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Gaëtan Merlhiot [a,*], Laurie Mondillon [a], Alain Méot [b], Frederic Dutheil [c,d], Martial Mermillod [e]

[a] Université Clermont Auvergne, CNRS, LAPSCO, Physiological and Psychosocial Stress, 63000 Clermont-Ferrand, France
[b] Université Clermont Auvergne, CNRS, LAPSCO, 63000 Clermont-Ferrand, France
[c] Université Clermont Auvergne, CNRS, LAPSCO, Physiological and Psychosocial Stress, CHU Clermont-Ferrand, Santé Travail Environnement, WittyFit, 63000 Clermont-Ferrand, France
[d] Australian Catholic University, Faculty of Health, Melbourne, 3105 Victoria, Australia
[e] Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, LPNC, 38000, Grenoble, France

The facial width-to-height ratio (fWHR) is a perceptual cue that affects the perception of psychological traits such as dominance. The current research examined whether the fWHR would impact the perception of dominance and emotional intensity when expressing emotions. In study one, we examined whether the emotional facial expressions (EFEs) modify the visually perceivable fWHR by following a specific pattern reflecting the perception of dominance associated with basic EFEs. We found that EFEs differed from neutral poses following the expected pattern: high dominance EFEs (anger, disgust, happiness) increased the fWHR, whereas low dominance EFEs (fear, sadness, surprise) decreased the fWHR. In study two, we investigated whether manipulating the fWHR (low, average, high) would affect the perception of dominance and emotional intensity. We obtained that the fWHR influenced the perception of dominance and emotional intensity but its effect on dominance was only present with high dominance EFEs. One social implication of this effect is that individuals for which expressing dominant emotions lead to high increase of their fWHR would be perceived highly dominant. We discuss that such effect could participate in the development of individuals' dominance and further researches are still needed to determine its social impact in interaction with other factors.

1. Introduction

In human interactions, first impression can be driven by facial features (Oosterhof & Todorov, 2008) that contribute to judgments about individuals' traits and intentions, which is not a trivial matter when it comes to dominance, aggressiveness or trustworthiness as such judgments can dramatically influence political voting preferences (Olivola & Todorov, 2010) and even court sentences (Flowe & Humphries, 2011; Hehman et al., 2013; Wilson & Rule, 2015, 2016). Some facial characteristics, such as lowered eyebrows (Hess et al., 2009; Zebrowitz & Montepare, 2008) or large facial width-to-height ratio (fWHR) (Boshyan et al., 2014; Carré et al., 2009; Geniole et al., 2015; Stirrat & Perrett, 2010, 2012), can make people appear to be more dominant, but also less reliable and more aggressive.

The fWHR is a face perceptual cue (Carré et al., 2010; Geniole et al., 2015), which corresponds to the perceivable rectangle formed from the distance between the eyebrows (nasion) and the upper lip (prosthion), which is extrapolated across the width between the most lateral points of the face (zygions) (Fig. 1). Using a method which they developed themselves, Weston et al. (2007) showed that the fWHR differs between genders[1] (males would tend to have a greater fWHR than females). The fWHR can affect the perception of psychological traits or states such as dominance[2] (Carré et al., 2009, 2010; Carré & McCormick, 2008; Lefevre & Lewis, 2013; Stirrat & Perrett, 2012), aggressiveness (Carré

* Corresponding author at: Department of Psychology, Clermont Auvergne University, 34 avenue Carnot, 63037 Clermont Ferrand, France.
E-mail addresses: gaetan.merlhiot@gmail.com, martial.mermillod@univ-grenoble-alpes.fr (G. Merlhiot).

[1] They concluded that this sexually dimorphic characteristic is due, in particular, to differences in testosterone concentration during puberty (Swaddle & Reierson, 2002), which would lead to differences in the growth trajectories of certain parts of the skull. Besides, the veracity of this gender dimorphism was also disputed (Köllner et al., 2018; Kramer, 2017; Lefevre et al., 2012)

[2] Dominance is defined as the tendency to be assertive, forceful, or self-assured, in order to keep a certain power over others (Anderson & Berdahl, 2002; Hareli et al., 2009; Hess et al., 2005).

et al., 2009, 2010; Carré & McCormick, 2008; Costa et al., 2017; Geniole et al., 2012, 2015), and trustworthiness (Carré et al., 2009; Costa et al., 2017; Ormiston et al., 2017; Stirrat & Perrett, 2010, 2012). This facial cue can also be applied to non-human primates since Lefevre et al. (2014) showed that the fWHR could predict assertiveness (defined primarily in terms of dominance and aggression) in brown capuchin monkeys. Taken together, these findings indicate that a larger fWHR should provoke an increased perception of dominance (Carré et al., 2009, 2010; Carré & McCormick, 2008; Lefevre & Lewis, 2013; Stirrat & Perrett, 2012). However, these latter studies investigated the effect of the fWHR exclusively on neutral poses (for a review on fWHR, see Geniole et al., 2015), without considering the compounding effect of the emotional facial expression (EFE). In everyday life, however, the neutral pose is unlikely to be encountered and is usually misinterpreted as expressing an emotion (Carvajal et al., 2013) or even as a threat (Vrana & Gross, 2004).

There are still many open questions regarding how the fWHR acts in day-to-day living, such as whether the fWHR could be modified by the facial movements related to the EFEs or could interact with the intentions communicated by the EFEs (e.g., dominance, affiliation). The EFEs also play a prominent role in the communication of feelings and intentions (e.g., dominant, aggressive, friendly) (for short reviews, see Ekman & Cordaro, 2011; Tracy & Randles, 2011). More specifically, Hess et al. (2000) studied the effect of the EFEs on the perception of dominance and affiliation. They showed that the EFEs of happiness, anger and disgust received the highest rating of dominance while the EFEs of fear and sadness received the lowest (Hareli et al., 2009; Hess et al., 2000; Hess et al., 2005; Mignault & Chaudhuri, 2003; Moeller et al., 2011). However, facial characteristics and EFEs cannot be dissociated from each other, as they share more or less overlapping patterns. For example, babyfaceness, a trait attributed to mature faces with baby-like facial characteristics (e.g., big eyes, round cheeks), interacts with the features of anger, happiness and surprise (Zebrowitz et al., 2007). This could partially explain the differences in the judgments and behavioural expectations shown towards such individuals (Hess et al., 2009). Crucially, the fWHR could also interact with the EFEs. For example, by lifting the upper lip, the EFE of happiness should lead to an increase in the fWHR, whereas sadness should have quite the opposite effect (Fig. 1). It thus appears that the study of the fWHR in a more ecological setting, namely in the natural presence of EFEs, is important for assessing its impact on the perception of social traits.

