Degree project

UNIVERSITY OF SKÖVDE

Facial-Width-to-Height Ratio and the Late Positive Potential: An Electroencephalography Study on Male and Female Face Stimuli

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Abstract

The facial-width-to-height ratio (FWHR) measures the distance between the left and right cheekbones and divides it with the height between the brow ridge and the upper lip area. The FWHR has been proposed as a predictor of aggressive behavior, with larger FWHRs in males reportedly being perceived as more aggressive. Recent studies have utilized the late positive potential (LPP) to examine the electrophysiological correlates of FWHR. However, these studies have exclusively used male faces as stimuli, leaving the effect of the gender of the stimuli unexplored. The present study investigated how the combination of gender, FWHR, and threatening facial expressions influences the LPP response. Twenty-three participants were recruited for this study. The study used computer generated faces that varied across three variables: gender (male/female), FWHR (high/low), and expression (angry/neutral). The faces were displayed to participants while EEG was recorded to measure LPP amplitudes. Significant LPP modulations were observed for facial expressions (i.e., angry vs. neutral) but not for the FWHR or gender. These results may be attributed to the small sample size, the fact that FWHR was manipulated solely by adjusting cheekbone width, or the challenges in accurately distinguishing the gender of the faces. Future research should aim to create more distinct facial features to better explore potential gender effects.

Keywords: facial width-to-height ratio, late positive potential, gender, expressions, faces.

Facial Width-to-Height Ratio and the Late Positive Potential: An Electroencephalography Study on Male and Female Face Stimuli

The face contains more information than one might expect, accurate information about an individual's traits such as age, gender, and weight, can be extracted from only seeing a face for a brief period of time (Geniole, et al., 2015; Said et al., 2009). Faces can display a plethora of different emotions which are very useful for social interactions: being able to make quick judgments of an individual's inner state by observing their facial expression could prove very useful for deciphering whether they are friend or foe. Although not all faces are created equal, some people have narrow faces with features such as raised eyebrows and a round jawline, while others have wide faces with low eyebrows and a pointed jawline. Such different facial structures have been suggested to affect the perceived aggressiveness of an individual (Geniole et al., 2015).

One of the more researched metrics used to measure aggressiveness and facial features is the facial width-to-height ratio (FWHR), which takes the bizygomatic (left and right cheekbones) distance and divides it with the height between the brow ridge of the eyes and the upper lip area (Windmann et al., 2023; See Figure 1).

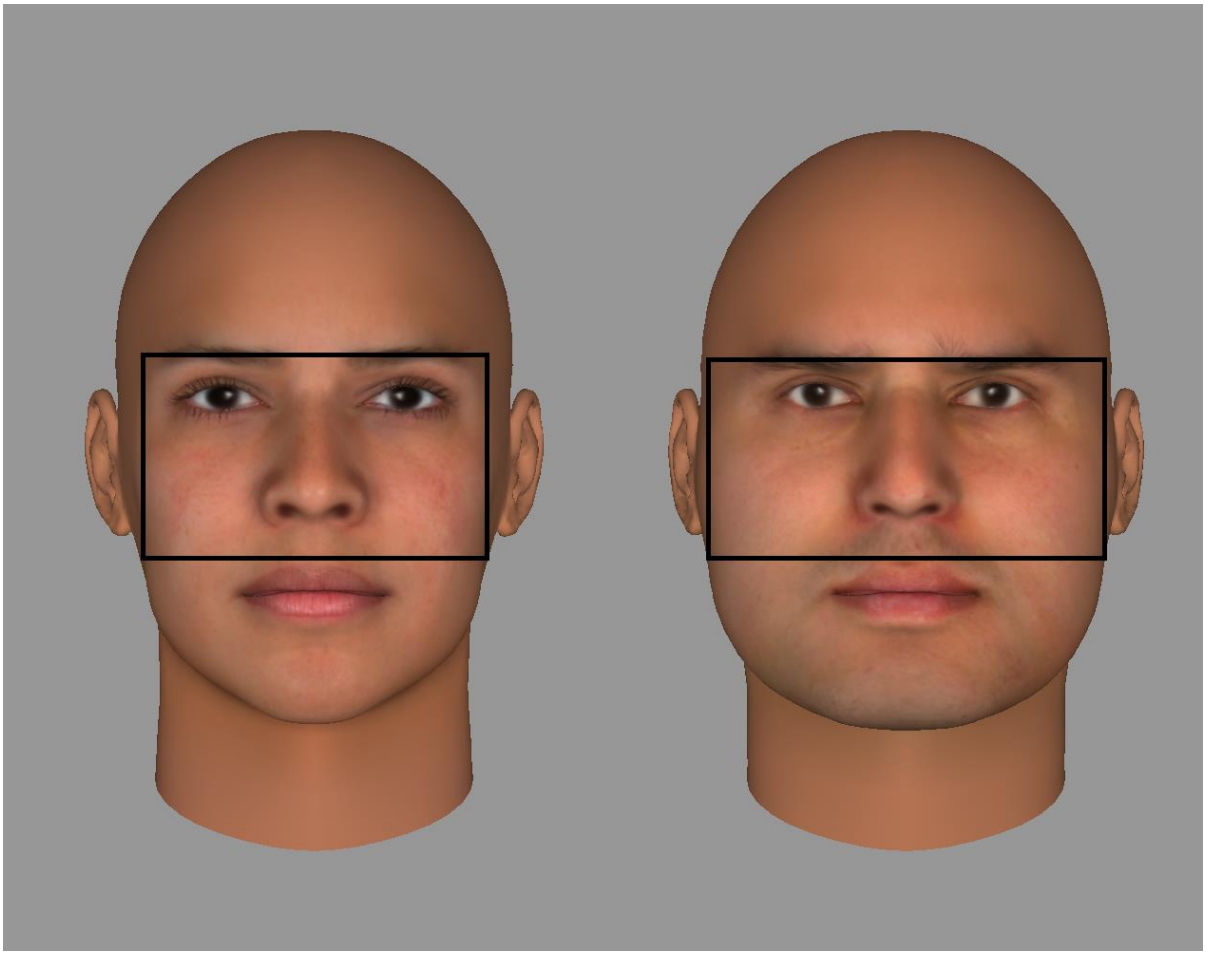
The FWHR has been suggested to have evolved as a cue for aggression and dominance in males (Geniole et al., 2015). However, some researchers have argued against the evolutionary theory. Eisenbruch et al. (2017) proposed that faces with high FWHR look more threatening due to their eyebrow position being relatively lower, and thus resembling an angry face. Additionally, recent research on FWHR and aggression has reported that eyebrow height mainly influences the degree of perceived threat and aggressiveness (Lindersson, 2019; Magnusson, 2021; Sutradhar, 2020), further supporting Eisenbruch's proposal.

The majority of the FWHR literature has been conducted using questionnaires. In recent years, researchers have been using electroencephalography (EEG) to measure neural activity in response to different male FWHRs (Eldblom, 2018; Jones, 2019; Kajonius & Eldblom, 2020; Lindersson, 2019; Magnusson, 2021; Pieslinger, 2019; Sutradhar, 2020). An Event-related potential (ERP) is a time-locked EEG that occurs in response to a specific

event. The late positive potential (LPP) is an ERP component that is sensitive to threat-related facial expressions (Schupp et al., 2003; Schindler & Bublatzky, 2020). The LPP is most prominent over centro-parietal scalp regions. It has an onset of around 350-400 ms after a stimulus has been shown and it lasts for seconds after stimulus onset (Hajcak et al., 2010; Schindler & Bublatzky, 2020).

Figure 1

Female Face with Low Facial Width-to-Height ratio vs. Male Face with High Facial-Width-to-Height Ratio



Note. The FWHR takes the distance between the left and right cheekbones and divides it with the distance between the upper lip and the eyebrow ridge. An example of low vs. high FWHR faces. The low FWHR face had a ratio of 1.71, and the high FWHR face had a 2.05 ratio.

The LPP has been reported to be modulated by threatening facial expressions compared to neutral ones, and in some cases modulated by different FWHRs. Hierarchical social factors have been shown to influence the LPP response differently depending on the gender of both the observer and the observed face (Rodríguez-Gómez et al., 2020).

To date, all studies examining the relationship between FWHR and LPP have exclusively utilized angry and neutral male faces as stimuli. Consequently, it remains unclear whether FWHR is the sole factor influencing LPP, as the potential effects of the gender of the stimuli have not yet been investigated. The objective of the current study is to determine whether female faces elicit a similar LPP response as male faces with comparable FWHRs

The Facial Width-to-Height Ratio as an Indicator of Aggressive Behavior

The FWHR metric was first introduced by Weston et al. (2007) in which they measured and compared human male and female skulls. The authors reported that male skulls had larger FWHR than females and suggested that the evidence for the sexual dimorphism was caused by sexual selection. Carré and McCormick (2008) used the metric of Weston et al. (2007) and found a positive correlation between high FWHR and aggressive behavior in male hockey players. Male faces with large FWHRs have been reported to be perceived as more threatening than males with lower FWHRs (Carré et al., 2010).

