Facial width-to-height ratio as a cue of threat: 
An ERP study

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Abstract

The late positive potential (LPP) is an event-related potential (ERP) component associated with increased affective processing. Studies have shown that stimuli with high evolutionary significance (e.g. a threatening face) induce increased activity over centro-parietal areas of the brain. In an electrophysiological context, this is hypothesized to be indexed by greater LPP amplitudes. The facial width-to-height ratio (fWHR) is a facial-masculinity metric which refers to cheekbone width, divided by upper facial height (top of the lip to between the brows). For the first time, LPP amplitudes were examined in subjects upon observing faces with high vs. low facial fWHRs. Prior studies suggest that faces with high fWHRs are perceived as more threatening than faces with low fWHRs. Consequently, fWHR has by some researchers been proposed to serve as a cue of threat. Two separate tasks in the present study were used to investigate this. In the aggression task, males with high fWHRs were judged as more aggressive. Moreover, when put in a threatening context, high fWHR faces also elicited greater LPP amplitudes in subjects compared to faces with low fWHRs. Conversely, in the self-regulation task, differences in LPP amplitudes did not reach significance. In this task, statistical power was low due to few blocks/trials in the ERP experiment and subjects were not primed on threat, which may explain the non-significant results. Taken together, the results provide modest support to the theory that fWHR serve as a cue of threat. Future studies will need to take the present study’s limitations into consideration.

Keywords: Facial width-to height ratio, late positive potential, fWHR as cue of threat, facial masculinity, sexual-selection.
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1. Introduction

What does seeing a face tell you? At times, it might feel like you can assess a person’s personality by a quick glance. But is it possible to infer personality traits from the face? *Physiognomy*, the art of assessing personality traits from faces dates back thousands of years (Hassin & Trope, 2000). Aristotle is believed to have been one of the earliest promoters of physiognomy along with several other Greek philosophers. Since then, reading personality traits from the face has been practiced by people all over the world. Physiognomy lacked scientific methods and seriousness in its approaches and experienced a substantial decline in interest in the topic in the mid to late 19th century (Valla, Ceci, & Williams, 2011).

Going further than laymen beliefs, it is plausible however to believe that the face is an important part in social cognition. In Darwin’s final work, the book “*The expression of the emotions in man and animals*” Darwin stressed the adaptive significance of using physical features as reliable cues during human interaction (Valla et al., 2011). Indeed, the face is almost always present in human interactions, shaping our impressions of other people. Thus, there are reasons to believe that throughout evolutionary history the face might have become an important source of information (Hassin & Trope, 2000).

Research from cognitive neuroscience and psychology, suggest that the human visual system is highly sensitive to and quickly processes cues in the face such as identity, gender, age and emotional expression and monitor human-to-human interactions (McGugin & Gauthier, 2013). Emotional expressions in particular, account for much of this communication. Intriguingly, static facial characteristics may also convey important information (Geniole, Denson, Dixson, Carré, & McCormick, 2015). Most studies that have examined static facial characteristics have been in relation to sexual selection and have fixated on what humans perceive as attractive to an observer. In evolutionary psychology, the general consensus is that judgements of what is attractive functions as honest signals of health and
genetic fitness and such facial characteristics and traits are often tied to pronounced sexual dimorphism (Rhodes, 2006).

One sexually dimorphic facial metric in men that has been linked to various behavioral traits, is the facial width-to-height ratio (fWHR). This facial measure refers to the bizygomatic width (cheekbone width), divided by upper facial height (top of the lip to between the brows) (Carré & McCormick, 2008; see Figure 1). It has repeatedly been shown that males with a high fWHR are more behaviorally aggressive and dominant (Geniole, Keyes, Carré, & McCormick, 2014; Haselhuhn & Wong, 2012; Lefevre, Etchells, Howell, Clark, & Penton-Voak, 2014). A meta-analysis including 56 peer-reviewed manuscripts revealed that fWHR was larger in men compared to women ($d = .11$), and that a high fWHR in men predicted aggressive behavior ($r = .11$) and facial masculinity ratings ($r = .35$).