1.1. Overview of the research

The present research examined whether the fWHR, as an underlying perceptual factor, would impact the perception of both dominance and emotional intensity conveyed by the basic EFEs. In the first study, we examined whether the EFEs would modify the visually perceivable fWHR by means of facial measurements, with the hypothesis that the dominance associated with each basic EFE would impact the fWHR accordingly (i.e., high dominance resulting in high fWHR). In the second study, we then investigated how the fWHR, in a behavioural experimental design, would affect the perception of a) dominance and b) emotional intensity attributed to the EFEs in line with the results of the first study.

2. Study one

In this first study, we examined whether the EFEs would impact the visually perceivable fWHR. According to previous studies investigating the perception of dominance (Hess et al., 2000), we assumed that this EFE-related change in fWHR would follow a specific pattern reflecting the perception of the dominance conventionally associated with each basic EFE (Table 1). Similarly to how the EFE evolved (Smith et al., 2005), this specific configuration of the fWHR in function of the EFE may be the result of a trade-off between skeletal and muscle constraints of the emitter and signal decoding capacities of the observer.

H1. We hypothesized that the distinctiveness of each basic EFE, based on the uniqueness of the associated patterns of activated action units (AU), would distinctly impact the fWHR (Table 1). Specifically, we expected that the EFE would differ from the neutral pose such that (H1a) high dominance EFEs (anger, disgust, and happiness) would increase the fWHR, while (H1b) the low dominance EFEs (fear, sadness, and surprise) would decrease it.

H2. Alongside these main hypotheses, we also tested the gender dimorphism hypothesis on the neutral pose about which males present greater fWHR than females.

2.1. Method

2.1.1. Material and measures

2.1.1.1. Database selection dedicated to emotional facial expressions. We

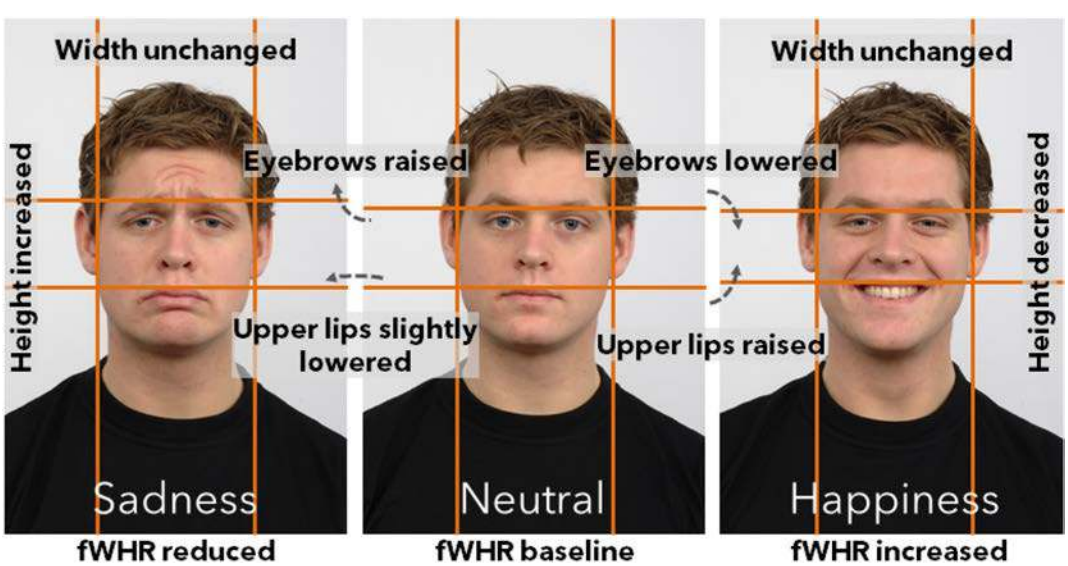

Fig. 1. Our example in image showing how expressing EFEs can impact the fWHR – face extracted from the Radboud Faces Database (Raf D; Langner et al., 2010).

Table 1
Expected effects of the facial AUs on the fWHR.

	Action on		
	Eyebrows	Upper lip	fWHR
AUs			
AU 1 - Inner brow raiser	Raise	–	Decrease
AU 2 - Outer brow raiser	Raise	–	Decrease
AU 4 - Brow lowerer	Lower	–	Increase
AU 9 - Nose wrinkler	Lower	–	Increase
AU 10 - Upper lip raiser	–	Raise	Increase
AU 12 (C-D-E) - Lip corner puller	–	Raise	Increase
AU 15 - Lip corner depressor	–	Lower	Decrease
AU 17 (C-D-E) - Chin raiser	–	Raise	Increase
AU 20 - Lip stretcher		Lower	Decrease
AUs combinations			
Anger: AU 4 + 5 + 17 + 23 + 24	Lower	Raise	**Increase ++**
Disgust: AU 9 + 10 + 25	Lower	Raise	**Increase ++**
Happiness: AU 6 + 12	–	Raise	Increase +
Fear: AU 1 + 4 + 5 + 20 + 25	Raise	Lower	**Decrease ++**
Sadness: AU 1 + 4 + 15 + 17	Raise	Slight to no effect	Decrease +
Surprise: AU 1 + 2 + 5 + 25	**Raise ++**	–	**Decrease ++**

Note. Most prominent impacts are presented in bold. The "+" symbol was used to denote a higher level of impact, such as "+" for high and "++" for very high.

used two databases of EFEs to construct the sample of stimuli, namely the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998) and the Radboud Faces Database (Raf D; Langner et al., 2010). The advantage of the KDEF is that the displayed emotions show a variability of activated action units between actors because they had to express the required emotion in a way that felt natural to them. In contrast, the Raf D was designed on the basis of the emotion prototypes from the Facial Action Coding System (FACS) manual (Ekman et al., 2002) using the method defined in the Directed Facial Action Task (Ekman, 2007). The participants involved in the construction of this database had to activate the targeted action units until each emotion was properly reproduced on their faces and felt by them, thereby greatly reducing the variability of activated action units between actors.

2.1.1.2. Picture selection from selected databases of emotional facial expressions. Since the facial measures (width and height) require a canonical view of the face in order to be assessed correctly, we selected faces from the KDEF and the Raf D that fulfilled these criteria (i.e., frontal orientation, no hair across the face, similar plane on each view, and only canonical views). Only 15 male and 15 female faces fulfilled these criteria in the KDEF, and were consequently chosen. The faces displayed the six basic EFEs (anger, disgust, happiness, fear, sadness, and surprise) as well as a neutral pose. In the case of the Raf D, we used the entire sample of Caucasian faces, which consisted of 20 male and 19 female faces.