The perceived strength and combat ability of a male can be predicted by measuring their facial features (Sell et al., 2009). Males with wider cheekbones have been associated with more acts of violence (Christiansen & Winkler, 1992). The FWHR has been suggested to act as a cue for fighting ability and dominance among males (Stirrat et al., 2012). Additionally, males exhibiting higher FWHRs tend to win more in competitive fighting sports and are perceived as more formidable opponents (Zilioli et al., 2014). Conversely, males with narrower faces (i.e., low FWHR) were more likely to die due to homicides involving direct physical violence (e.g., strangulation, stabbing, or bludgeoning) compared to their wider-faced counterparts (Stirrat et al., 2012).

In line with previous observations (Carré & McCormick, 2008; Sell et al., 2009), Stirrat and colleagues (2012) proposed the FWHR in males to function as an indicator of

aggression. A meta-analysis of the relationship between FWHR and male aggression concluded that FWHR in males is significantly associated with aggression, social status, and dominance (Geniole et al., 2015). Moreover, the hypothesis that FWHR serves as an indicator of male aggression received substantial support from this meta-analysis, establishing it as a prominent theory in the field.

Discrepancies in the Facial Width-to-Height Ratio Literature

Recent research has encountered difficulties aligning with previous conclusions regarding FWHR and aggressiveness. For instance, Krenn and Meier (2018) did not find any significant associations between FWHR and aggressive behavior from over 400 football players. Furthermore, Kosinski (2017) compared FWHR with 55 psychometric scales, including measures such as anger and friendliness, among approximately 130000 participants. This study found no significant association between FWHR and these psychological measurements. Notably, a few weak correlations were observed, one of which contradicted earlier findings in the FWHR literature: individuals with wider faces reported themselves to be more trusting and cooperative, which is in opposition to the reports by Geniole et al. (2015) in their meta-analysis.

Schurgin and colleagues (2014) conducted an experiment in which participants were shown faces displaying various emotions. Utilizing eye-tracking techniques, the researchers analyzed which facial regions participants fixated on most during each displayed expression. Their findings indicated that when participants viewed angry faces, they predominantly focused on the eyes. This observation aligns with the findings of Eisenbruch et al. (2017) concerning the perceived aggressiveness of individuals with high FWHRs. The key regions from which individuals seem to derive the most information about threatening facial expressions are around the eyes and nose (Schurgin et al., 2014). This would suggest that it is rather the height between the eyebrows and the eyes that gives the perception of aggressiveness.

Another issue with the FWHR literature is that most studies have primarily utilized male faces as stimuli. This trend may originate from early studies (e.g., Carré & McCormick,

2008; Carré et al., 2009) that predominantly used pictures of male faces as stimuli, setting a precedent for subsequent research. Additionally, a meta-analysis by Haselhuhn et al. (2015) on FWHR and aggression prediction excluded papers examining female FWHRs. Another comprehensive meta-analysis conducted by Geniole et al. (2015) identified a small subset of articles (among 50+ articles) that included either male and female faces or only female faces as stimuli. Geniole and colleagues reported a small but significant difference between male and female FWHRs, indicating that male FWHRs are generally larger. However, Kramer (2016) challenged these findings by conducting a meta-analysis on FWHR in human skulls and faces and found no significant effects of sexual dimorphism. The idea that the FWHR metric evolved as a cue system for *male aggression* stands on uneasy grounds due to the large discrepancies previously mentioned.

Gender Differences in Facial Width-to-Height Ratio and Aggressive Behavior

While the FWHR has been associated with aggression in males, the relationship between FWHR and aggressive behaviors in females remains less understood. Wen and Zheng (2020) investigated whether FWHR was associated with aggressive and dominant behavior in males and females within committed relationships. The researchers measured the FWHR of each participant and administered questionnaires assessing dominance and intimate partner violence. Among 144 participants (71 men and 73 women), Wen and Zheng reported no significant difference in FWHR between male and female participants. Men with larger FWHRs had significantly more experiences of physical assault compared to those with smaller FWHRs. However, no significant difference in FWHR was found between women who had experienced physical assault and those who had not. Interestingly, a significant correlation was found between high FWHR and dominance in women, but not in men. Similar findings have been reported previously (Geniole et al., 2015; Haselhuhn et al., 2015; Lefevre et al., 2014).

A recent study by Liu et al. (2022) explored the impact of altering components of the FWHR on perceived aggression. The researchers employed Photoshop to manipulate the FWHR of images of male and female faces by adjusting either the height or width. The

study was conducted in two parts. In the first part, participants rated the faces based on perceived aggression, dominance, femininity, and likelihood of displaying intimate partner violence. In the second part, participants evaluated the faces according to six traits: aggression, dominance, femininity, physical aggression, psychological aggression, and sexual coercion dimensions of intimate partner violence.

In the first part of the study, the researchers found that, regardless of the gender of the person displayed on the image, a high FWHR produced differing effects based on whether the height or width of the face was altered. Wider faces were associated with a higher likelihood of involvement in intimate partner violence, while longer vertical faces were perceived as less aggressive and less likely to be involved in intimate partner violence. In the second part of the study, reducing the upper face height (distance from eyebrows to upper lip) while maintaining the lower face height (upper lip to chin) increased perceived aggression. The type of perceived aggression varied by the gender of the person displayed on the image: female faces were associated with psychological aggression, whereas male faces were linked to physical aggression and sexual coercion.

The findings from Wen and Zheng (2020) and Liu et al. (2022) suggest that the gender of the face influences different types of perceived aggression, and the upper part of the face plays a more significant role in this perception than the lower part. Specific components of the FWHR, particularly the upper face area (eyes and nose), appear to have a greater impact on perceived threat compared to the lower face area (mouth and cheeks).

The Late Positive Potential: What it is and What it Reflects

Recently, studies have been researching the FWHR using EEG by measuring electrical potentials during specific time-windows of a stimulus (see e.g., Eldblom, 2018; Jones, 2019; Magnusson, 2021), known as ERPs. The LPP is an ERP component that reflects the processing of emotional stimuli (Hajcak et al., 2012). The LPP has an onset of approximately 350-400 ms after a stimulus has been shown, with its effects persisting for several seconds. It is characterized by a positive drift and is typically measured in the centroparietal region of the scalp (Hajcak et al., 2010; Schindler & Bublatzky, 2020). The LPP is sensitive to both

negative and positive valenced stimuli, which is indicated by increased LPP amplitudes to emotional as compared to neutral stimuli (Hajcak et al., 2010). Furthermore, LPP amplitudes have been shown to be higher when observing threatening facial stimuli as compared to neutral or friendly ones (Schupp et al., 2004).

Gender roles and social hierarchies have been suggested to modulate the LPP response when observing faces. Breton et al. (2019) reported that female participants exhibited a larger LPP response when observing high-status faces (e.g., lawyers) compared to low-status faces (e.g., waiters). Additionally, Rodríguez-Gómez et al. (2020) found that assigning stereotypically feminine (e.g., "her favorite toy was a Barbie doll") and masculine (e.g., "he smoked a cigar at a wedding") gender roles to male and female faces influenced the LPP response of the observers. Feminine female faces observed by female participants elicited the highest LPP response, while feminine male faces observed by male participants also elicited the highest LPP response. Interestingly, masculine female faces did not elicit a significant LPP response from male participants. Congruent stimuli (e.g., feminine female faces) resulted in a larger LPP response in women, whereas incongruent stimuli (e.g., feminine male faces) elicited a larger LPP response in men. This suggests that social and contextual factors, along with the congruency of the stimuli and the gender of the observer, can influence the LPP response when observing faces.

The exact neural activity associated with the LPP is not fully understood but attempts have been made to provide a clearer picture of the neural substrates of the LPP. Researchers have used a combination of EEG and functional magnetic resonance imaging (fMRI) to achieve this. fMRI measures the blood oxygenation level-dependent (BOLD) signal, which contrasts oxygenated and deoxygenated blood, providing high spatial resolution of brain activity. Studies have shown that negative stimuli eliciting LPP activity are associated with BOLD responses in the insula, which is involved in emotional processing and regulation, and the ventrolateral prefrontal cortex, which is related to emotion and threat detection (Sun et al., 2017; Liu et al., 2012).

To gather sufficient data, an EEG experiment typically includes hundreds of repeated presentations of stimuli during a session. This approach can be problematic, as participants may habituate to the stimuli, resulting in weaker or inconsistent ERP responses. However, the LPP has been reported to be resistant to habituation, meaning that repeated presentations of stimuli do not diminish the amplitude of the LPP (Hajcak et al., 2010).

Current Research on Facial Width-to-Height Ratio and the Late Positive Potential

To date, only seven papers (found in Google Scholar and PubMed) have investigated FWHR and threatening faces by measuring the LPP (Eldblom, 2018; Jones, 2019; Kajonius & Eldblom, 2020; Lindersson, 2019; Magnusson, 2021; Pieslinger, 2019; Sutradhar, 2020). Three papers stem from the same experiment (Jones, 2019; Lindersson, 2019; Pieslinger, 2019). Kajonius and Eldblom (2020) is based on Eldblom's (2018) study. Additionally, all papers, except for Kajonius and Eldblom (2020), are student dissertations. Eldblom (2018) was the first to investigate the relationship between FWHR and LPP amplitudes, reporting that in a threatening context, high FWHR male faces elicited larger LPP amplitudes than low FWHR faces.

