble eyes leads individuals to treat a target as social (e.g., Senju & Hasegawa, 2006; Windhager et al., 2008).” (Wirth, Sacco, Hugenberg, & Williams, 2010, p. 879)

Indeed, Windhager et al.’s (2008) recent study of car designs confirms the widespread tendency for people to see faces on products. ... Furthermore, other research has found that design elements corresponding to facial features affect product liking (Aggarwal and McGill 2007; Windhager et al. 2008).” (Landwehr et al., 2011, p. 132)

Concluding discussion and prospects for future research

In applying the concept of the psychomorphospace, facial shape was linked to both biological measurements (such as the second-to-fourth digit ratio, physical strength) and perceptions (e.g., dominance and maturity attributions). One shape pattern pervaded all four morphometric studies: One direction of deformation consists of a human face/car front with a relatively high, visually-separated upper part (forehead/windshield), relatively large, bilaterally-symmetric ellipsoids (eyes/headlights), longer noses and narrower grilles, respectively, as well as a narrower jaw/smaller car body (Figure 5, upper panels). The same dimension to the other extreme (Figure 5, lower panels) was associated with lower forehead/smaller (more tilted) windshield, more slit-like eyes/headlights, a wider nose/grille as well as a wider, more prominent lower jaw/wider lower part of the car body. The analogy of the single facial features and the specific parts of a car front were confirmed in an eyetracking study (Chapter 2.6). In one analysis, this shape pattern was the result of a shape regression onto the digit ratio in boys (as a proxy for prenatal testosterone; Figure 5, first column), and in a separate analysis, it was associated with perceived dominance and perceived masculinity in adult men (Figure 5, second column)
and, last but not least, with maturity, masculinity and dominance attributions to car fronts (Figure 5, third column).

The latter also confirmed that people concordantly ascribe certain person characteristics to car fronts analogously to inference from facial shape geometry. It further showed that the major dimensions in social perception could be replicated for car fronts (Chapter 2.4; Windhager, Slice, Schaefer et al., 2008). This abstraction in turn strengthens the consistency of these fundamental dimensions in interpersonal perception and social stereotyping. The question for future studies will be whether, beyond trait attribution, also social behavior is generalized to car fronts: Are dominant-looking cars afforded more space on the road (comparable to an increased personal space for dominant humans: Greene & Burleson, 2003)? Do pedestrians stop later in an attempt to cross the road when a child-like car approaches with the same speed as a dominant-looking one? Follow-up projects are currently set up to more closely investigate these issues.

**Figure 5. Comparison of shape patterns.**
The first column shows the facial shape variation associated with prenatal testosterone exposure (approximated through the second-to-fourth digit ratio) in boys as reported in Chapter 2.3. The second column depicts the facial correlates of perceived dominance in adult men from Chapter 2.2, and the third column gives the shape correlates of car fronts for the same perceptions depicted in Chapter 2.5. The upper row corresponds to low prenatal testosterone (left) and perceived submissiveness (middle and right), the lower panels to high prenatal testosterone (left) and high perceived dominance (middle and right). The overall shape characteristics and proportions in each upper panel are highly similar. The same holds true for the lower panels. There was only one small mismatch between dominant faces and dominant cars (a shorter nose, yet a taller grille). Thus, perceived dominance in cars may be driven by the attribution of maturity to a greater extent than in faces.
Returning to human face research: In replication and extension of previous studies (e.g., Fink et al., 2005; Neave et al., 2003), this thesis showed that dominance and masculinity attributions relate to highly similar facial characteristics independent of the level of facial abstraction (i.e. for both adult male facial photographs and pictures of car fronts; Chapters 2.2 and 2.5). Facial dominance and masculinity, however, were found to be only moderately correlated with perceived attractiveness. For the first time, this thesis showed that facial dominance did not closely resemble shape changes associated with high physical strength or body fat (as suggested by Sell et al., 2009) based on quantitative morphometrics. Facial dominance, however, did resemble the shape variation associated with prenatal testosterone exposure (in adults: Schaefer et al., 2009; in children: Chapter 2.3), but not morphological correlates of circulating testosterone in adult men (e.g., Schaefer et al., 2009). This result has implications for a variety of ultimately related research questions:

1. **How do facial dominance and masculinity relate to allometry, sexual dimorphism and, ultimately, intra- and intersexual selection?**

   In extension of this thesis, my aim for the near future will be to continue working with my supervisor Katrin Schaefer in taking her work on craniofacial sexual dimorphism (Schaefer, Mitteroecker, Gunz, Bernhard, & Bookstein, 2004) forward towards facial soft-tissue. This work showed that sexual dimorphism in the human adult skull shape can be attributed in part to extended growth in men (allometric component), and in part to a remainder, the non-allometric shape difference (see also Weston, Friday, & Liò, 2007). The greater the potential for a male to monopolize more than one female, the greater not only the strength of intermale competition, but the greater the allometric component (Cobb & O’Higgins, 2007; Schaefer et al., 2004). Until now, there has been no thorough approach to the puzzle of the degree of non-allometric human sexual dimorphism, which seems to intermediate between one-(monopolizing)-male mating systems [as in gorillas and orang-utans] and multi-male, multi-female systems [as in chimpanzees and bonobos] (Schaefer et al., 2004). This puzzle actually concerns not only the calvarium as investigated, but also the lower face, soft tissue, and, importantly, the perception of mate quality (for a recent review see Puts, 2010). Geometric morphometrics including the concept of the psychomorphospace allows for the first time the comparison of allometric and non-allometric shape variation to attributions of attractiveness, maturity, dominance, masculinity, and the like. Attractiveness ratings, for example, can be seen as a reasonable proxy for mate preferences in the study of inter-sexual selection in *Homo sapiens*. They can provide the theoretically missing part, which is impossible to realize when the craniofacial skeleton is the sole object of investigation. Does facial dominance reflect the allometric component and, hence, male-male competition? To answer such questions, we will take advantage of the GMM-based psychomorphospace and establish ontogenetic trajectories of human faces for both sexes of two cultures (Austria and Ethiopia; similar to Strand Viðarsdóttir, O’Higgins, & Stringer, 2002 and Schaefer et al., 2004 with facial skeletons or crania, respectively), visualize facial shapes typical of certain trait attributions and locate them in the context of the growth vectors. We further plan an extension to three-
dimensional facial data and the collection of steroid and growth hormones as a follow-up project. This line of research will also assess the different effects of testosterone on facial shape and trait inference from these features at various stages in life. Not only do facial correlates of prenatal testosterone exposure and of circulating testosterone differ in adult men (e.g., Schaefer et al., 2009), there is also recent evidence that attractiveness judgments of male facial characteristics might be modulated by testosterone levels in combination with cortisol levels (stress-linked immunocompetence hypothesis: Moore et al., 2011; Rantala et al., 2012). Which features underlie these judgements remain to be scrutinized. We are currently investigating these issues in an Austrian dataset using the geometric morphometrics toolkit.

2. **What are the social implications of facial dominance?**

Facial dominance seems to have far-reaching consequences for everyday life. For example, cadets with dominant faces achieve higher military rank in later life (Mueller & Mazur, 1997). Moreover, male financial traders with lower digit-ratios make greater long-term profits (Coates, Gurnell, & Rustichini, 2009). CEOs of particularly successful companies receive higher ratings of competence, dominance and facial maturity by undergraduates (Rule & Ambady, 2008), and consistent with the results of my thesis, they were found to have a higher facial width-to-height ratio (Wong, Ormiston, & Haselhuhn, 2011). In the same line, competence judgements based on facial appearance are positively linearly correlated with perceptions of maturity (Olivola & Todorov, 2010); the association with perceived masculinity, however, was less clear and somewhat dependent on the sex of the stimulus face in their study. As these results were based on computer-generated faces, it would be interesting to further investigate this issue using real photographs and the geometric morphometric toolkit (analogously to Chapter 2.2). This approach would also allow testing the argument of Riggio and Riggio (2010) that judgements of relative competence are based on facial features “that indicate strength/dominance and [to a lesser extent] approach-ability/trust” (p. 120). Finally, and astonishingly, the results of elections can be predicted by children from the face of a politician alone (by choosing their desired captain for a fictive boot trip; Antonakis & Dalgas, 2009). Thus, facial dominance might be a reliable indicator for socioeconomic status in modern human societies—at least in men.