2.1.1.3. Facial width-to-height ratio measurement procedure. The sample of faces was assessed for fWHR by means of a method which was first introduced by Weston et al. (2007), and which is commonly used in the fWHR literature. According to this method that was conducted by a human operator, the width of the face is measured as the distance between the zygions (i.e., the two most distant points on a horizontal plane as seen from the front), and the height is measured as the distance between the nasion (i.e., at the intersection of the line drawn across the lower part of the eyebrows and the vertical line up from the axis of the nose) and the prosthion (i.e., at the top of the upper lip and on the same vertical line as the axis of the nose). The coding process was straightforward and followed this process: (i) find and determine the lower part of the eyebrows, (ii) find and determine the upper part of the upper lips, (iii) find and determine the two extremities of the face, (iv) calculate the fWHR based on the previously mentioned measurements. All fWHR calculations (in pixels) were performed on the EFEs and the neutral pose. In order to limit measure-related biases, each fWHR calculation was performed twice over a three months period and averaged for all measures of fWHR.

2.1.2. *Data processing*

We posit that expressing an EFE would distinctly modify the fWHR, compared to the neutral pose. For this purpose, we had to reduce any inter-subject variability (e.g., the fWHR sexual dimorphism between males and females, and the genuine fWHR of each face). For each face, we thus considered the percentage of change in fWHR from the neutral pose to the EFE, with the following formula:

$$A_{pEFEi} = \frac{fWHR_{EFEi} - fWHR_{Ni}}{fWHR_{Ni}} \times 100;$$

where A_{pEFEi} is the percentage change for an EFE of a given *i* face, $fWHR_{EFEi}$ is the fWHR measured from the EFE of the given *i* face and $fWHR_{Ni}$ is the fWHR measured from the neutral pose of the given *i* face.

Since the statistical analysis was based on ANOVA analyses, each variable was checked for normal distribution and extreme data. We did not have any outlier or aberrant measures in our dataset.

2.1.3. *Statistical analysis*

Given that the two databases are based on different theoretical frameworks, we separated the analysis of the KDEF from that performed on the Raf D for the EFE analyses. To examine the gender dimorphism hypothesis, we applied a *t*-test to analyse the differences between genders on the fWHR of the neutral pose on the combined datasets (KDEF + Raf D). Then, all subsequent analyses were conducted on the scores of the fWHR percentage change between the EFE and the neutral pose. We performed a repeated-measures analysis of variance (ANOVA) on the fWHR percentage change, with gender (male, female) as a between-subjects factor, and EFEs (anger, disgust, fear, happiness, sadness, and surprise) as a within-subjects factor, followed by pairwise comparisons between the EFEs with Bonferroni corrections. We finally tested whether the fWHR percentage change for each EFE differed from zero using a series of one sample two-tailed *t*-tests with Bonferroni corrections. Statistical analyses were conducted using SPSS v.22.0 (IBM Corp., USA).

2.2. *Results*

2.2.1. *H1: effect of the EFE on the fWHR*

2.2.1.1. KDEF. The results of the ANOVA are illustrated in Fig. 2. We obtained a significant main effect of EFE, $F(5, 140) = 133.78$, $p < .001$, $\eta_p^2 = 0.83$ (H1). Pairwise comparisons showed that all the EFEs were significantly different from each other (all $p < .001$, except for anger vs. happiness, $p > .05$, and fear vs. sadness, $p > .05$). The one sample two-tailed *t*-tests revealed that the fWHR percentage change for all the EFEs were significantly different from zero (all $p < .001$, except for sadness, $p = .006$) (H1a, b).

2.2.1.2. Raf D. We applied the same procedure as used for the KDEF and the results are reported in Fig. 3. The ANOVA revealed a main effect of EFE, $F(5, 185) = 422.80$, $p < .001$, $\eta_p^2 = 0.92$ (H1). Pairwise comparisons showed that all the EFEs were significantly different from each other (all $p < .001$, for fear vs. surprise $p = .025$). The one sample two-tailed *t*-tests revealed that the fWHR percentage change for all the EFEs were significantly different from zero (all $p < .001$) (H1a, b).

2.2.2. *H2: gender dimorphism*

The means of the fWHR measurements for males and females were 1.89 ($SD = 0.10$) and 1.82 ($SD = 0.08$), respectively. The *t*-test revealed

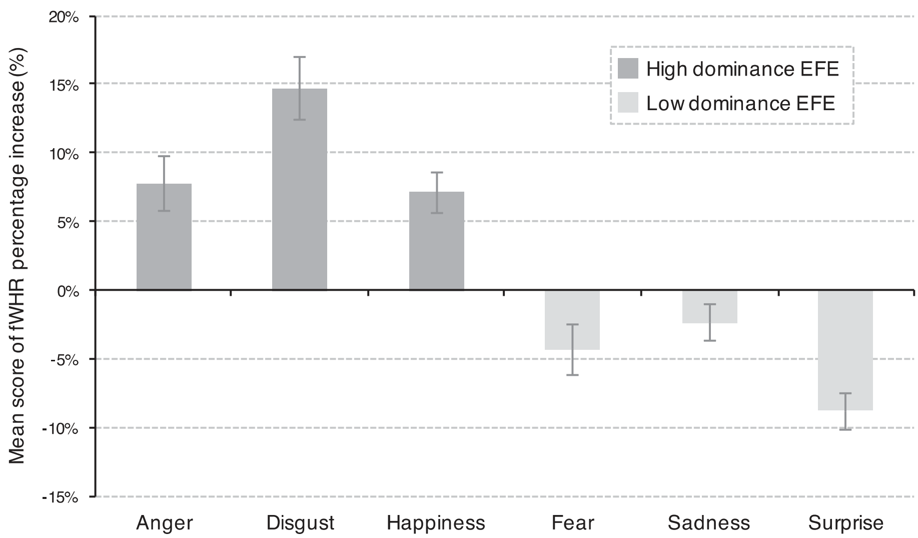

Fig. 2. Mean scores of fWHR percentage change as a function of the EFE, for the KDEF.
Note. EFE = emotional facial expression; bar represents 95% confidence interval.

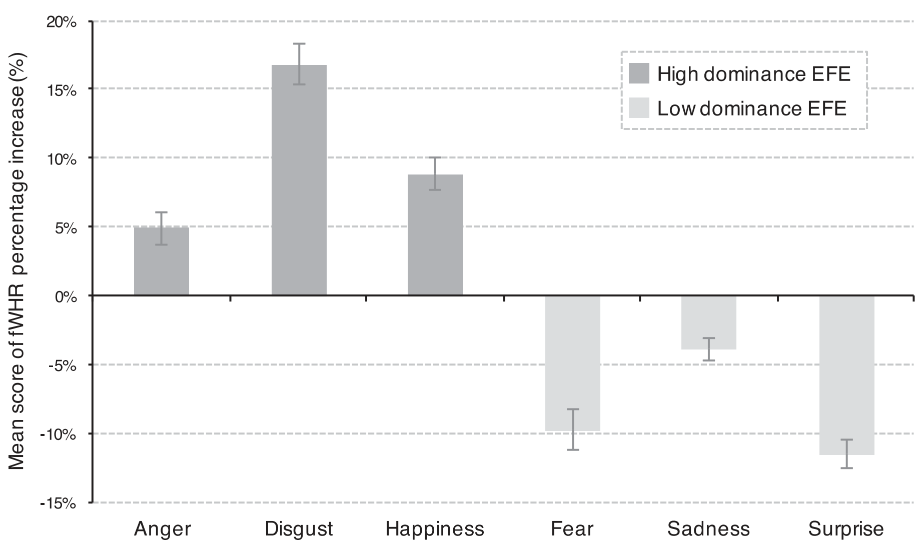

Fig. 3. Mean scores of fWHR percentage change as a function of the EFE, for the Raf D.
Note. EFE = emotional facial expression; bar represents 95% confidence interval.

a significant difference, $t(67) = 3.28$, $p = .002$, $\eta_p^2 = 0.14$ (H2).