To summarize the findings of these studies: all studies reported that angry male faces elicited larger LPPs than neutral male faces, regardless of FWHR. However, the results were mixed concerning LPP amplitude differences between high and low FWHR male faces. Pieslinger (2019) and Jones (2020) did not find a significant LPP amplitude difference between low and high FWHRs, while Lindersson (2019), Kajonius and Eldblom (2020), Sutradhar (2020), and Magnusson (2021) did observe such differences. Moreover, certain components of FWHR appear to have a greater impact on threat ratings and LPP amplitudes than others. Specifically, Lindersson (2019), Sutradhar (2020), and Magnusson (2021) reported that brow height had a significant effect on both threat ratings and LPP amplitudes compared to facial width. These findings support the notion that individuals tend to focus their gaze on the eye area when perceiving emotional facial expressions (Eisenbruch et al., 2017; Schurgin et al., 2014).

The Present Study

All papers in the FWHR and LPP literature share a common feature: the exclusive use of male faces as stimuli. Previous research has suggested that males and females react differently depending on whether they see a male or female face (Wen & Zheng, 2020; Liu et al., 2022). Furthermore, both women and men have been reported to exhibit greater LPP responses when presented with faces of their respective sex (Rodríguez-Gómez et al., 2020). This suggests that the gender of the facial stimuli might modulate the LPP response.

Since all previous FWHR and LPP studies have only used threatening male faces as stimuli, it remains unknown how much the gender of a face affects the LPP. Therefore, this study aims to investigate whether the combination of gender, FWHR, and threatening facial expressions influences the LPP response.

For the first hypothesis, it is anticipated that threatening faces will elicit larger LPP amplitudes compared to neutral faces, regardless of FWHR and gender, consistent with previous studies (Jones, 2019; Magnusson, 2021). The second hypothesis posits that high FWHR male faces will elicit larger LPPs than high FWHR female faces, for both neutral and angry expressions. This hypothesis is based on the premise that males with larger FWHRs are perceived as more masculine (Geniole et al., 2015), a perception that aligns more closely with gender norms than masculine female faces, which have been shown to elicit weaker LPP responses (Rodríguez-Gómez et al., 2020). For the third hypothesis, building on the findings of Kajonius and Eldblom (2020), it is expected that faces with high FWHRs will elicit greater LPP responses compared to those with low FWHRs.

Methods

Participants

Before the recruitment of participants commenced, a power analysis was conducted to gauge the minimum number of participants needed to detect a large effect (power = 0.80; Szucs & Ioannidis, 2017, 2021). The minimum number of participants needed to detect a large effect (f = 0.4) for a 2x2x2 ANOVA was 64 (effect size (f) = 0.4, power = 0.8, alpha (p) = 0.05).

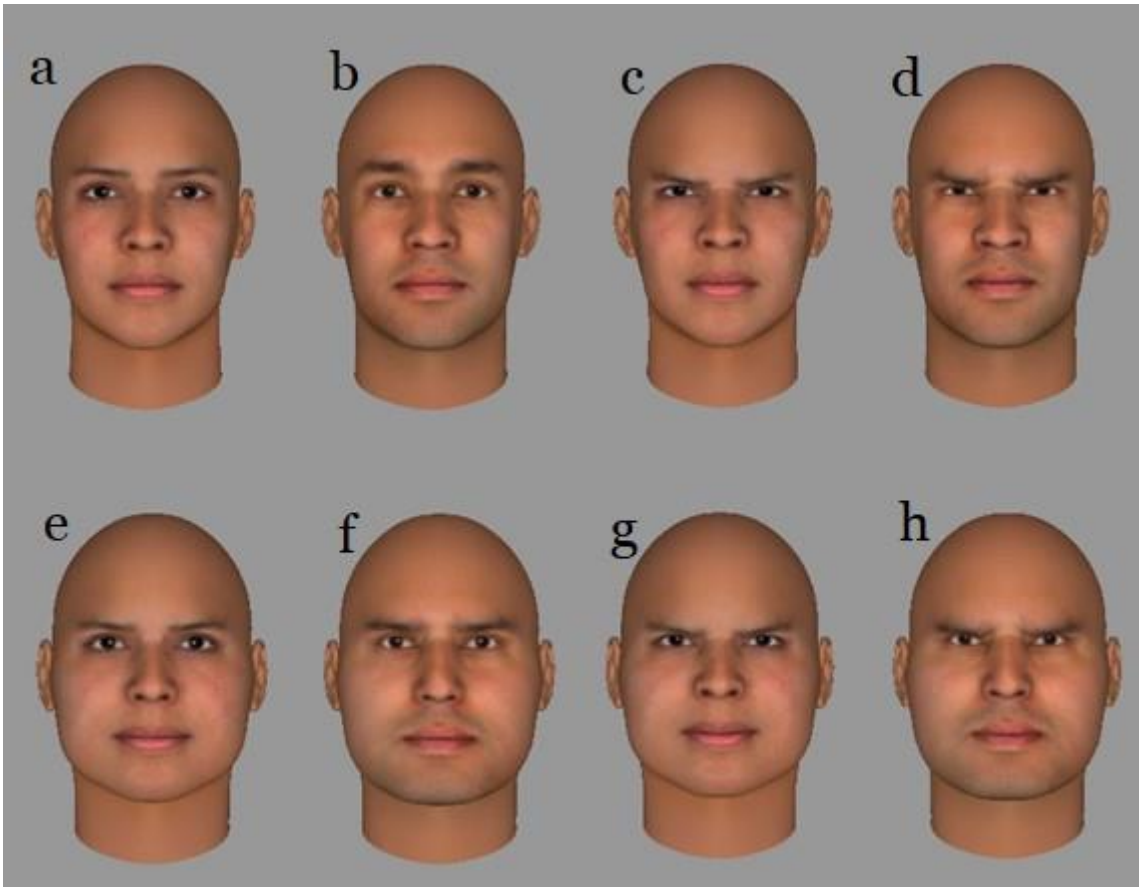
This study suffered from time constraints which led to 23 healthy participants being recruited instead of the minimum requirement of 64. These 23 participants (Male = 9, M_{age} = 22, SD_{age} = 1.89) were recruited from the University of Skövde through posters and social media to participate in this study. The inclusion criteria required participants to (1) be healthy and not have any neurological diagnoses, (2) be between 18-40 years old, (3) be right-handed, (4) be able to see clearly 2 meters ahead with or without glasses or contact lenses, (5) have a good English comprehension when it comes to both reading and listening. Participants were excluded if they: (1) suffered from epilepsy, (2) were colorblind, (3) were dyslexic, (4) had any ongoing psychiatric or neurological illness. Participants were recruited via social media and campus advertisements. Participants received no monetary compensation. All participants provided written consent in accordance with the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 2013).

Experimental Design and Stimuli

The experiment consisted of a picture-viewing task and a face-rating task. The facial stimuli used for both tasks were computer generated using the FaceGen Modeller Core version 3.34 (Singular Inversions). The stimuli followed a 2x2x2 factorial design, resulting in the creation of eight distinct facial images. These images were generated by manipulating three variables: gender (male or female), facial expression (angry or neutral), and FWHR (high or low). The FWHR variable was specifically altered by lowering or increasing brow height and widening or narrowing the cheekbones. The FaceGen program offered *any* ethnicity for face generation which was chosen as it produced a neutral ethnicity for the faces. This was done by combining average European, African, and Asian faces. The ages of the face stimuli were set at 25 which was the default setting. The facial expressions and the FWHR were adjusted to be as similar as possible between the male and female faces without compromising gender characteristics that might make the face ubiquitous to the intended gender (see Figure 2.).

Figure 2

All Eight Face Stimuli Used in the Study by Varying Gender (male/female), FWHR (high/low), and Expression (neutral/angry)



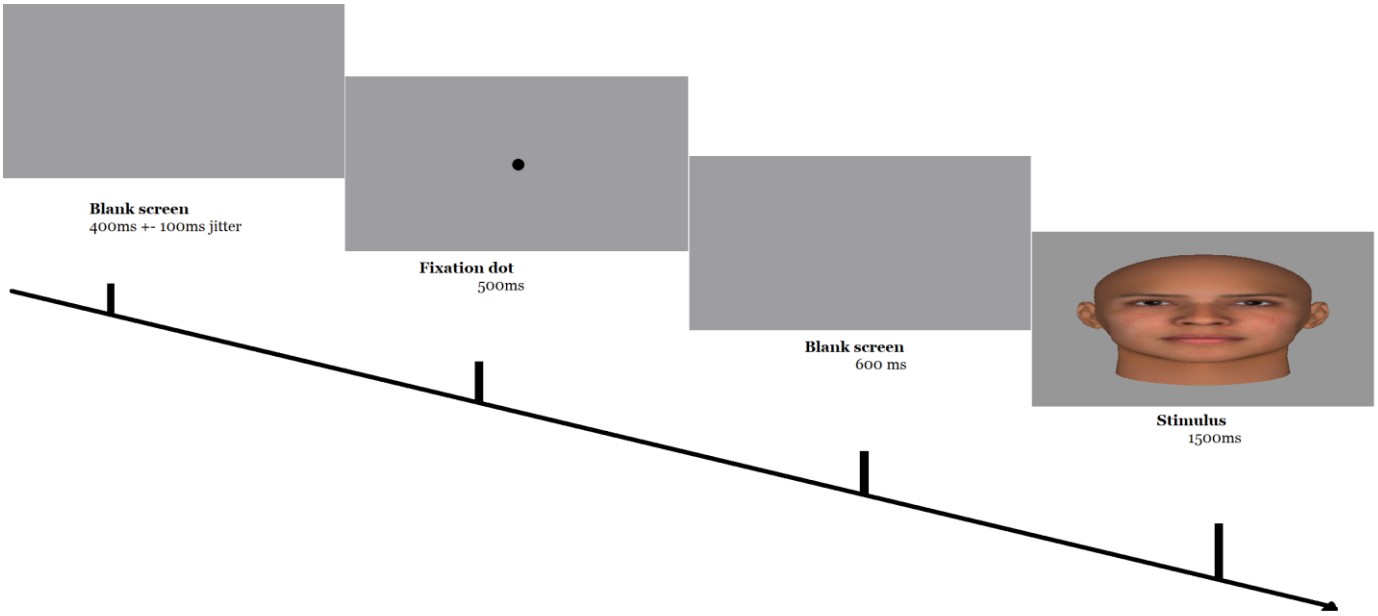
Note. Face (a) low FWHR neutral female face, (b) low FWHR neutral male face, (c) low FWHR angry female face, (d) low FWHR angry male face, (e) high FWHR neutral female face, (f) high FWHR neutral male face, (g) high FWHR angry female face, (h) high FWHR angry male face.