Congruent with the notion that high fWHR males are more aggressive, third-party observers also perceive faces with a high fWHR as more aggressive ($r = .46$) in Geniole et al. (2015; cf. also Borgi & Majolo, 2016; Lieberz et al., 2017). Lastly, faces with a high fWHR are judged as less trustworthy (Stirrat & Perrett, 2010) less feminine (Costa, Lio, Gomez, & Sirigu, 2017) more formidable (Zilioli et al., 2015) and perceivers more readily see anger in them (Deska, Lloyd, & Hugenberg, 2018).

Evidence from behavioral sciences show that males with a high fWHR tend to act more aggressive and dominant and observers can accurately predict this. This opens the possibility that a specific mechanism might have developed through evolutionary history. Perhaps, to assess certain facial metrics as a cue of threat to efficiently guide behavior (Carré & McCormick, 2008). Ultimately, being able to accurately assess a man’s intentions based on his facial characteristics might provide important reproductive and survival benefits to an individual (Carré & McCormick, 2008).
Figure 1. Examples of males with a low and high fWHR. In the left image, the male has a fWHR of 1.93, which may be considered relatively high. The male on the right has a fWHR of 1.60, which may be considered relatively low. The black lines indicate the portion of the face implied in fWHR (Bizygomatic width divided by upper facial height).

There are important insights in unraveling the functional significance of certain facial characteristics. For instance, learning how facial cues might influence our perceptions about a person before interacting can have noteworthy implications in various contexts where judgements must be made within a limited time frame. In fact, it has been shown that physical appearance has a biasing effect in a variety of job-related outcomes (Hosoda, Stone-Romero, & Coats, 2003) as well as in criminal trials (Ahola, Hellström, & Christianson, 2010). Similarly, fWHR might have a significant impact on the outcomes in such settings and others. Consequently, individuals upon learning about this phenomenon, might adjust their strategies to moderate the effects of their fWHRs depending on the context.

To this date, there has been no electroencephalogram (EEG) study that has examined whether observers’ brain activity follows a pattern in line with their psychological experiences when observing males with different levels of fWHR.

EEG serves to record electrical fields from the brain and allows for millisecond to millisecond recordings of brain activity (da Silva, 2013). Thus, it enables us to gain insight
into human brain functioning by deriving electrophysiological measures from the scalp (Keil et al., 2014). However, since EEG is a rather rough measure of brain activity, it cannot be used to measure too specific neural processes (Luck, 2014). Neural responses are often associated with different events (e.g. cognitive, sensory) and the aim is to make sense of them. Using an averaging technique, there is a way to extract these responses from the more general EEG recording. These responses are referred to as event-related potentials (ERPs), and they constitute a key methodology in EEG research.

The late positive potential (LPP) is an Event-related-potential (ERP) component that reflects facilitated attention to emotional stimuli. Specifically, it is thought that emotionally arousing (both pleasant and unpleasant) stimuli elicit greater LPPs (Schupp et al., 2004). It develops at around 300-400 ms after stimulus onset over centro-parietal areas of the brain and may last for several seconds, depending on the duration of the stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). In terms of experimental reliability, the LPP has strong internal consistency (MacNamara & Hajcak, 2010) and is not particularly sensitive to habituation (Van Strien, Eijlers, Franken, & Huijding, 2014). Moreover, pictures, with high evolutionary relevance (e.g. threat) are found to be linked to increased LPP amplitudes (Schupp, Flaisch, Stockburger, & Junghöfer, 2006). For instance, Schupp et al. (2004) found that images of high evolutionary significance such as threatening and sexual contents were associated with increased LPP amplitudes compared to image categories that produced the same valence but less evolutionary significance.

If fWHR provides a cue of threat, as proposed by some researchers (Geniole et al., 2015) it is possible that the LPP will be affected, perhaps signaling an observers’ subjective feelings of threat.

In the present study the aim is to explore whether the findings regarding fWHR translate into an electrophysiological context. Consequently, the author will conduct an ERP
study were the LPP will be examined in response to faces of various fWHRs. The main hypothesis is that the LPP component - a proxy for emotional arousal in response to stimuli of high evolutionary significance - will yield higher amplitudes in subjects when observing a face with a high fWHR compared to a face with a low fWHR.