2.3. Discussion

In this first study, we tested and verified the hypothesis (H1) that expressing an EFE would modify the visually perceivable fWHR. More precisely, the EFEs differed from one another in both databases (KDEF and Raf D). Moreover, their change in fWHR was significantly different from that of the neutral pose and followed the expected pattern: (H1a) the high dominance EFEs (anger, disgust, and happiness) involved an increase in fWHR, whereas (H1b) the low dominance EFEs (fear, sadness, and surprise) involved a decrease in fWHR (Fig. 4). This specific pattern reflects the perception of dominance associated with each basic EFE (Hess et al., 2000). One can therefore infer that the dominance perceived from faces could be partially driven by the fWHR, which is itself impacted by the EFE.

Besides, the gender dimorphism (H2) associated with the fWHR (males having a higher fWHR than females) was present, which goes along with already reported similar results (e.g., Carré & McCormick, 2008; Weston et al., 2007) and the meta-analysis that exhibited a small but significant gender dimorphism (Geniole et al., 2015). Nevertheless, this result strengthens the debate on the genuineness of the gender dimorphism, which is not systematically observed in the literature (Köllner et al., 2018; Kramer, 2017; Lefevre et al., 2012) and still requires further exploration.

We then investigated, in the second study, whether manipulating the fWHR, in a behavioural design, would affect the perception of dominance and emotional intensity attributed to the EFEs.

3. Study two

In this second study, we investigated how the fWHR contributes, at a perceptual level, to changes in the perception of dominance and emotional intensity attributed to the EFEs. Our first study settled the hypothesis that fWHR could be significantly modified when expressing facial emotions and followed the exhibited pattern: high dominance emotional facial expressions (EFE) (anger, disgust, happiness) increased the fWHR whereas low dominance EFEs (fear, sadness, surprise)

Fig. 4. Examples of how expressing EFEs would interact with the fWHR: fWHR delineations and action units (AU) on a face extracted from the Radboud Faces Database (Raf D; Langner et al., 2010).

decreased the fWHR. In other words, Study 1 points to a correlational link between different perceptual but invoked variables (fWHR and EFE). The aim of Study 2 is to determine the causal link between these variables by manipulating in a provoked manner the fWHR in order to determine its causal impact on the perception of dominance in EFEs (H1). We also examined whether the effect of the fWHR differed according to the gender and the EFE. More specifically, high and low dominance EFEs are characterized respectively by an increase and a decrease in fWHR (Fig. 4, Table 1). We thus hypothesized that the fWHR would influence the dominance and emotional intensity perceived from the EFEs. More specifically, the effect of the fWHR for the emotional intensity would differ as a function of the high and low dominance EFEs, since the expression of high dominance EFEs is characterized by an increase in fWHR and the expression of low dominance EFEs is characterized by a decrease in fWHR (see study 1, Fig. 4, Table 1).

H1. We tested whether an increase or decrease of the fWHR, distributed over three conditions (low, average, high), would lead to an increased or decreased perception of a) dominance and b) emotional intensity.

H2. For the perception of dominance, we assumed that an increase in fWHR would lead to an increased perception of dominance for both the high dominance EFEs (anger, disgust, and happiness) and low dominance EFEs (fear, sadness, and surprise).

H3. For the perception of emotional intensity, we expected that an increase in fWHR would lead to an increased perception of emotional intensity for the high dominance EFEs (anger, disgust, and happiness) and a decreased perception of emotional intensity for the low dominance EFEs (fear, sadness, and surprise), which corresponds to an interaction effect between high and low dominance EFEs.

3.1. Method

3.1.1. Participants

We recruited 59 participants (51 females, 8 males) with a mean age of 19.24 ± 1.30 years from Clermont Auvergne University (formerly Blaise Pascal University) in Clermont-Ferrand (France). All of them signed a written informed consent form and received course credits for their participation. The protocol of this study was implemented according to the principles set out in the Declaration of Helsinki and in the ethical laws applied in France at the time of data collection. The nature and potential risks of the study were fully explained, and all participants signed a written informed consent and received course credits for their participation.

3.1.2. Material

3.1.2.1. Manipulation of the fWHR of the faces. To manipulate the fWHR, we applied a number of equal transformations to the vertical and horizontal axes (by stretching or compressing) on our selection of 15 males and 15 females from the KDEF (see study one). We declined our selection according to three variants of the fWHR (Fig. 5): (i) a low fWHR variant that used a neutral pose fWHR value fixed at 1.6 for females and 1.66 for males, (ii) an average fWHR variant that used a neutral pose fWHR value fixed at 1.8 for females and 1.86 for males, (iii) a high fWHR variant that used a neutral pose fWHR value fixed at 2.0 for females and 2.06 for males. To obtain these three variants of the fWHR (i.e., low, average, high), we first determined for each face the coefficient needed to be applied to the neutral pose to reach the expected fWHR values then we applied the same coefficients to the six EFEs for each face. We also maintained a canonical gender difference for fWHR (set at 0.06), as observed in the literature (Carré et al., 2009, 2010; Carré & McCormick, 2008). We finally cropped each picture to the smallest width and height in order to keep the same cut plane for all stimuli.