All face stimuli had the same luminosity as the background to limit potential sensory confounds caused by size variations between stimuli. The grey background of the facial stimuli had an RGB index of 152, 152, 152. The picture-viewing task consisted of ten blocks and 64 displays of face stimuli per block, each face stimuli were displayed eight times per block. Within each block the stimulus order was pseudorandomized to prevent the same face being shown twice in a row. Every picture-viewing task started with a blank screen for 400 ms (jitter ± 100 ms), followed by a fixation dot for 500 ms, another blank screen for 600

ms, and the stimulus for 1500 ms. The stimulus onset asynchrony (SOA) was 3000 ms (see Figure 3).

Figure 3.

Timeline of a Single Trial from the Picture Viewing Task



Note: Time moves from left to right, SOA = 3000ms. The face stimuli in the figure is an illustrative example created for this figure, and face stimuli was not presented in such a distorted manner during the experiment.

Before starting the first block of the picture-viewing task, participants performed a face-rating task. A second face-rating task was performed after the fifth block of the picture-viewing task. During the face-rating task participants were shown a face stimulus and asked to rate how threatening the face was on a scale from 1 (“the least threatening”) to 9 (“the most threatening”). Each face stimulus was displayed once during the task and remained on the screen until the participant responded. The threat ratings from the picture-rating task were used to confirm if the angry expressions were perceived as more threatening than the neutral ones. E-prime 3.0 (Psychology Software Tools) was used to present the stimuli.

Procedure

Before starting the experiment, participants had to sign an informed consent form. Information about the experiment and an electronic version of the consent form were sent to participants before the day of the experiment. The experiment appeared on an HP Compaq LA2306x 23-inch monitor (native screen resolution 1920 x 1080, refresh rate: 60 Hz), and ran on E-prime 3.0 (Psychology Software Tools). Participants were seated approximately 105 cm from the screen in a 20-22°C room with dim lighting. A stretchable EEG electrode cap (g.GAMMAcap2) was fitted to the participant's head. Four external electrooculograms (EOG) and two mastoid electrodes (left and right) were attached. The EOGs were placed ~1 cm lateral to each eye's outer canthi and above and below the right eye. A highly conductive water-soluable gel (g.tec) was used for the gel application of the electrodes. After all the electrodes had been gelled and inspection of the EEG recording looked good, the participants were then presented with instructions for the task.

A computer keyboard was given to the participants to use for the picture-rating task of the experiment, and later, participants were given an Xbox controller for the picture-viewing task. After participants had read and understood the instructions, the experiment started, and participants were first introduced to the picture-rating task. EEG was recorded during both the picture-rating task and picture-viewing task, but only data from the picture-viewing task was used for further analysis. The experimental session took approximately 40 minutes to complete.

EEG Recording

Twenty-seven Ag-AgCl electrodes were utilized for online EEG recording (g.SCARABEO electrodes, manufactured by g.tec). The electrodes were located at standard scalp locations based on the 10/20 system (Fz, FCz, AF3, AF4, F7, F8, F5, F6, F3, F4, T7, T8, C3, C4, CP1, CP2, P3, P4, PO3, PO4, O1, O2, CPz, Pz, Poz, Oz, Cz) as well as over the left and right mastoids. The system was referenced online to electrode Cz, and AFz was used as the ground electrode. Two g.GAMMAbox interface/driver boxes and two g.USBamp amplifiers

(g.tec) recorded the EEG signal. The range of the amplifiers was ± 250mV, which allows for recording on DC without saturation. The system transformed active electrode impedances to output impedances of approximately 1kΩ. The data sampling rate was set at 256Hz and a 6th-order Butterworth filter was used for band-pass filtering of the continuous data (half-amplitude cutoff = 0.01-60Hz, slope = 36dB/octave). The EEG data were pre-processed offline in EEGLAB version 23.0 (Delorme & Makeig, 2004) and ERPLAB version 9.10 (Lopez-Calderon & Luck, 2014) as an extension of MATLAB R2020a (9.8.0.1873465).

EEG Preprocessing

During pre-processing, continuous EEG data was re-referenced to the average of the mastoids. A highpass filter of 0.1 Hz second order Butterworth filter was applied using the pop_basicfilter() function in EEGLAB. The EEGLAB plugin Cleanline was used to filter line noise at 50 Hz, additionally a 180th order Parks-McClellan stop-band notch filter (half-amplitude cutoff = 50Hz, slope = 6dB/octave) was applied as well. The pop_rejchan() function was used to remove channels that deviated over three standard deviations from the norm. The removed channels were then interpolated using the pop_interp() function.

A temporary pipeline of the data was created to run the Independent Component Analysis (ICA). Using the ERPLABs pop_basicfilter() function, the data was filtered with a highpass 1 Hz second-order Butterworth filter. Epochs were extracted at 300ms before stimulus onset and 1600ms after stimulus onset. The pop_eegthresh function was used to reject artifacts from each epoch outside of the thresholds -100 μV to 100 μV. ICA was started with the pop_runica() function in EEGLAB, and the pop_icalabel () was used to flag components that were more than 80% likely to be either muscle or eye activity. The ICA weights were then reapplied to the data before the pipeline was created.

The data was epoched into 1900 ms segments (300 ms pre- and 1600 ms post-stimulus). The moving window peak-to-peak function performed epoch-based rejection. Epochs containing activity greater than 150 μV within a 200 ms moving window with a step size of 20 ms were rejected. Participants with more than 25% of epochs rejected during

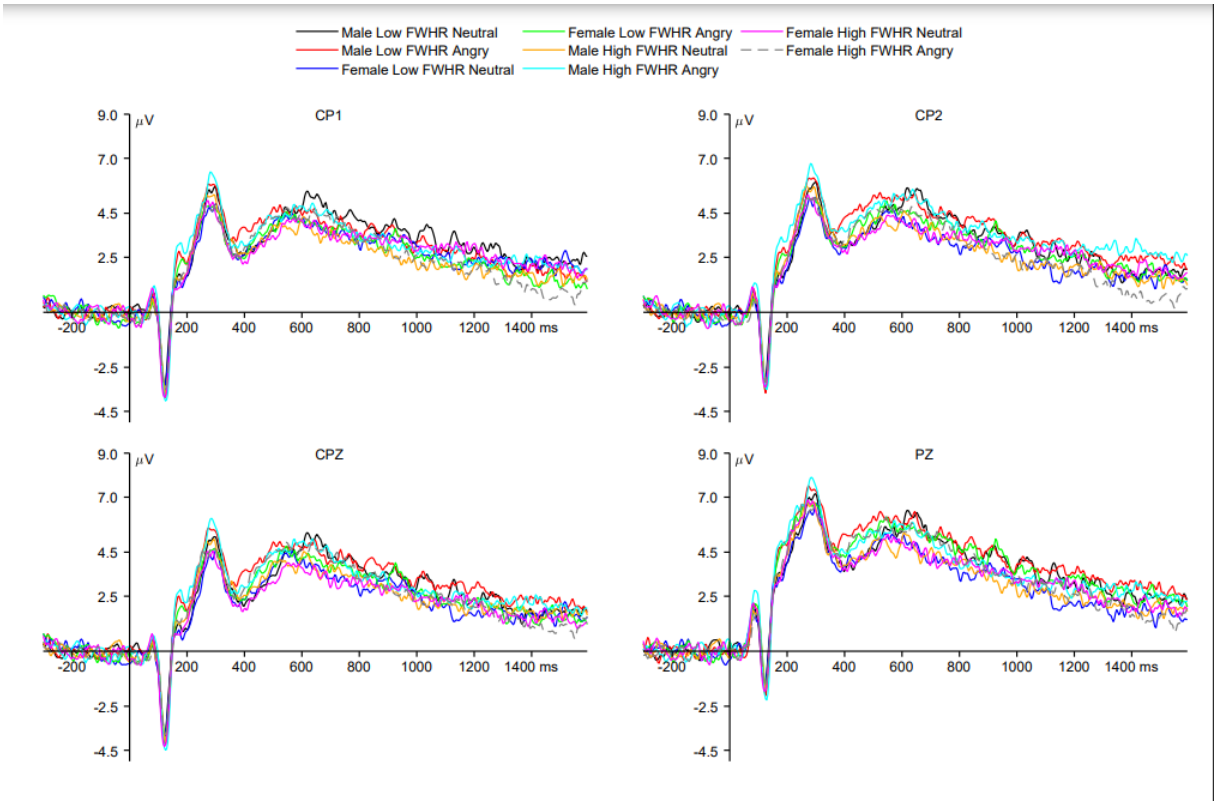
moving window peak-to-peak were automatically rejected from further analysis. As a result, three participants were rejected. The remaining epochs were averaged across each participant. The first four participants' data were rejected as well after noticing an error in the E-prime program that displayed the facial stimuli in a specific and predictable order. The remaining participants' (n=16, Male = 5, M_{age} = 22.1, SD_{age} = 1.45) data were then used for data analysis.