2. Background

In this chapter, a comprehensive overview will be given on fWHR. First, facial masculinity and fWHR will be explored through an evolutionary perspective. Second, the link between threatening behaviors and fWHR will be presented. Third, mechanisms linking fWHR to observer judgements and behavior will be investigated. Finally, issues of fWHR measurement will be presented.

2.1 Evolution as a driving force in facial masculinity and facial width-to-height ratio

Research suggest that fWHR is largely sexually dimorphic and a measure of facial masculinity (Carré & McCormick, 2008; Geniole et al., 2015). Individuals who manage to survive until sexual maturation and reproduce pass down their genes to the subsequent generation. Darwin termed this natural selection and it refers to the force that pushes an increase in prevalence of advantageous traits (Workman & Reader, 2014).

Charles Darwin realized, however, that many animals also possessed both physical and behavioral characteristics that were difficult to explain through natural selection. Since the members of both sexes face the same ecological pressures, natural selection should drive male and female characteristics in the same direction. Instead, in many species males are notably larger and more conspicuous and sometimes differed in terms of facial features (Workman & Reader, 2014). In addition, men on average engage in risk-taking behavior to a greater extent. One remarkable discrepancy which is difficult to explain in terms of natural selection is the male peacock’s tail. This elaborate feature makes him conspicuous to
predators. Since natural selection is thought to promote anti-predator adaptations it seems odd that such traits would arise in his ancestors (Workman & Reader, 2014).

The function of the male peacock’s tail seems instead to lie in its desirability by females (Workman & Reader, 2014). Despite the tail’s handicapping effects, this attractive feature helped males increase their chances of mating and thereby of passing on such features to the next generation. Upon noting this, Darwin concluded that a certain feature that might increase your reproductive success might paradoxically be selected for, even up to the point of shortening the life-span. Consequently, Darwin identified a new selective force called sexual selection (Workman & Reader, 2014). This evolutionary feature relates to those characteristics that provide individuals with benefits in gaining access to mates. Darwin outlined two forms of sexual selection, intra-sexual competition and inter-sexual selection. Intra-sexual competition consists of individuals competing with members of their own sex for access to the opposite sex. Generally, this means (for males) physical and mental combat for access to females where the loser typically fails to mate. Intra-sexual competition is thought to be responsible for why males develop weapons, such as horns and musculature to, compete with each other (Workman & Reader, 2014). In contrast, inter-sexual selection refers to members of one sex attempting to attract members of the other. As with the peacock, it is believed that inter-sexual competition has driven the evolution of sexual ornamentation, such as brighter plumage and other colorful displays in order to attract females (Workman & Reader, 2014).

Consistent with the hypothesis that males develop distinct facial characteristics in humans, is that men’s and women’s facial structure differ. Facial masculinity measures are based on the fact that males tend to have broader and larger chins, more prominent brow ridges, broader jaws (Gangestad, Thornhill, & Garver-Apgar, 2005) and more robust cheekbones (Weston, Friday, & Liò, 2007). Thus, greater embellishment of these features is
equal to higher facial masculinity (Gangestad et al., 2005) and is hypothesized to be related to levels of the sex hormone testosterone in puberty (Gangestad et al., 2005). In one study examining 68 male and 53 female skulls, researchers found that sexual size dimorphism was present in most cranial traits. Adult males had relatively shorter upper faces for their breadth compared to females ($p < 0.001$). The researchers proposed that the sexual dimorphism in fWHR may reflect a sexual selection pressure that is independent of selection for body size (Weston et al., 2007). The great question that emerges is *why is there such a thing as facial masculinity*?

In order to grasp the origins of male facial characteristics, it is imperative to understand their driving forces. The upcoming section will aim to explore this in a more detailed manner. Many researchers suggest that it may have developed by inter-sexual selection to serve as cues of genetic fitness (Carré & McCormick, 2008; Workman & Reader, 2014) and through intra-sexual competition to demonstrate dominance, aggression and fighting ability (Geniole et al., 2015; Zilioli et al., 2015; Workman & Reader, 2014).