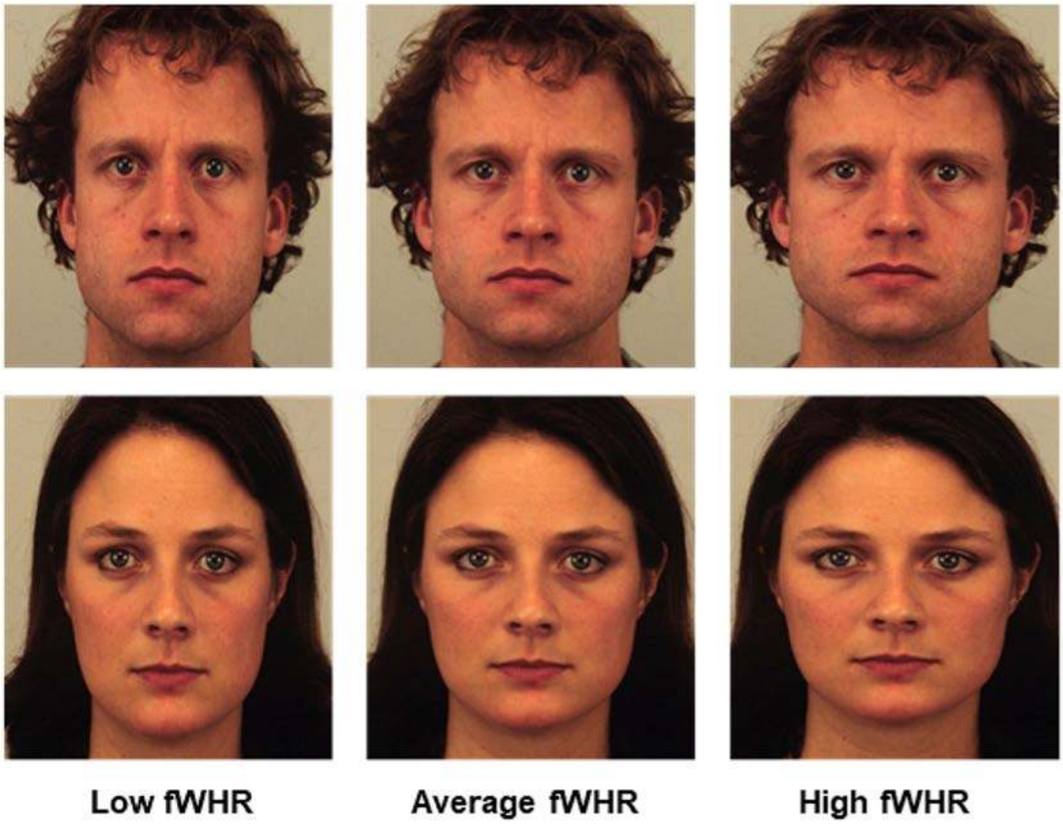

Fig. 5. Examples of manipulated male and female faces for each fWHR condition.
Note. The participant had to rate only one stimulus at a time, displayed in a random order, and never saw the three fWHR conditions simultaneously.

Other studies have already used a more complex but similar process to modify the fWHR of images of real faces (Lefevre & Lewis, 2013; Stirrat & Perrett, 2010).

All images were in 24-bit colour (16 million) with a size of 489 × 688 pixels and were centred at the middle of the screen on a black background. The complete set of images resulted in 630 faces obtained as follows: 15 female and 15 male faces expressing the 6 basic EFEs (anger, disgust, happiness, fear, sadness, and surprise) and neutrality in three different fWHR conditions (low, average, high). We randomly generated a different set of 210 faces for each participant on the basis of the configuration described above: 15 female and 15 male faces expressing the 6 basic EFEs and the neutral pose, with an equal proportion of the three different fWHR conditions (low, average, high). On the overall of the participants, each stimulus was presented in each of the three fWHR conditions. All the stimuli were displayed using a random distribution. Moreover, an extra set of 28 stimuli was also used as a training set: 2 females and 2 males expressing basic EFEs and a neutral pose.

3.1.3. *Procedure*

The experiment was run using E-Prime 2.0 (Psychology Software Tools, Pittsburg, PA) on a PC with a 17-inch CRT monitor (4:3). After the investigator had fully explained the purpose of the task, each participant signed a written informed consent, and then performed the task alone. The task consisted of a series of presentations of images that participants had to rate according to the following instructions: (i) determine what emotion was displayed, (ii) rate dominance and (iii) emotional intensity on a linear intensity scale ranging from 0 (*low*) to 100 (*high*). In the instructions, we used the same definition of dominance as in the study by Hess et al. (2005), and we also presented the list of adjectives used to define dominance in the IAS-R (Wiggins, Trapnell, & Phillips, 1988). Dominance was explained to the participants as follows: "*A dominant person is someone who is assertive, decisive, and dominant across different situations. It is someone who emerges as a leader who other people follow*"; "*You can say that this type of person seems to be self-assured, self-confident, persistent, firm, forceful, domineering*". The participants started by performing a training task that consisted of a training set (28 images) displayed in a random order. During the test phase, the participants saw a set of 210 images presented in a random order. At the end of the experiment, participants were debriefed.

3.1.4. *Data processing*

Upon verification of the dataset, one of the participants presented abnormal data (44% of the ratings of dominance and emotional intensity perception were close to 0), and was removed for the subsequent analysis. We consequently obtained a final sample of 58 undergraduate students (50 females, 8 males) with a mean age of 19.26 ± 1.31 years.

Since the statistical analysis was based on LMM (Linear Mixed Model) analyses, each variable was checked for normal distribution and extreme data, which can have a transcendent effect on the predictions of the model. Consequently, we removed any extreme data based on the Interquartile range test, which corresponds to restricting data to the following distribution interval: $]Q1 - 1.5 \times IQR; Q3 + 1.5 \times IQR[$ with $Q1$ as the first quartile, $Q3$ as the third quartile and IQR as the interquartile range ($IQR = Q3 - Q1$). This resulted in the suppression of 0.16% (17 of 10,440 observations) of the dataset.

3.1.5. *Statistical analysis*

To examine the effect of the fWHR on the perception of dominance and emotional intensity as a function of the EFEs, we conducted LMM analyses on the scores of perceived a) dominance and b) emotional intensity. For both analyses, we used EFEs (6 modalities: anger, disgust, fear, happiness, sadness, surprise), fWHR conditions (3 modalities: low, average, high), and face gender (2 modalities: male, female) as fixed factors, fWHR measure as covariate, as well as participants and faces as random factors. For the neutral poses, which were only evaluated for dominance and had a constant fWHR within each condition, we conducted a specific LMM analysis on the scores of perceived dominance only. For this analysis we used fWHR conditions (3 modalities: low, average, high) and face gender (2 modalities: male, female) as fixed factors, as well as participants and faces as random factors. All pairwise comparisons were Bonferroni corrected. Statistical analyses were conducted using SPSS v.22.0 (IBM Corp., USA).

3.2. Results

3.2.1. Emotion recognition

Recognition rate percentages were high overall (anger, $M = 83.4$, $SD = 3.72$; happiness $M = 98.4$, $SD = 1.26$; disgust $M = 80.5$, $SD = 3.96$; sadness $M = 80.3$, $SD = 3.98$; surprise $M = 90.8$, $SD = 2.89$; neutral $M = 92.4$, $SD = 2.66$), with the exception of fear ($M = 39.3$, $M = 4.89$).