Data Analysis

Prior studies on LPP and FWHR have used a central-parietal cluster of electrodes usually consisting of Cz, CPz, Pz, CP1, CP2 (Eldblom, 2018; Jones, 2019; Kajonius & Eldblom, 2020; Lindersson, 2019; Pieslinger, 2019; Sutradhar, 2020). Magnusson (2021) reported from his mass univariate analysis that the CPz had the highest voltage activation in response to angry and high FWHR faces. Visual inspection of electrodes adjacent to CPz, such as CP1, CP2, and Pz, showed no noticeable differences compared to CPz (See Figure 4).

Figure 4

Voltage Graph of ERPS Over Electrodes CP1, CP2, CPZ, and PZ in Response to the Facial Stimuli



Note: The Y-axis represents the electrode voltage in micro-volts and the X-axis represents time in milliseconds (ms) with stimulus presented at 0ms.

Thus, only the CPz electrode was used as the region of interest for the analysis. The analyses were carried out in SPSS v.28 on mean ERP amplitudes across a time window of 400-600ms (early LPP), 600-1000ms (middle LPP), and 1000-1600ms (late LPP) after stimulus onset (see Figure 7). Since there is no general rule of what time windows to use for the LPP, the early LPP time window was chosen based on the study by Rodríguez-Gómez et al. (2020). The middle and late LPP time windows are based on previous LPP studies examining FWHR and facial expressions (Eldblom, 2018; Jones, 2019; Kajonius & Eldblom, 2020; Lindersson, 2019; Pieslinger, 2019; Sutradhar, 2020).

The variables of gender (male vs. female), FWHR (high vs. low), and facial expression (angry vs. neutral) were used as factors in a repeated-measures ANOVA. An ANOVA was conducted for each time window (early, middle, and late LPP) on the CPz electrode. Significant interactions found from the ANOVA were then subjected to paired-sample t-tests as a post hoc test.

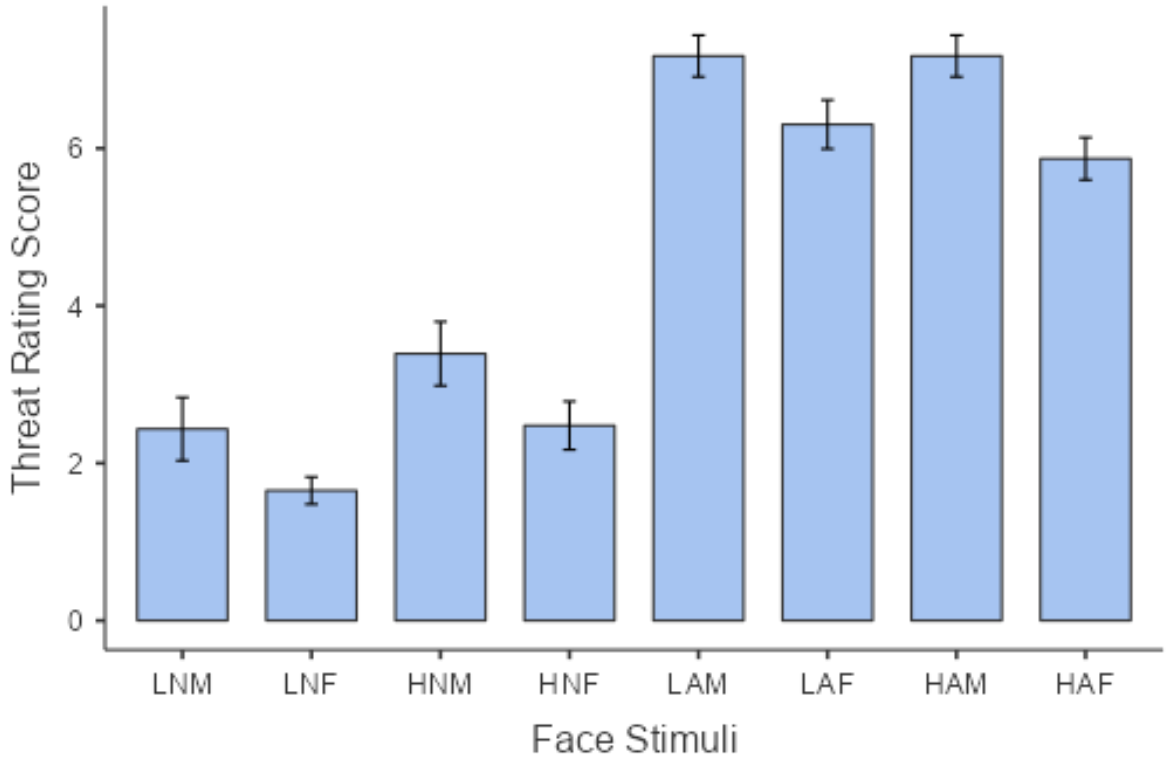
Results

Picture-Rating Task

The picture-rating task confirmed that angry expressions were rated much more threatening than neutral expressions (Figure 5). The Low FWHR neutral female face was rated as the least threatening out of all faces (M = 1.65 ± 0.83). Low FWHR angry male faces (M = 7.17 ± 1.27) and high FWHR angry male faces were rated equally as the most threatening (M = 7.17 ± 1.27) faces. The high FWHR male neutral face was rated the highest out of all other neutral faces (M = 3.39 ± 1.94).

Figure 5

Mean Threat-Rating Scores of all Face Stimuli



Note: Each column represents a face stimulus with its variables shortened as an abbreviation. The first letter denotes the FWHR; L = Low facial width-to-height ratio, H = High facial width-to-height ratio. The second letter denotes expression; N = neutral, A = angry. The third

letter denotes gender; M = male, F = female. For example, LNM = low facial width-to-height ratio neutral male. Error bars: 95% CI.

Early Time Window of the Late Positive Potential

A repeated measures ANOVA with the factors Gender (male or female), Expression (angry or neutral), and FWHR (high or low) was conducted on the mean amplitude on the early LPP (400-600ms) window (see Table 1). A significant main effect was found for the expression variable ($p < 0.05$).

Table 1

Effects of Gender, Expression, and FWHR on the Early LPP Time Window

Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p	η^2_p
Gender	1.4584	1	1.4584	0.5726	0.461	0.037
Residual	38.2041	15	2.5469			
Expression	16.4014	1	16.4014	9.9695	0.007	0.399
Residual	24.6774	15	1.6452			
FWHR	0.2143	1	0.2143	0.1394	0.714	0.009
Residual	23.0562	15	1.5371			
Gender ✻ Expression	0.0996	1	0.0996	0.0532	0.821	0.004
Residual	28.0744	15	1.8716			
Gender ✻ FWHR	0.0221	1	0.0221	0.0103	0.921	0.001
Residual	32.1754	15	2.1450			
Expression ✻ FWHR	0.3928	1	0.3928	0.3463	0.565	0.023
Residual	17.0158	15	1.1344			
Gender ✻ Expression ✻ FWHR	2.1282	1	2.1282	1.5721	0.229	0.095
Residual	20.3058	15	1.3537			