3. **Which findings in men also hold true for women? And what are the consequences?**

Especially the first two chapters on human faces dealt with the male sex only. Although the association of prenatal testosterone and facial shape is about three times greater in men, the overall shape pattern could also be depicted in women (Fink et al., 2005). Masculinity attributions to female faces, for example, show a curvilinear trend with regard to judgements of competence (Olivola & Todorov, 2010). Female attractiveness, however, is strongly positively correlated with
perceived femininity and youthfulness (Buss, 1989; Law Smith et al., 2006; Perrett et al., 1998). Although understandable in terms of reproductive success, what does this gap mean for the professional success of women in modern Western societies?

I believe that another promising direction for future research is an extension of the dominant mother hypothesis (Grant, 1998, 2003; see also Chapter 2.3 this thesis) towards the explanation of intra-sex variations. For example, do dominant mothers not only more likely give birth to sons than to daughters, but do their sons also show greater facial dominance? Stressors such as famine (Gibson & Mace, 2003; Song, 2012) and lower social status (e.g., Mealey & Mackey, 1990), however, make the birth of a daughter more likely. Nonetheless, maternal and fetal cortisol levels seem to be positively correlated with fetal testosterone (Gitau, Adams, Fisk, & Glover, 2005). Does this potentially result in more dominant-looking girls that are also socially dominant in interactions with their peers? How does this interfere with perceptions of the baby schema and cuteness, which generally elicit adult aid? Extending these findings (facial shape, ratings, endocrinology, social and environmental context) in a framework based on the concept of the psychomorphospace thus opens a wide array of novel research possibilities that include women and children.

Geometric morphometrics therefore has the potential to contribute to an evolutionary understanding of the biology (including epigenetics) behind common sense snap judgements and to a modern physiognomy of the human face that overcomes moral justifications and the naturalistic fallacy (Voland, 2000). As David M. Buss puts it: “...knowledge of our evolved social psychological adaptations along with the social inputs that activate them gives us tremendous power to alter social behavior, if that is the desired goal.” (2008, p. 19).
References

In-text citations and references were formatted according to APA 5th style.


Lavater, J. C. (1866). *Physiognomy; or the corresponding analogy between the conformation of the features and the ruling passions of the mind*. London: William Tegg.


presented at the 16th Congress of the European Anthropological Association (EAA), Odense, Danemark.


Appendices

Appendix A: Abstract

Geometric morphometrics is a fairly recent development in modern shape analysis. This suite of methods enables, for the first time, preserving the whole geometry of facial measurements throughout the analyses. Questions such as the following can be answered: What facial shape pattern is associated with a certain hormone level and which facial features exactly determine a certain rating of appearance? And more importantly, what do these patterns have in common? Answers to these questions provide a bridge between physical anthropology and evolutionary psychology.

This thesis consists of a summary and recent history of geometric morphometric methods including the concept of the psychomorphospace, followed by four articles that show how this novel approach systematically tests long pending issues in face research. Two of these issues involve determinants of human facial shape variation (prenatal testosterone exposure, physical strength) and another two the determinants of shape that lead to face-like interpretations.

To address these issues, geometric morphometric methods are combined with rating studies. A fifth article deals with the overgeneralization of face perception on a preconscious level through the analysis of gaze direction.

The major findings are that—against previous hypotheses—facial correlates of prenatal testosterone exposure can be identified before male puberty. Secondly, facial shape features associated with physical strength in adult men are more closely related to perceived masculinity and dominance than to attractiveness. I show that these trait attributions are generalized to inanimate objects with the same shape patterns.

Altogether, this thesis presents a strong case for the fruitful synthesis of biological anthropology and psychological disciplines in both methods and research topics concerned with facial shape. In this respect, geometric morphometrics proved to be a powerful promoter.
Appendix B: Abstract in German (Zusammenfassung)

Die Geometrische Morphometrie ist eine relativ neue Entwicklung innerhalb der modernen Gestaltanalyse. Ihre Methoden ermöglichen es erstmals, die gesamte Geometrie von Gesichtsabmessungen während der Analyse zu erhalten und Fragen wie die folgenden zu beantworten: Welches Muster im Gesicht ist mit einem bestimmten Hormonlevel assoziiert, und welche Gesichtseigenschaften sind es genau, die einer bestimmten Wahrnehmung zugrundeliegen? Und wichtiger, was haben diese beiden gemeinsam? Antworten auf diese Fragen erfordern eine Verbindung von physischer Anthropologie und evolutionärer Psychologie.