3.2.2. Perception of dominance

For the perception of dominance (Table 2), our main model explained 37.44% of the total variance. H1: The fWHR conditions had no effect on the perceived dominance both for neutral poses and EFEs (all $p > .1$). However, we observed a significant effect of the fWHR measure (covariate), $F(1, 9997.45) = 17.41$, $p < .001$, with an increase in fWHR resulting in an increased perception of dominance ($\beta = 11.56$, $t = 4.17$, $p < .001$). H2: We also obtained a significant interaction between the EFEs and the fWHR measure (covariate), $F(5, 10{,}034.10) = 4.97$, $p < .001$, with an increase in fWHR leading to an increase in the perceived dominance for the EFEs related to a high dominance: anger ($\beta = 20.92$, $t = 4.1$, $p < .001$), disgust ($\beta = 15.09$, $t = 3.13$, $p = .009$), and happiness ($\beta = 23.41$, $t = 3.24$, $p = .006$). This effect was not observed for the EFEs related to a low dominance: fear ($\beta = -14.73$, $t = -2.37$, $p = .09$), sadness ($\beta = 14.5$, $t = 1.94$, $p = .3$), surprise ($\beta = 10.48$, $t = 1.31$, $p = .96$).

Besides, we obtained an effect of EFE, $F(5, 10{,}026.03) = 3.97$, $p < .001$, with the following scores of perceived dominance for each EFE: anger ($M = 55.6$, $SEM = 1.94$), happiness ($M = 53.38$, $SEM = 2.11$), disgust ($M = 48.29$, $SEM = 2.14$), surprise ($M = 49.46$, $SEM = 2.81$), fear ($M = 42.43$, $SEM = 2.13$), and sadness ($M = 42.8$, $SEM = 2.26$). Most of the EFEs were significantly different from each other ($p < .05$), with the exception of: fear vs. sadness and surprise; anger vs. happiness and surprise; disgust vs. happiness, sadness and surprise; happiness vs. surprise, sadness vs. surprise ($p > .05$). Moreover, we obtained a trend interaction between the gender and the EFEs, $F(5, 9468.92) = 2.12$, $p = .060$, since female faces were perceived as more dominant than male faces while expressing happiness $F(1, 10{,}275.41) = 10.18$, $p = .006$, $\beta = 4.35$.

3.2.3. Perception of emotional intensity

Regarding the perception of emotional intensity (Table 2), our main model explained 36.64% of the total variance. H1: The fWHR conditions had no effect on the perceived intensity both for neutral poses and EFEs (all $p > .1$). Again, we found a significant effect of the fWHR measure (covariate), $F(1, 9642.74) = 11.46$, $p < .001$, as an increase in fWHR led to an increased perception of emotional intensity ($\beta = 9.14$, $t = 3.39$, $p < .001$). H3: We also observed an interaction between the EFEs and the fWHR measure (covariate), $F(5, 10{,}043.27) = 32.04$, $p < .001$, with an increase in fWHR leading to an increase in the perceived emotional intensity for the EFEs related to a high dominance: anger ($\beta = 43.78$, $t = 8.80$, $p < .001$), disgust ($\beta = 11.83$, $t = 2.52$, $p = .059$, trend effect), and happiness ($\beta = 46.62$, $t = 6.6$, $p < .001$). We obtained the opposite effect for the EFEs related to a low dominance, where an increase in fWHR resulted in a decrease in the perceived emotional intensity: fear ($\beta = -28.78$, $t = -4.74$, $p < .001$), and sadness ($\beta = -38.63$, $t = -5.1$, $p < .001$). The EFE of surprise, however, yielded a trend effect similar to that observed for high dominance EFEs ($\beta = 20.05$, $t = 2.52$, $p = .058$). We noticed an interaction between gender, the EFEs and the fWHR, $F(5, 9464.11) = 4.01$, $p = .001$, since the fWHR had no effect for the emotion of disgust in the case of female faces ($\beta = 2.26$, $t = 0.36$, $p = 1$).

Moreover, we obtained an effect of EFE, $F(5, 10{,}034.94) = 30.35$, $p < .001$, with the following scores of perceived emotional intensity for each EFE: anger ($M = 56.48$, $SEM = 1.84$), happiness ($M = 65.8$, $SEM = 1.81$), disgust ($M = 70.25$, $SEM = 1.85$), surprise ($M = 72.42$, $SEM = 2.56$), fear ($M = 56.48$, $SEM = 1.84$), and sadness ($M = 50.58$, $SEM = 1.98$). Most of the EFEs were significantly different from each other ($p < .05$), with the exception of: fear vs. anger and sadness; disgust vs. happiness and surprise ($p > .05$). We also obtained an interaction effect between gender and the EFEs, $F(5, 9464.57) = 4.65$, $p < .001$, since male faces were perceived as expressing more fear $F(1, 10{,}229.17) = 13.25$, $p < .001$, $\beta = 5.33$, sadness $F(1, 10{,}228.24) = 55.28$, $p < .001$, $\beta = 10.03$, while female faces were perceived as expressing more happiness than male faces $F(1, 10{,}277.74) = 19.57$, $p < .001$, $\beta = 5.88$.

Table 2
Effect of an increase in fWHR as a function of the EFEs on the perception of dominance and emotional intensity.

EFE	Perceived dominance		Perceived emotional intensity	
	β	p	β	p
High dominance EFEs				
Anger	**20.92**	<.001	**43.78**	<.001
Disgust	**15.09**	.009	**11.83**	.059
Happiness	**23.41**	.006	**46.62**	<.001
Low dominance EFEs				
Fear	−14.73	*n.s.*	**−28.78**	<.001
Sadness	14.5	*n.s.*	**−38.63**	<.001
Surprise	10.48	*n.s.*	20.05	.058

Note. Expected effects are presented in bold.

3.3. Discussion

Despite an absence of effect of the fWHR conditions (low, average, high) on the perception of dominance and intensity (H1), our results showed that the fWHR had a great influence on both the perception of dominance and intensity. In accordance with our hypothesis (H2), a higher fWHR resulted in an increased perception of dominance, which is consistent with the literature (Carré et al., 2009, 2010; Carré & McCormick, 2008; Geniole et al., 2015; Lefevre & Lewis, 2013; Stirrat & Perrett, 2012). We also found that the effect of the fWHR on the perception of dominance differed according to the high vs. low dominance EFEs. For the high dominance EFEs (anger, disgust, and happiness), an increase of the fWHR was associated with an increased perception of dominance. These results go in the direction of what has been showed for the expression of anger, when the fWHR was increased by reducing the vertical distance between the eyes and month (Neth & Martinez, 2009, 2010). On the other hand, for the low dominance EFEs (fear, sadness, and surprise), an increase of the fWHR was not associated with an increased perception of dominance. We did not expect such differential effect between high and low dominance EFEs, yet this could be consistent with the genuine function of each EFE to express dominance or not (Hareli et al., 2009; Hess et al., 2005, 2000; Mignault & Chaudhuri, 2003; Moeller et al., 2011). In other words, the effect of the fWHR on the perception of dominance would be mostly effective in the case of congruent EFEs that actually convey dominance, but not in the case of incongruent EFEs.