### 2.1.1 Facial masculinity and intra-sexual competition

Men with masculine facial features are regarded as socially and physically dominant by their rivals (Puts, 2010; Puts, Jones, & DeBruine, 2012). In line with this, evidence suggest that men with high fWHRs are accurately judged as more aggressive, dominant and formidable (Geniole et al., 2015; Stirrat, Stulp, & Pollet; Zilioli et al., 2015). In addition, fWHR, has been linked to higher circulating levels of testosterone and higher levels of testosterone exposure in puberty and in the fetal stage. In turn, individuals with high levels of testosterone during these three periods are linked to physical and social dominance (Archer, 2006)

In fights, the face is usually a target, which means a possibility to induce facial and especially mandibular fractures. Over human evolution, such conditions may have helped
to create the robustness of male morphology as robust facial features plausibly enhance fighting success. (Stirrat, Stulp, & Pollet, 2012) In a study by Stirrat, et al. (2012) the researchers hypothesized that males with greater fWHR, would be less likely than narrower-faced males to die from violence (stabbed, strangled or bludgeoned to death) compared to other forms of homicide. Using a sample of 523 skeletons from diverse sources including forensic anthropology departments, the researchers found that men with narrower faces were more likely to have died as a result of homicides involving direct physical contact than men with broad masculine facial features such as large mandible and cheekbones. The researchers thus hypothesized that faces with high fWHRs may convey an honest signal of dominance and fighting ability. Consistent with this, Zilioli et al. (2015) examined whether fWHR ratio co-varied with actual physical formidability. Indeed, they found that fighters who won more fights had higher fWHRs ($r = .203, p = 0.011$; Zilioli et al., 2015).

There is an apparent relationship between facial fWHR and threat behavior. This is portrayed as both resilience in fights but also aggressiveness and actual fighting performance. This suggest that intra-sexual competition may have played a role in shaping the perceptual system to be particularly attuned to cues of threat and/or aggression. More specifically, fWHR might in part have evolved as a cueing system of intra-sexual threat and dominance in men (Geniole et al., 2015), like signals that predict genetic quality (Puts et al., 2012). Interestingly, there is not much evidence supporting that facial masculinity fWHR is predictive of any changes in aggressive behavior in women. This could imply that it is less likely that fWHR might have been a result of intra-sexual competition in women. However, studies that have looked into this are few. Thus, the relationship between women and fWHR is not clear. In an upcoming section this will be further elaborated on.
2.1.2 Facial masculinity and inter-sexual selection

Through an inter-sexual selection lens, there are some theories that have attempted to explain the prevalence and origin of masculine facial features (e.g. fWHR). In 1975, Israeli evolutionist Amotz Zahavi presented the handicap theory. This theory holds that costly physical features such as the peacock’s handicapping tail, are a cue of a superior physical condition and genetic quality to prospective mates (Zahavi, 1975). Contrary to the notion that these traits might have developed because of its sheer attractiveness, Zahavi argued that these traits developed as means to demonstrate their abilities to survive, despite having such a handicap. According to this principle, males develop elaborate ornaments in order to signal that he must be a good quality male if he can survive while carrying that burden (Zahavi, 1975).

In a similar vein, although somewhat different, Bill Hamilton and Marlene Zuk termed the parasite theory (Hamilton & Zuk, 1982). They suggested that male ornaments evolved to demonstrate that they are not significantly affected by parasites. Parasites, such as bacteria and viruses account for a large proportion of deaths. Thus, if a man can show that he is not affected by parasites, he should be desired by females since he is more likely to pass on healthy genes to offspring. Because it is thought that elaborate masculine features (e.g. robust facial morphology) are costly to produce, only males with superior genetic quality could afford producing them (Hamilton & Zuk, 1982). The handicap and the parasite theories have both been supported and criticized. Which one better accounts for the truth is still up for debate. There is however a broad consensus that female choice has been a driving force in the development of masculine features. Consistent with this notion, females rate masculine facial traits as healthier (Thornhill & Gangestad, 2006). In a sample of 203 men, facial masculinity correlated negatively with respiratory disease number and duration (Thornhill & Gangestad, 2006). Facial masculinity is also positively correlated with facial symmetry across culture and
species, which in turn is thought to be a cue of high developmental stability (Little et al., 2008).