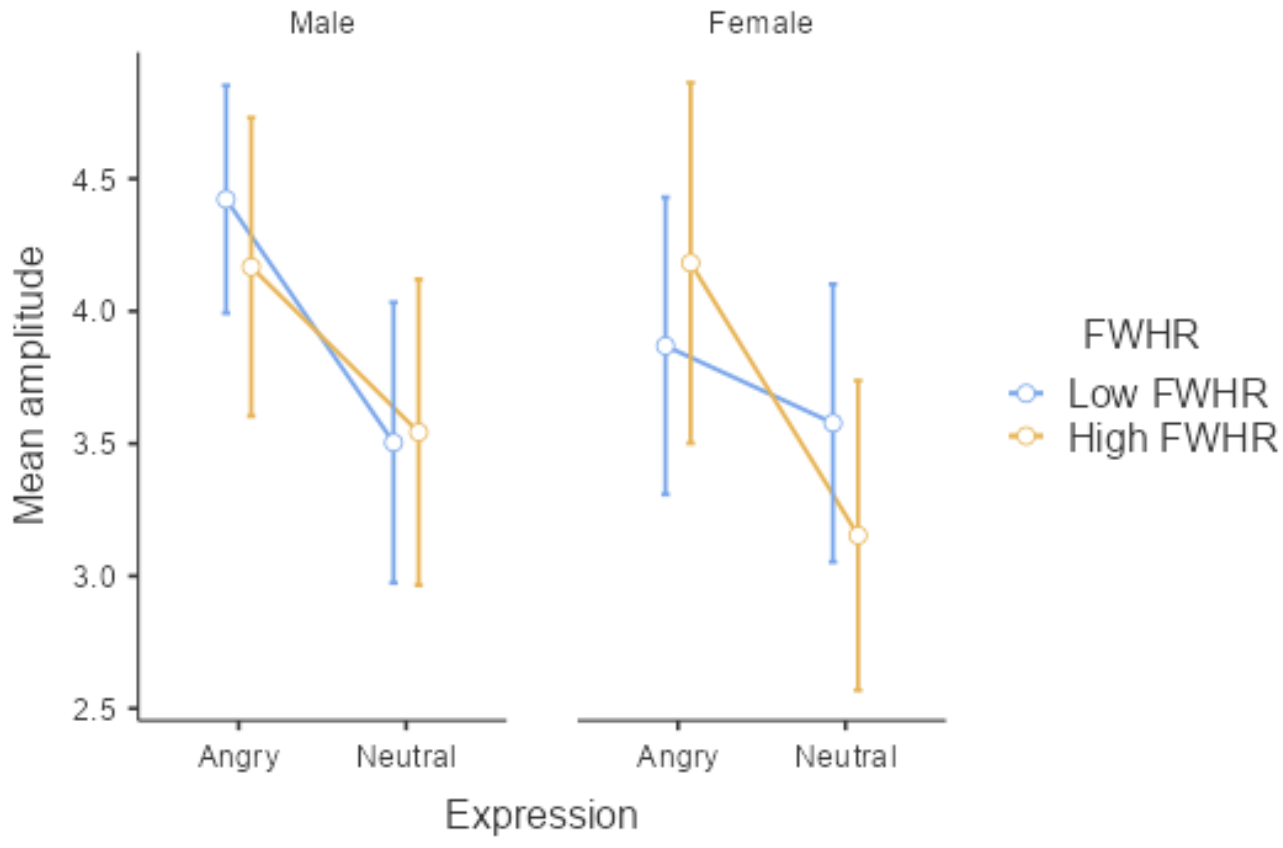
Note: $p < 0.05$ = significance

A paired sample t-test was conducted on the expression conditions as a post hoc test. The analysis revealed significant mean amplitude differences between several conditions (see Figure 6; Table 2). Specifically, low FWHR angry male faces (M = 4.42, SD = 1.72) elicited a significantly larger LPP amplitude compared to: (1) high FWHR neutral male face (M = 3.54, SD = 2.31; t(15) = 2.23, p = 0.041, Mdiff = 0.88, SDdiff = 0.394, CIdiff = [0.04,

1.72], Cohen's Ddiff = 0.558), (2) low FWHR neutral female (M = 3.58, SD = 2.10; t(15) = 2.62, p = 0.019, Mdiff = 0.845, SDdiff = 0.322, CIdiff = [0.15, 1.53], Cohen's Ddiff = 0.656), (3) high FWHR neutral female (M = 3.15, SD = 2.34; t(15) = 3.15, p = 0.007, Mdiff = 1.269, SDdiff = 0.403, CIdiff = [0.403, 2.13], Cohen's Ddiff = 0.787). Low FWHR angry male face had a significantly larger mean amplitude compared to high FWHR neutral male face, low FWHR neutral female face, and high FWHR neutral female face.

Figure 6

Graph of the Mean Amplitude From the Early LPP Time Window Across the Conditions: Gender, Expression, and FWHR



Note. FWHR = facial width-to-height ratio. The vertical lines are the standard error of the mean (SEM)

Table 2

Table of the Estimated Marginal Means From the Early LPP Time Window Across the Conditions: Gender, Expression, and FWHR

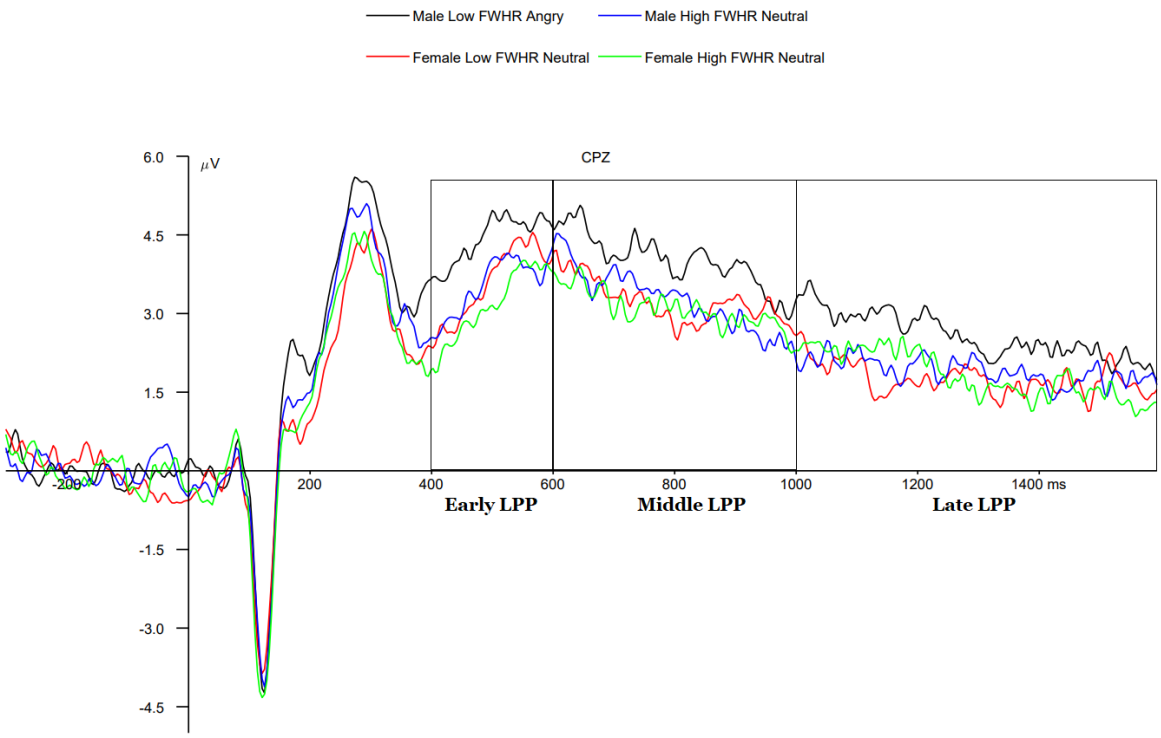
Estimated Marginal Means - Expression ✻ Gender ✻ FWHR

					95% Confidence Interval	
FWHR	Gender	Expression	Mean	SE	Lower	Upper
Low FWHR	Male	Angry	4.42	0.430	3.51	5.34
		Neutral	3.50	0.530	2.37	4.63
	Female	Angry	3.87	0.561	2.67	5.06
		Neutral	3.58	0.525	2.46	4.70
High FWHR	Male	Angry	4.17	0.563	2.97	5.37
		Neutral	3.54	0.577	2.31	4.77
	Female	Angry	4.18	0.681	2.73	5.63
		Neutral	3.15	0.584	1.91	4.40

Note: SE = standard error

Figure 7

Gand Average of the Mean Amplitude of the LPP in the CPz Electrode With all Time Windows and Conditions Used for the Post hoc Analysis



Note: The Y-axis represents the electrode voltage in micro-volts and the X-axis represents time in milliseconds (ms) with stimulus presented at 0ms.

Middle Time Window of the Late Positive Potential

A repeated measures ANOVA was conducted on the middle time window (600-1000ms) of the LPP with the same variables used in the early time window analysis. No significant main effects or interactions were found for the middle time window (see Table 3-4; Figure 8). The low FWHR neutral male face (3.98 ± 0.616) had a very similar amplitude to the low FWHR angry male face (4.02 ± 0.468), which was unexpected.