An increase in the fWHR also led to a higher perception of emotional intensity (H3). Again, this relationship differed according to the high vs. low dominance EFEs. While an increase in fWHR led to an increased perception of dominance and intensity for high dominance EFEs (anger, disgust, happiness), the perceived intensity of the low dominance EFEs of fear and sadness followed the opposite trajectory. As we expected, the perception of intensity thus followed the modifications of the fWHR induced by the specific patterns of activated AUs related to each EFE

(Fig. 4, Table 1) (Ekman et al., 2002; Scherer & Ellgring, 2007a). For example, the EFE of happiness led to an increase in fWHR (Study 1) and, similarly, an increase in fWHR implied higher perception of intensity for this EFE. Only the EFE of surprise differed from this expectation as it also implied that an increase in fWHR involved an increase in the perception of intensity. Again, this outcome remains in accordance with the ambiguity conveyed by the EFEs of surprise (Scherer & Ellgring, 2007a; Tracy & Randles, 2011). Overall, these findings are quite consistent with the results of our first study.

Besides, our results on the emotion recognition rates are in line with the literature using KDEF with high recognition rates for all the EFEs with the exception of fear (Goeleven et al., 2008). Even though the low recognition rate of fear emotion was common in the literature, we checked this was not interfering with our results. We thus verified that we obtained similar results by using only the correct identifications and the whole sample, which was the case in our study. Moreover, in accordance with the literature, female faces were perceived as expressing more happiness than male faces (Hareli et al., 2009; Hess et al., 2005, 2000). Male faces were perceived as expressing more fear and sadness, which is less frequently found in the literature (Becker et al., 2007). In addition, the EFEs related to a low dominance (fear and sadness) resulted in the lowest perception of dominance and the EFEs related to a high dominance (anger, disgust, and happiness) implied the highest perception of dominance. The expression of surprise, however, led to a high perception of dominance similar to that of anger and disgust, which can result from the controversial aspects of the EFE of surprise, such as being hedonically neutral (Scherer & Ellgring, 2007a) and mostly preceding other EFEs (Ekman & Cordaro, 2011).

4. General discussion

The current research examined whether the fWHR, as an underlying perceptual factor, would impact the perception of both dominance and emotional intensity conveyed by the EFEs. In the first study, we investigated whether the basic EFEs would impact the perceivable rectangle that constitutes the fWHR (i.e., distance between the eyebrow and upper lip extrapolated across the width of the face). We assumed that this EFE-related change in fWHR would follow a specific pattern reflecting the perception of the dominance conventionally associated with each basic EFE. In accordance with our hypothesis, the fWHR significantly changed from the neutral pose to the EFEs. Our results confirmed that this change would follow the expected pattern, since the EFEs could be divided into two categories corresponding respectively to the changes in fWHR and their corresponding perception of dominance (Hess et al., 2000): those associated with an increase in fWHR, the high dominance EFEs (anger, disgust, and happiness), and those associated with a decrease in fWHR, the low dominance EFEs (sadness, fear, and surprise). Therefore, our results would support the fact that expression signals transmitted by the face evolved towards orthogonal signals such as EFEs (Smith et al., 2005) and, in our case, the fWHR. Perceptually, the fWHR increased with the EFEs of anger, disgust and happiness, which, in turn, evolved to express dominance as well. The fWHR may thus act as a low correlated expression signal of the dominance emitted by the face through EFEs, which could have, conjointly with the EFEs, evolved as a trade-off between skeletal and muscle constraints of the emitter and signal decoding capacities of the observer.

The basic EFEs differed from each other on the basis of the various combinations of AUs that are involved, whether we refer to the FACS prototypes described in the *Basic Emotion Theory* – BET (Ekman, 1989, 1992, 2007; Ekman et al., 2002; Ekman & Friesen, 1978; Izard, 1992, 1994) (for a review see Ekman & Cordaro, 2011; Tracy & Randles, 2011), or to the studies conducted within the framework of the *Componential Appraisal Theory* (Krumhuber & Scherer, 2011; Scherer & Ellgring, 2007a, 2007b). A recent study, however, revealed that the fWHR would seem to be more sensitive to the vertical variations (Costa et al., 2017). Yet, the changes in the width of the face would not be attributed to the dynamics of the facial movements since the width from the fWHR is mainly affected by a weight gain (Coetzee et al., 2010). Consequently, the fWHR measurement would be almost impacted by the AUs which produce an elevation/lowering of the eyebrows and/or the upper lip, as noticed during most of the basic EFEs (Fig. 4, Table 1).

In addition, our hypothesis has been validated for both the Raf D and the KDEF (Langner et al., 2010; Lundqvist et al., 1998, respectively), despite the fact that these two databases were developed using distinct theoretical models. While the Raf D database has been based on the BET emotional patterns (Ekman, 2007; Ekman et al., 2002), the creation of the KDEF has not been underpinned by any model mentioning the EFE prototypes (the actors had to express the EFEs as naturally as possible), but with a similar approach to that of the Componential Appraisal Theory (Krumhuber & Scherer, 2011; Scherer, 2009; Scherer & Ellgring, 2007a, 2007b). However, all of those studies, whether they were based on the use of the FACS or on the Componential Appraisal Theory, finally revealed similar AU patterns for the basic EFEs, so it is not surprising that our results appear also equivalent for those two sets of faces.

Alongside these main outcomes, we observed that the gender dimorphism of the fWHR, according to which males would have a higher fWHR than females, was present in our database. This finding is consistent with the scientific literature (see meta-analysis, Geniole et al., 2015), with some studies revealing a gender dimorphism (Carré et al., 2009, 2010; Carré & McCormick, 2008; Weston et al., 2007) while others highlight discordant outcomes (Köllner et al., 2018; Kramer, 2017; Lefevre et al., 2012; Özener, 2012). Indeed, numerous factors could account for gender-related fWHR differences, such as the positive relationship between the Body Mass Index (BMI) and the fWHR (Coetzee et al., 2010). These results strengthen the need for further research regarding the reliability of such a gender difference in fWHR.