Whether facial masculinity is exclusively associated with general attraction is not clear, although what we generally perceive as attractive, is usually linked to cues of health (Thornhill & Gangestad, 2006). Women who are in their late follicular and ovulatory phase of their menstrual cycles prefer masculine facial features, but only for short-term mating (Gangestad, Thornhill et al., 2005). Some suggest that this shift reflects a dual-mating strategy. Women prefer masculine and symmetrical men when they have the highest chance to conceive, to promote seeking out a mate that can provide with increased genetic benefits to offspring (Puts et al., 2012). However, since masculine men are thought to be less invested in relationships and less attuned to children, females prefer less masculine men as long-term partners as they are thought to be more heavily involved in the relationship and child-rearing (Peterson, Carmen, & Geher, 2013). In line with both the handicap and parasite theory, these findings provide further credibility to the notion that masculine facial traits are valued as cues of genetic fitness. In conclusion, there are good reasons to believe that facial masculinity has partly been driven by inter-sexual selection as means for females to secure the benefits of high genetic-quality males (e.g offspring and resources).

When it comes to fWHR in particular, evidence suggest that females find enlarged cheekbones attractive (Borelli & Berneburg, 2010; Cunningham, Barbee, & Pike, 1990; Weston, Friday, Johnstone, & Schrenk (2004); but see also Stirrat & Perrett, 2010), plausibly as a signal of high genetic quality (Carré & McCormick, 2008). Consequently, Weston et al. (2004) proposed that prominent cheekbones in men as reflected by a broad face is a result of inter-sexual selection. Furthermore, Weston et al. (2004) also hypothesized that prominent cheekbones could have replaced canine teeth through inter-sexual selection in early hominids and thus serve as a reason for why the size of canines in humans were reduced. In
conclusion, there is a possibility that men have greater fWHRs than women because women may generally be more attracted to men with more robust cheekbones and thus a broader face. If this is the case, men with greater fWHRs will have more opportunities to pass this feature to future generations (Weston et al., 2007).

2.2 Facial width-to-height ratio’s link with aggression and threat

A growing amount of research, coming both from biological and psychological sciences, has found links between men’s fWHR and a range of behaviors (Haselhuhn, Ormiston, & Wong, 2015). Perhaps the most pronounced link is that between fWHR and threatening behaviors such as aggression (Geniole et al., 2015; Haselhuhn et al., 2015). The theoretical basis for this research stems from Carré & McCormick (2008) where they observed that fWHR is positively correlated with aggression. Carré & McCormick (2008) revealed that hockey players with a higher fWHR were more likely than faces with a low ratio to receive a penalty for behaving aggressively in the game. In a sample of 21 varsity hockey players, individual differences in fWHR explained 29.2% of the variance in penalty minutes per match ($r = .54$, $p = 0.01$). In a larger sample of 112 National Hockey League (NHL) players, individual differences in fWHR explained a significant proportion of the variance in aggressive behavior ($r = .30$, $p = 0.005$; Carré & McCormick, 2008).