Appendix C: Curriculum vitae

Mag.rer.nat. Sonja Windhager

Personal
Born on 23rd of June 1982 in Vienna, Austria
Nationality: Austria

Education
2005– PhD studies in Anthropology at the University of Vienna, Austria.
Supervisor: Prof. Dr. Katrin Schaefer
Mai 2005 Master of Science at the University of Vienna
Supervisor: Prof. Dr. Katrin Schaefer
Degree in Zoology, University of Vienna
2000–2005 Studies in Zoology and Anthropology at the University of Vienna:
Focusing on animal and human behaviour.
2000–2002 Study of Common Biology at the University of Vienna, Austria
2000 Matura (school leaving examination) in Vienna, Austria
Positions

Mar 10 – Oct 2005
Lecturer at the Department of Anthropology, University of Vienna, Austria.

Oct 2005 – Jul 2010
Scientific research (rating and geometric morphometric studies) at EFS Unternehmensberatung GmbH (a Viennese business consultancy), Austria.

Jul – Dec 2010
Scientific project staff at the Department of Anthropology, University of Vienna, Austria.

Mar – Aug 2010
Lecturer at the Department of Anthropology, University of Vienna, Austria.

Oct 07 – Feb 10
Research and teaching assistant at the Department of Anthropology, University of Vienna, Austria.

Jul – Aug 09
Employment for data analyses in context of the project FA 547009 ("Cross-Cultural Generalization of Face Perception – a Geometric Morphometrics Study.") to K. Schaefer, University of Vienna, Austria.

Mar 2008
Employment for data collection and processing in context of the project FA 547005 ("Psychomorphometrics of car fronts in Ethiopia") to K. Schaefer, University of Vienna, Austria.

Mar 06 – Feb 07
Research associate at the Ludwig Boltzmann Institute for Urban Ethology, Vienna, Austria.

Oct 05 – Feb 06
Lecturer at the Department of Anthropology, University of Vienna, Austria.

Jul 2003
Work experience at the Viennese zoo (Tiergarten Schönbrunn), Austria.

Research (Field) Experience

Apr 2009
Addis Ababa and surrounding areas, Ethiopia: Morphometric study on human facial growth, rating study on the cross-cultural perception of car fronts.

Feb 2008
Addis Ababa and surrounding areas, Ethiopia: Morphometric study on human facial shape variation, rating study on car fronts.
Workshop Participation

2010  “EVAN Toolbox (ET) Training Day: Form and shape analysis for biological objects” (EVAN-Society Training Day), Oct 22, Vienna, Austria.

2010  “Virtual anthropology meets biomechanics” (EVAN-Society Workshop), Oct 21, Vienna, Austria.


2008  “Multivariate techniques for growth and evolution of form” (EVAN Summer School), Jul 6–10, Vienna, Austria.

2008  “Surface scanning of soft and hard tissue” (EVAN Workshop), Jun 11–13, Meersburg, Germany.

2008  “Bone histology and growth” and “Growth and development of the craniofacial complex”, EVAN workshops, Mai 28–30, Madrid, Spain.

2007  “Geometric Morphometrics in R-software, Amira and Edgewarp” EVAN Fellow’s Training Workshop, Nov 12–14, Vienna, Austria.


EVAN (European Virtual Anthropology Network): EU FP6 Marie Curie Actions grant MRTN-CT-2005-019564

Teaching Experience (Curriculum of Anthropology, University of Vienna)

2010 – Digital Acquisition of Human Surface Morphology and Behavior (Lecture + Practicum); Practical Course: Human Ethology (Seminar + Practicum)


2005/2006 Practical course V: Human ethology (Practicum)

Oct 2007– Teaching assistance in Digital Acquisition of Human Surface Morphology and Behavior (Lecture + Practicum); Basic Human Ethology Course for Anthropologists (Practicum); Practical course IV (formerly V): Human ethology (Practicum); Human Behavioral Ecology (Lecture); Palaeoethology (Seminar); Seminar for Masters, Diploma and PhD-students in Anthropology.
2005–2007 Tutorial in Basic Human Ethology Course for Anthropologists (Practicum)