In the second study, we showed that the fWHR influenced the perception of dominance conveyed by the EFEs, such that an increase in the fWHR (based on the fWHR difference score) was associated with an increase in the perception of dominance. These results go along with the fact that increasing the fWHR by reducing the vertical distance between the eyes and month would increase the perception of anger (Neth & Martinez, 2009, 2010). The presence of this effect varied depending on high and low dominance EFEs, as it was observed only for high dominance EFEs (anger, disgust, and happiness), but not for low dominance ones (sadness, fear, and surprise). This differential effect was not excepted and may stem from the fact that, when exposed to low dominance EFEs, individuals would ignore some of the perceptual signals of dominance (e.g., fWHR), since these EFEs are not used to convey dominance information (Hareli et al., 2009; Hess et al., 2005, 2000; Mignault & Chaudhuri, 2003; Moeller et al., 2011). Such effect could be similar to the effect of the fWHR on the perception of aggressiveness, where it was more frequently exhibited for males than females according to the meta-analysis on the fWHR (Geniole et al., 2015). Finally, the reason of this differential effect of the fWHR between high and low dominance EFE could be the result from complex mechanisms associated to the fWHR and perception of EFE. Indeed, a recent article suggested that the increase or decrease in fWHR would facilitate the recognition of specific emotions such as anger or fear accordingly (Deska, Lloyd, & Hugenberg, 2018). However, we must emphasize that this interpretation remains speculative, and that further studies would be required to verify this assumption. Nevertheless, these results show that the role of the fWHR in the perception of dominance conferred by the EFEs should be considered in the future.

With regards to the perception of intensity, the fWHR had a large impact on the perception of intensity, such that an increase in the fWHR was associated with an increase in the perceived intensity of the EFEs. Again, the presence of this effect varied depending on high and low dominance EFEs, following a quite similar pattern to that mentioned above: the change in fWHR was positively related to the perception of intensity for the high dominance EFEs (anger, disgust, and happiness), but negatively related to the low dominance EFEs of fear and sadness. In agreement with the previous results, the effects of the facial AUs involved in the EFEs (Fig. 4, Table 1) would impact the fWHR in such a way that the congruence between the increase/decrease of the fWHR with the high/low dominance conferred by the EFE would produce a greater perception of intensity.

In terms of social implications, this study exhibited that those individuals about which expressing dominant emotions lead to high increase in fWHR would be perceived as expressing such emotions more intensely and be perceived as more dominant. On the opposite, individuals about which expressing non-dominant emotions with less increase in fWHR would be perceived as expressing those emotions with more intensity but not less dominant. Considering that expressing EFEs is the result of different skeletal and muscle constraints (see Fig. 4 and Table 1), it would be important to determine whether dominant individuals would be characterized by a greater increase of the fWHR when expressing dominant emotions. Indeed, this greater increase of the fWHR could be the result of a learned process that could settle in a long developmental aspect during which individuals would be learning implicitly to express dominant expressions in such ways that would potentially improve the fWHR and the resulting dominance. On the other hand, we cannot exclude the possibility that individuals with a favourable morphology to express dominant emotions with high fWHR increase would support the development of their own dominance towards others. All such questions are still to be explored.

Nevertheless we can think about practical implications of our work. In the case of therapy, the fWHR could be used as a broad implicit measure of dominance. In cognitive behavioural therapy, it is not uncommon that practitioners use quantitative measures from self-reported questionnaires that can be used with patients. For example, we can conceive a possible use in the case of self-confidence or anger management therapies where the practitioner could be asking patients to express dominant emotions and use the fWHR as a quantitative measure of theoretically expressed dominance. As concern of interpersonal relationship, our study goes along with the already exhibited effects where individuals with higher fWHR are favoured in terms of relationship and mating (e.g., Stirrat & Perrett, 2012; Valentine et al., 2014), and tend to occupy more frequently higher social positions, such as management or political positions (e.g., Alrajih & Ward, 2014; Lefevre & Lewis, 2013; Re et al., 2013; Wong et al., 2011), which could be the result of the subtle interactions unifying emotion and dominance during social interactions. Nevertheless, it might be possible that working on how individuals would be expressing dominant expressions could be modified in order to gain in perceived dominance and gaining in probability of mating or occupying higher social positions.

This study has some limitations that we delineate below. We have to emphasize the undefined origin of the effect of the fWHR on the perception of dominance. Despite a meta-analysis towards an evolutionary origin of the effect of the fWHR on the perception of dominance (Geniole et al., 2015) and the gender dimorphism (Köllner et al., 2018; Kramer, 2017; Lefevre et al., 2012), its origin is still subject to discussion. Regarding the manipulation of the fWHR, we gradually increased the fWHR of the faces, as we expected an impact on the perception of dominance and intensity. Our results do not support such an effect of the manipulation, despite the use of an image processing very similar to that used in previous works (Stirrat & Perrett, 2010). This lack of effect could be due to the within-subject design in which participants rated neutral and emotional versions of the faces, which might alter the dominance of neutral faces relative to the faces expressing an EFE. For example, an increased focus on the differences between neutral poses and EFEs may have reduced participants' attention to differences within the neutral faces. Moreover, it has been shown that individuals would have a canonical representation of face associated with dominance that is specific to the fWHR (Re et al., 2013), such as the perceived height that could influence dominance perception. Our manipulation of the fWHR could have partially interfered with this canonical representation, even if the manipulation were homogenous on both width and height, and could influence the obtained results, even if such influence was not quantifiable. In addition, a recent study has shown that horizontal and vertical modifications differently contribute to the perception of trustworthiness and aggressiveness (Costa et al., 2017), highlighting a more complex impact of the fWHR components than originally anticipated. This suggests that further investigations are still required to fully understand the effect of the fWHR components on the perception of social traits.

5. Conclusions

The EFEs have a great influence on the fWHR, which could therefore act as a significant factor in the perceptions of the social traits conveyed by faces. Overall, the fWHR allowed to differentiate the basic EFEs based on their associated dominance (high vs. low dominance EFEs), and to predict their respective relationships with the perception of dominance and emotional intensity. However, the influence of fWHR on the perception of dominance was only effective for dominant emotions. The social implications of the effect of the fWHR on the expression of EFEs would be that individuals with higher increase in fWHR would express dominant emotions more intensely, while those with a lower increase in fWHR would express non-dominant emotions more intensely. As a result, individuals for which expressing dominant emotions lead to high increase of their fWHR would be perceived highly dominant. Since, the expression of an EFE is dependent of the skeletal and muscle constraints of the emitter; it is be essential to determine whether dominant individuals would be characterized by a greater increase of the fWHR when expressing dominant emotions. Such effect could participate in the development of individuals' dominance, in two possible ways: (i) dominant individual may learn to express high dominance EFEs in such way that would significantly increase their fWHR, (ii) their skeletal and muscle structures gives them the ability of expressing high dominance EFE with high fWHR increase, which would contribute to the development of their own dominance towards others. Since this could contribute to the understanding of the evolution of individuals' dominance, we thus believe it is worthwhile consider and investigate this effect in real-life situations for future research.

Credit authorship contribution statement

Gaëtan Merlhiot: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization. **Laurie Mondillon:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Supervision. **Alain Méot:** Formal analysis. **Frederic Dutheil:** Writing - review & editing. **Martial Mermillod:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Supervision.

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