In another study, Carré, McCormick, & Mondloch (2009) carried out two experiments to determine whether third party observers’ estimates of propensity for aggression were associated with individual variations in fWHR. In the first experiment, observers, both female and male, predicted propensity for aggression by looking at the faces of 37 men photographed showing neutral facial expressions for, 2,000 ms. For each face, a behavioral measure of aggression was obtained. Their results showed that the observer’s estimates correlated powerfully with the fWHR of the men’s faces ($p < 0.001$) as well as with the actual aggression of the men ($p < 0.01$). The mean predicted aggression for each face
across subjects was correlated with both fWHR ($r = .59$, $p < 0.002$) and actual aggression of the men’s faces ($r = .42$, $p = 0.04$). In experiment two, the difference compared to the first study was that the observers’ viewed the stimulus faces for 39 ms as opposed to 2,000 ms. The results from the first experiment were replicated where observers’ estimates of aggression for each face were highly associated between experiment two (39 ms exposure) and experiment one (2,000 exposure). In summary, results from both experiments suggested that observers can based on fWHR make accurate judgements of propensity for aggression from faces showing neutral facial expressions both for longer periods of exposure (2,000 ms) and shorter (39 ms) periods of exposure. Lastly, another noteworthy finding was that observers’ estimates of aggression correlated more strongly with fWHR than actual aggression. The authors of the study hypothesized that a possible reason for this could be that fWHR is a stable facial trait that provides a static estimate of the propensity for aggression whereas actual aggression will vary over time. According to the authors, fWHR meets the requirements for an honest signal of aggressiveness propensity, similar to honest signals that guide behavior in other species (Carré et al., 2009). This explanation is moreover consistent with the notion that broad faces (high fWHRs) might have evolved through important intra-sexual competition in order to modulate adaptive behavior.

On the other hand, some studies have failed to replicate the association between fWHR and aggression (Gómez-Valdés et al., 2013; Ozener, 2012) which has led some researchers to question whether the findings linking fWHR to aggression are simply due to a type 1 error (Ozener, 2012). Haselhuhn et al. (2015) conducted a meta-analysis in which they sought to examine whether men’s fWHR were a reliable predictor of aggressive behavior. The authors did not, however, examine studies that had addressed whether fWHR may affect others’ perception of these men. For their meta-analysis they were left with 19 studies, 32 effect sizes and a total sample of 4,327 subjects,
The results showed that the sample-size weighted average correlation between fWHR and aggression was positive ($r = .11$, $p < 0.001$). This is a rather small but robust link between fWHR and aggression suggesting that fWHR may be an indicator of aggression in men. The researchers did however point out a few issues in their meta-analysis. First of all, there is a compromised ability to compile studies with varied methods and samples. For instance, researchers have employed several different dependent measures when investigating the fWHR-aggression link. Some measured aggression directly while others indirectly touched upon the construct. Moreover, differences in the measurement of fWHR may make comparisons difficult. The researchers did however address some concerns by conducting supplementary analysis to explore some potential impacts from these differences (Haselhuhn et al., 2015).

Somewhat differently to the meta-analysis just presented by (Haselhuhn et al. 2015), Geniole et al. (2015) conducted a systematic meta-analysis addressing not only the magnitude of the link between fWHR and actual threatening behaviors in men. They also included studies that had examined observers’ perceptions of faces with different fWHRs and to what extent this reflected actual threatening behaviors in individuals of both sexes. According to the authors this approach provides a more definitive test of the hypothesis that fWHR also operates as an evolved cueing system of intra-sexual threat and overall aggressiveness in men. (Geniole et al., 2015).

The researchers analyzed 19 manuscripts to explore the relationship between fWHR and threat behavior. Effect sizes were extracted from 32 samples. In total, 4,573 men from 23 samples and 634 women from 9 samples were included. Results showed that fWHR predicted threat behavior ($r = .12$, $p < 0.0001$). Furthermore, sex did interact with fWHR ($p = 0.02$) where the relationship was significant only in men ($r = .16$, $p < 0.0001$), but not in women ($r = .04$, $p = 0.77$).
For the analysis of the relationship between fWHR and perceptions of threat and dominance, 18 manuscripts were included. The effect sizes were extracted from 38 samples involving 779 male observers from 36 of the samples and 1313 female observers from all 38 samples. The stimuli included 1679 male faces from 36 of the samples and 72 female faces from three of the samples (Geniole et al., 2015). Their results showed that fWHR did indeed predict perceptions of threat ($r = .48$, $p < 0.0001$). Lastly, nationality of observers, percentage of male observers, age of observers and whether the stimuli included female, were not significant moderators, (all $p > 0.10$) (Geniole et al., 2015).