Table 3

Effects of Gender, Expression, and FWHR on the Middle LPP Time Window

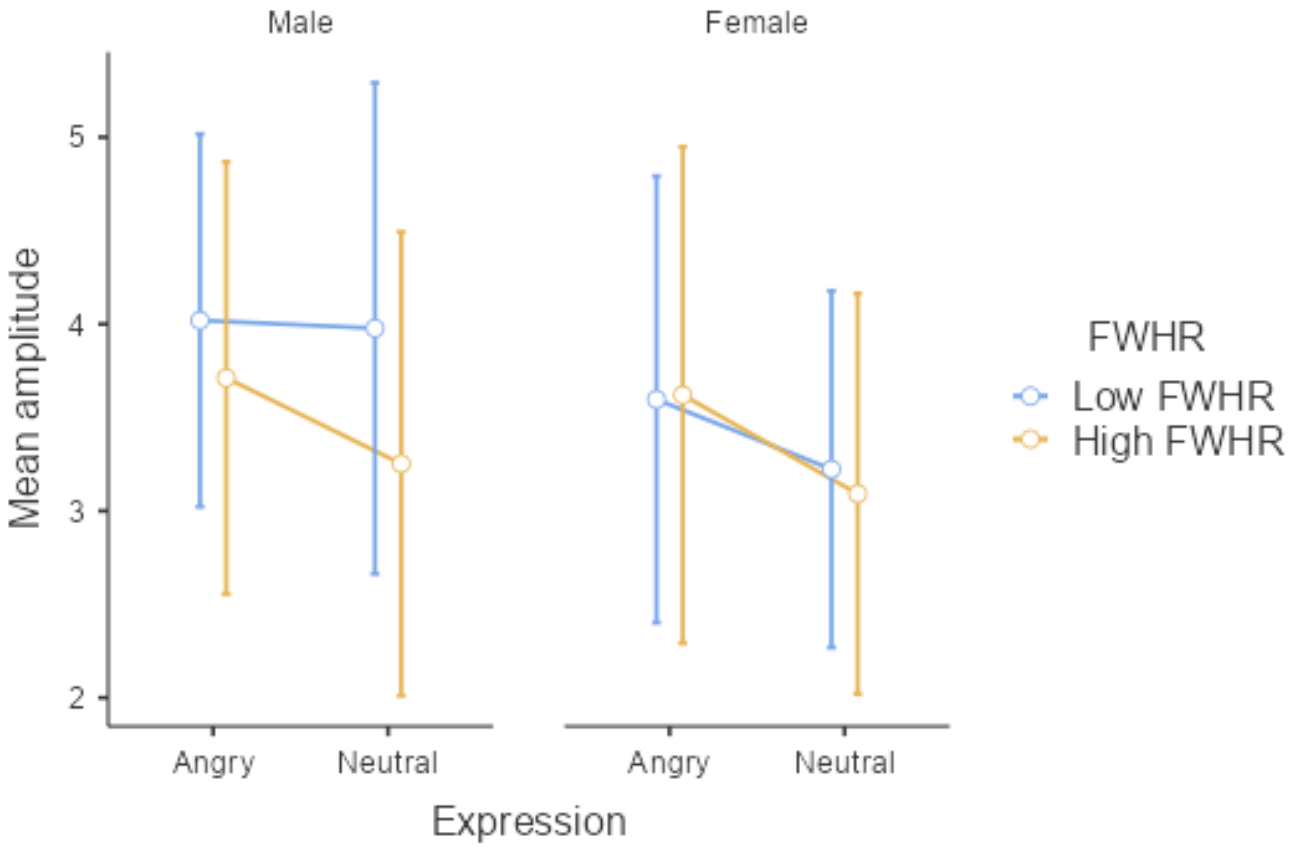
Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p	η^2_p
Gender	4.087	1	4.087	1.7534	0.205	0.105
Residual	34.963	15	2.331			
Expression	3.944	1	3.944	1.2813	0.275	0.079
Residual	46.171	15	3.078			
FWHR	2.601	1	2.601	1.8291	0.196	0.109
Residual	21.334	15	1.422			
Gender ✻ Expression	0.320	1	0.320	0.2460	0.627	0.016
Residual	19.522	15	1.301			
Gender ✻ FWHR	1.714	1	1.714	0.6888	0.420	0.044
Residual	37.315	15	2.488			
Expression ✻ FWHR	0.657	1	0.657	0.4701	0.503	0.030
Residual	20.962	15	1.397			
Gender ✻ Expression ✻ FWHR	0.137	1	0.137	0.0568	0.815	0.004
Residual	36.181	15	2.412			

Note: $p < 0.05$ = significance

Figure 8

Graph of the Mean Amplitude From the Middle LPP Time Window Across the Conditions: Gender, Expression, and FWHR



Note: FWHR = facial width-to-height ratio. The vertical lines are the standard error of the mean (SEM)

Table 4

Table of the Estimated Marginal Means From the Middle LPP Time Window Across the Conditions: Gender, Expression, and FWHR

Estimated Marginal Means - Expression * FWHR * Gender

Gender	FWHR	Expression	Mean	SE	95% Confidence Interval	
					Lower	Upper
Male	Low FWHR	Angry	4.02	0.468	3.02	5.02
		Neutral	3.98	0.616	2.66	5.29
	High FWHR	Angry	3.71	0.543	2.55	4.87
		Neutral	3.25	0.582	2.01	4.49
Female	Low FWHR	Angry	3.60	0.561	2.40	4.79
		Neutral	3.22	0.448	2.27	4.18
	High FWHR	Angry	3.62	0.623	2.29	4.95
		Neutral	3.09	0.503	2.02	4.16

Note: SE = Standard error

Late Time Window of the Late Positive Potential

A repeated measures ANOVA was conducted on the late time window (1000-1600ms) of the LPP with the same variables used in the other previous analyses. No significant main effects or interactions were found for the late time window (see Figure 9; Table 5-6).

Table 5

Main Effects of the Middle LPP Time Window with the Factors: Gender, Expression, and FWHR

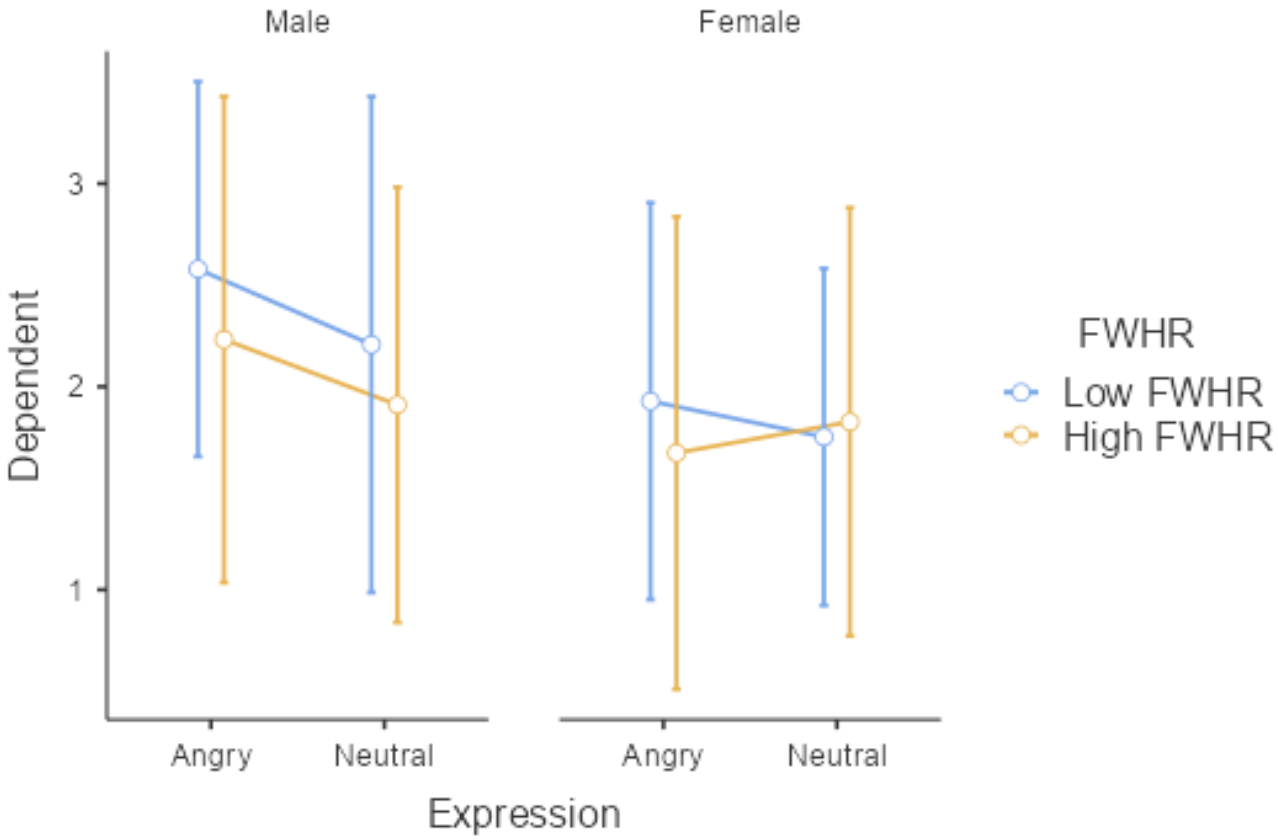
Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p	η^2_p
Gender	6.113	1	6.113	2.6054	0.127	0.148
Residual	35.195	15	2.346			
Expression	1.026	1	1.026	0.4034	0.535	0.026
Residual	38.148	15	2.543			
FWHR	1.359	1	1.359	0.7614	0.397	0.048
Residual	26.772	15	1.785			
Gender ✻ Expression	0.897	1	0.897	0.7537	0.399	0.048
Residual	17.846	15	1.190			
Gender ✻ FWHR	0.430	1	0.430	0.1131	0.741	0.007
Residual	56.979	15	3.799			
Expression ✻ FWHR	0.287	1	0.287	0.3672	0.554	0.024
Residual	11.740	15	0.783			
Gender ✻ Expression ✻ FWHR	0.157	1	0.157	0.0498	0.826	0.003
Residual	47.177	15	3.145			

Note: $p > 0.05$ = significance

Figure 9

Graph of the Mean Amplitude From the Late LPP Time Window Across the Conditions: Gender, Expression, and FWHR



Note. The vertical lines are the standard error of the mean (SEM)

Table 6

Table of the Estimated Marginal Means From the Late LPP Time Window Across the Conditions: Gender, Expression, and FWHR

Estimated Marginal Means - Expression * FWHR * Gender

Gender	FWHR	Expression	Mean	SE	95% Confidence Interval	
					Lower	Upper
Male	Low FWHR	Angry	2.58	0.433	1.656	3.50
		Neutral	2.21	0.573	0.987	3.43
	High FWHR	Angry	2.23	0.562	1.035	3.43
		Neutral	1.91	0.503	0.839	2.98
Female	Low FWHR	Angry	1.93	0.459	0.951	2.91
		Neutral	1.75	0.389	0.923	2.58
	High FWHR	Angry	1.67	0.546	0.510	2.84
		Neutral	1.83	0.495	0.772	2.88

Note: SE = Standard error

Discussion

The aim of this study was to investigate whether the combination of gender, FWHR and threatening facial expressions influences the LPP response. Firstly, there were no significant main effects or interactions involving gender or FWHR. Only the main effect of expression was significant. Specifically, in the early time window (400-600ms after stimulus), angry expressions elicited a significantly higher mean LPP amplitude compared to neutral expressions.