2006/2007 Tutorial in Practical course V: Human ethology (Practicum)

Grants

2011 Dissemination – Support of Conference Attendances of PhD Students. University of Vienna Program for Student Mobility, € 350

2011 Research Advancement Program "International Communication". Austrian Research Association, € 400

2010 Travel grant from the Human Behavior and Evolution Society (HBES), USD 350

2010 Dissemination – Support of Conference Attendances of PhD Students. University of Vienna Program for Student Mobility, € 650 (not accessed)

2009 Cross-Cultural Generalization of Face Perception—a Geometric Morphometrics Study. EFS Unternehmensberatung GmbH research grant, PI K. Schaefer, University of Vienna, FA 547009

2009 Research Advancement Program "International Communication". Austrian Research Association, € 700

2009 Dissemination – Support of Conference Attendances of PhD Students. University of Vienna Program for Student Mobility, € 650

2008 Psychomorphometrics of car fronts in Ethiopia. EFS Unternehmensberatung GmbH research grant, PI K. Schaefer, University of Vienna, FA 547005

2008 Dissemination – Support of Conference Attendances of PhD Students. University of Vienna Program for Student Mobility, € 350

2008 Research Advancement Program "International Communication". Austrian Research Association, € 450

2006 Expressions of Automobiles. EFS Unternehmensberatung GmbH research grant, PI K. Grammer, LBI for Urban Ethology
Professional Memberships
Association for Psychological Science (APS)
European Human Behavior & Evolution Association (EHBEA)
Human Behavior & Evolution Society (HBES)
International Society for Human Ethology (ISHE)
The BioSocial Society (BioSocSoc)

Referee
African Journal of Agricultural Research
Journal of Environmental Psychology

Foreign Languages
English, French

Selected Public Outreach and Press Coverage
Kinderuni [“Children’s University”]: Ist der Mensch ein Säugetier? [Is a human a mammal?], Jul 17 and 18, 2012
“’Manly’ Fingers Make For Strong Jawline in Young Boys”, science news website LiveScience, Feb 14, 2012
“Fisch gibt’s”, Hannoversche Allgemeine Zeitung, Dec 27, 2011, No. 302, p. 11
“Schaut der Mini freundlich und der BMW grimmig?“, Die Presse am Sonntag, Nov 6, 2011, p. 24
“How your car could be giving away clues about your personality”, The Telegraph (United Kingdom), Oct 31, 2011
“People See Faces in Cars”, Iran Daily, No. 4087, Science, Oct 26, 2011, p. 8
Radiointerview über interkulturelle Wahrnehmung von Fahrzeugfronten, HiT FM
“Interkulturelles Phänomen: Autos haben Gesichter”, APA Pressemeldung/Austria Press Agency, Oct 20, 2011(reprinted by Science ORF.at, News.at, Krone.at, Kurier.at, TirolerTageszeitung Online, etc.)
“Cars With Big Grilles Look Like Old Men, Study Finds”, science news website LiveScience, Oct 19, 2011
“Schau mir in die Augen” Cabrio life, Germany, July/August, 2011, p. 100
“Fische angeln Menschen” Die Presse, Austria, Nov 14, 2010, p. 22
“Head-on Decisions: Examining belief that cars project personalities because they look like faces when viewed straight on” Cover story, Chicago Sun-Times, Jul 11, 2009
“What the “Faces” of Cars Reveal.” GEO magazine: Croatian (p. 22), Hungarian (p. 18), Indian (p. 26), Italian (p. 20) and Russian Edition, Jun 2009
“Wenn Autos lächeln.” Rheinischer Merkur, Germany, Nr. 50, Dec 2008, p. 16
“Mein Auto sieht mich so böse an”, Die Presse, Austria, Sep 23, 2008
Auto Business Review, Apr 2008, China, pp. 75–81
“Schöner als ein Aff.” ORF, art.genossen, Austria, Feb 3, 2008
PUBLICATIONS

Journal Articles (peer-reviewed)


Invited Talks


Oral Presentations


Poster Presentations


Abstracts (peer-reviewed)