In summary, the meta-analysis found that men with greater fWHR acted more aggressive and dominant, and described themselves as more aggressive than men with smaller fWHRs. Furthermore, fWHR strongly cued estimations of aggression and dominance. Another intriguing finding was that judgments of aggression were enhanced in younger male faces. According to the authors this may be because young men have higher rates of violence and aggression than do other groups. Moreover, the authors noted that there might be other facial metrics, such as jaw width, that play a role in masculine dominance and aggressiveness. However, whereas dominance and aggressiveness judgements of the jawline may become obscured by facial hair, the relationship between aggressiveness ratings and the fWHR is not affected by beardedness (Geniole & McCormick, 2015). The fWHR is well-situated in the upper face, where humans preferentially excerpt information about threat. Therefore, fWHR might be an especially important metric in facial-evaluations (Geniole et al., 2015).

The two meta-analyses presented in this sub-section provide further evidence suggesting that there is a robust link between fWHR and threatening behaviors. The effect is, however, small, as some studies have failed to find a connection.

One possible problem in many experiments is that the researchers typically do not control for BMI. Increased fat in the face may enhance fWHR and affect aggressiveness
judgments accordingly. Another thing to consider is that facial fat enhances fWHR and thus makes the face appear broader even without prominent cheekbones. A possibility is that the variable that links fWHR to threatening behaviors lies within the robustness and visibility of the cheekbones and not the facial width of the face per se. As mentioned earlier in this study, cheekbones are thought to be a measure of facial masculinity and may cue intra-sexual competitive behavior. Future studies should therefore consider fat adiposity in the face as confounding variable.

2.3 Is facial width-to-height ratio correlated with threatening behaviors in women?

Studies examining the relationship between fWHR and women’s behavior have not been central in fWHR research. Presumably because fWHR is thought to be a metric of facial masculinity (Weston et al., 2007). Males and females have different growth trajectories that diverge at puberty for cheekbone width and not for upper facial height. This is driven by substantially higher levels of testosterone (a driving force in development of male sexual dimorphism) in males compared to females during this stage. This leads to a greater ratio in men than in women that is independent of body size (Geniole et al., 2015; Weston et al., 2007). There have however been a few studies that have investigated whether female’s behavior can be linked to fWHR. Across two studies Haselhuhn & Wong (2012) found that in contrast to men, fWHR did not predict unethical behavior in women. On the other hand, Lefevre et al. (2014) found that in a sample of 49 females, fWHR did predict self-reported aggression. In the same study, it was found that overall facial masculinity in both men and women did not predict aggressive behavior. According to the authors, this indicates that fWHR but not facial masculinity is a valid predictor of aggressiveness. This is somewhat consistent with some findings suggesting that fWHR but not overall facial masculinity is associated with circulating testosterone levels (Lefevre, Lewis, Perrett, & Penke, 2013) and that testosterone is linked to status-striving behavior in both men and women (Eisenegger,
Haushofer, & Fehr, 2011). In sum, it is not impossible that fWHR could have link with threatening behavior in women as well. The reasons for this is (1) there has not been many studies that have investigated this and future studies could potentially find a relationship and (2) fWHR may be a facial metric associated with circulating testosterone levels as well as testosterone levels in puberty. More studies are however needed to explore this topic.

2.4 Biological and social forces that may link facial width-to-height ratio to observer judgements and behavior

People judge individuals with a greater fWHR as more threatening. What are the biological/evolutionary and social forces that underlie the relationship between fWHR and perceptions of threat and threatening behavior?

Perceptual and sensory systems have developed through evolution to detect threat (Blanchard, Griebel, Pobbe, & Blanchard, 2011). These systems are sensitive to cues of formidability and aggression in members of the same species and may allow for appropriate submissive or combat behaviors. Which behavior is employed depends consequently on the information conveyed by the cues (Parker, 1974).