The first hypothesis stated that threatening faces will elicit larger LPP amplitudes compared to neutral ones regardless of FWHR and gender. The significant difference between neutral and angry expressions was found in the early time-window. The low FWHR male face with an angry expression was the only face to elicit a significantly higher LPP response compared to the neutral faces. No other angry face expression was significantly different from neutral faces. Thus, the first hypothesis is partially confirmed.

The observation of the low FWHR angry male face being the only threatening face to significantly differ in LPP amplitudes compared to neutral faces seems to partially confirm previous findings (e.g., Hajcak et al., 2010; Magnusson, 2021; Schupp et al., 2004). A

possible explanation for the observation could be that the angry expressions on the high FWHR faces are not salient enough to elicit a larger LPP compared to the high FWHR neutral faces. However, that does not explain why the low FWHR angry female face did not elicit a significant LPP response compared to neutral expressions. Social factors might have influenced how threatening the female face was perceived (Rodríguez-Gómez et al., 2020), since aggressive behavior is more prevalent for the male population (Geniole et al., 2015). Furthermore, FWHR and perceived aggression are more strongly correlated with males than females (Geniole et al., 2012; Geniole et al., 2015). Thus, the female face might have been perceived as a lesser threat compared to its male counterpart.

The second hypothesis predicted that high FWHR male faces would elicit larger LPPs than high FWHR female faces. However, no significant effects for gender were found across all time windows, offering no support for the hypothesis. A potential explanation for this outcome may lie in the similarity between the high FWHR male and female faces. The facial features were subtly altered to change the genders of the face. However, this subtle manipulation may have led to some participants having trouble to distinguishing between male and female faces, thereby potentially diminishing any observable gender effects.

For the third hypothesis, it was expected to find faces with high FWHRs to elicit larger LPPs than faces with low FWHR. However, no significant effects were observed for the FWHR variable, indicating that this hypothesis was not supported. Furthermore, previous studies have reported that manipulating the FHWR has had no significant impact on the LPP (Jones, 2019; Pieslinger, 2019), except when specific alterations to the eyebrows were made (Lindersson, 2019; Magnusson, 2021; Sutradhar, 2020). The eyebrows and eyes are key areas where people typically fixate on when observing faces (Schurgin et al., 2014). Furthermore, Eisenbruch et al. (2017) suggested that faces with higher FWHR may resemble a threatening expression due to the relatively lower position of their eyebrows compared to faces with lower FWHR. This could explain why manipulating the cheekbones did not significantly impact the LPP response or the perceived threat.

A surprising finding was the high FWHR angry male face not eliciting a significant LPP amplitude compared to any neutral face. Previous research found faces with high FWHR and angry expressions to generate the highest LPP amplitudes (Jones, 2019). This contradicts the observation for high FWHR angry male faces from this study. However, other studies have reported faces with narrower cheekbones to elicit higher LPPs than faces with wider cheekbones (Lindersson, 2019; Magnusson, 2021). The FWHR manipulation in this study only focused on increasing the width of the face and thus keeping the eyebrow height static for all stimuli. This may explain why no significant findings were observed for the high FWHR angry male face but were found for the low FWHR angry male face instead. The width of the face may have had a slight influence on the LPP, but this remains speculative.

Implications

The early FWHR studies concluded that a high FWHR face should be more threatening than a low FWHR face (Geniole et al., 2015). However, this was not observed in the current experiment. The non-significance found for the FWHR variable for this study provides some insight of the extent to which FWHR components (eyebrow height and cheekbone width) may influence the LPP response. Previous research suggests that the threatening aspect of the FWHR lies within the eyebrow areas (Lindersson, 2019; Magnusson, 2021), which was not manipulated in the current study. Since some FWHR components seem to have a significantly larger impact on perceived threat than others, the FWHR as a metric for threatening/aggressive behavior becomes inconsistent. It is unclear what in the FWHR is causing the perceived threat. Thus, future studies should focus more on which components of the FWHR really contributes towards an increase in perceived threat rather than the FWHR.

The absence of gender effects suggests that the facial features distinguishing male and female faces may not be relevant to perceived aggression. However, social factors, such as gender roles, have been shown to influence the LPP response when observing faces of a specific gender (Rodríguez-Gómez et al., 2020), which implies that there should be

noticeable differences between male and female stimuli. Despite this, the current study did not find such differences. Some participants reported difficulty in identifying the intended gender of the facial stimuli, which may have contributed to the lack of observed gender effects. Future studies should further explore potential gender effects by using stimuli that more clearly represent different genders.

Societal and ethical implications

Regarding societal implications, research on FWHR presents a double-edged sword. On one hand, such research may increase our understanding of how facial features signal social cues and how it effects social interactions in society. On the other hand, drawing conclusions about correlations between larger FWHRs and increased aggression (Geniole et al., 2015) may inadvertently increase unwarranted prejudice against these individuals. Furthermore, the large discrepancies in the literature should warrant a high degree of scrutiny for conclusions drawn with regards to aggressive behaviors and FWHR.

The foundation of FWHR research is rooted in early observations of sexual dimorphism between male and female faces (Weston et al., 2007; Carré & McCormick, 2008). Studies that include both male and female faces remain limited, with the primary focus predominantly on the association between aggression and male faces. This narrow focus is problematic, as recent research has demonstrated that correlations between FWHR and aggressive behavior can be observed in females as well (Wen & Zheng, 2020; Liu et al., 2022). Thus, it is essential to establish a robust connection between FWHR and aggressive behavior across genders to avoid perpetuating unwarranted assumptions about gender norms that could have negative societal implications.

Limitations and Future Directions

The idea of this study was to expand the topic of FWHR and LPP by introducing gender interactions, which have not been done before. This experience led to a lot of hindsight on what could have been improved upon and what future studies should consider before conducting a similar experiment.

Firstly, due to time constraints, the number of participants was far below what the power analysis suggested, which may explain the non-significant findings. Future studies should aim to gather enough participants to obtain more data and increase the validity of results.

Secondly, the gender of the facial stimuli could be less ubiquitous. Discussions with participants after completion of the experiment did reveal that some participants had a hard time distinguishing male from female faces. The scalp of the female faces was bald like the male faces, which is typically not associated with feminine features. Furthermore, bald men have been suggested to be perceived as more dominant than males with hair (Mannes, 2013), which could have impacted the results as well. To my knowledge, it is not known if bald females are also perceived as more dominant than females with hair. A possible way to solve this issue without introducing confounding factors such as hairstyles would be to blur the surrounding areas of the face to make sure that participants are focusing their gaze on the face.

Thirdly, the design of this experiment was found to be monotonous for many participants, as their only task was to observe faces. This lack of engagement led to the emergence of unwanted alpha waves in several participants, with some even reporting that they fell asleep during the experiment. A lack of attention to the stimuli can adversely affect the results, as the LPP is known to be modulated by stimuli that require top-down cognitive processes. Reducing the number of trials per block and incorporating a concurrent task could mitigate this issue. For example, participants could be instructed to press a button each time they see a specific face, with the target face changing after each block.

Fourth, the FWHR manipulation was only done by widening or slimming the cheekbones, no specific manipulation of the eyebrows was made. Eyebrow height has been suggested to have a significant effect on the LPP and perceived threat by previous studies (Lindersson, 2019; Magnusson, 2021). Thus, facial stimuli with very high eyebrows should have been used as well to compare different FWHR components with gender differences.

Fifth, the effects of the gender of the participants were not considered, which may impact the results. Males have been reported to show an enhanced physiological response in seeing other threatening male cues compared to seeing a female face (Kret & De Gelder, 2012). Future studies should take potential gender effects among participants into account. To address this issue, it is recommended to either include only one gender group or compare different gender groups as a between-subjects factor. The latter approach would require a larger sample size, as two groups would be compared instead of one.

Conclusion

The aim of this study was to investigate whether the combination of gender, FWHR and threatening facial expressions influences the LPP response. The results of this study found a significant difference in LPP mean amplitudes between angry and neutral faces in the early time window, suggesting the LPP to be modulated by emotional facial stimuli. However, the significance was only found in the low FWHR angry male face and not in other angry face variants. No significant effects were found between the LPP amplitudes and FWHR variables. This study only manipulated the cheekbones of the FWHR and not eyebrow height, which may have impacted the LPP differently. No significant effects were found for the gender variable in any time window. However, the low sample size and possible between-subject effects makes it hard to draw any conclusion. Future research should aim to include larger sample sizes to achieve sufficient statistical power and to explore any potentially significant interactions that may have been overlooked in this study.

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