Earlier in this thesis, intra-sexual competition between males was described. The reasoning was that competition for reproductive resources might serve as a driving force in the development of male facial dimorphism, such as robust jaws and large cheekbones (greater fWHR). Robust cheekbones might then serve as both protection in fights but also as a signal that the male can withstand blows to the face, and thus is more likely to be successful in combat. There is a significant advantage in rapidly assessing another individual’s propensity for aggression and dominance, in both sexes (Sell et al., 2009). Evidence suggests that conflicts are settled more quickly and are less lethal when conspecifics have visual exposure to their opponent (Arnott & Elwood, 2009). As presented throughout this study, there is significant evidence suggesting that observers consistently judge high fWHR
individuals to be more aggressive. Intriguingly, observers can accurately predict a man’s propensity for aggression based on his fWHR. These findings present the possibility that fWHR and sensitivity to a man’s fWHR may be part of an evolved cuing system (Geniole et al., 2015) and thus a result of biological/evolutionary forces.

In contrast to the notion that fWHR evolved as a cue of threat, an alternative theory holds that high fWHRs resemble components of facial expressions of anger and are therefore considered threatening (Eisenbruch, Lukaszewski, Simmons, Arai, & Roney, 2017). Angry faces usually involve raising the chin and lowering the brow, which produces a configuration that both resembles high fWHR and enhances perceptions of formidability (Sell, Cosmides, & Tooby, 2014). A problem with this view, however, is explaining the fact that observers accurately can predict a man’s propensity for aggression solely based on fWHR. On the other hand, if wider-faced men are regularly perceived as angrier than narrow-faced men due to the resemblance of a high fWHR with an angry face, they might receive submissive, mistrustful and/or aggressive treatment. Over time, this could potentially lead to the acquisition of more exploitative and behavioral strategies (Eisenbruch et al., 2017). This model of explanation would essentially attribute the relationship between fWHR with behavior and observer judgements as something drive by social forces. In sum, it is difficult to know if the relationship between judgments of threat and fWHR is due to an evolved mechanism in humans or simply just an effect of the resemblance of high fWHRs with an angry face. Future studies need to address this problem.

It is unclear what constitutes the mechanisms underlying individual variation in fWHR as well as the particular behaviors associated with fWHR. As was just noted, a possible explanation for why fWHR is linked to threatening behaviors is the acquisition of exploitative and behavioral strategies as a result of unfair treatment over time. On the other hand, the perhaps most suggested explanation is that it has been driven by evolutionary forces.
(Geniole et al., 2015) and that the association between facial structure and behavior is caused by testosterone (Lefevre et al., 2013). Heightened levels of testosterone might stimulate development of a broader face and calibrate brain mechanisms toward more threatening behaviors. Thereby, producing a functional coordination between behavioral strategies and facial features that promote their effectiveness (Roney, 2016). Moreover, in one study Lefevre et al. (2013) found a positive association between fWHR and elevations in testosterone to potential mate exposure as well as a positive association between fWHR and baseline testosterone. Consistent with the notion that testosterone mediates the link between fWHR and behavior, several behavioral traits associated with fWHR have been linked to direct and indirect measures of testosterone (Lefevre et al., 2013). For instance, basal circulating levels of testosterone are associated with levels of dominance in males (Josephs, Newman, Brown, & Beer, 2003). In addition, the digit ratio (2D:4D), a proxy for measure of in-utero testosterone exposure, has been linked to levels of self-reported (Bailey & Hurd, 2005) and lab-induced (Millet & Dewitte, 2007) aggression. Furthermore, some support has been found linking testosterone directly to facial structure. Verdonck, Gaethofs, Carels, & de Zegher, (1999) showed in a study that testosterone administration enhanced craniofacial growth in delayed puberty adolescents. In line with this, several studies have found a link between testosterone levels and perceived masculinity in men (Roney, Hanson, Durante, & Maestripieri, 2006; Penton-Voak & Chen, 2004).

Despite some evidence linking facial masculinity and fWHR to testosterone, a meta-analysis with 9 studies and over 1,000 subjects found no significant association between fWHR and baseline testosterone levels. On the other hand, some research has found evidence suggesting that prenatal androgen exposure is linked to fWHR (Fink et al., 2005; Weinberg, Parsons, Raffensperger, & Marazita, 2015). One hypothesis is that the prenatal hormone environment might have significant organizational effects on postnatal development.
Whitehouse et al. (2015) did however report a null relationship between fWHR and prenatal testosterone levels. Another perspective is that fWHR may reflect pubertal testosterone exposure more than circulating concentrations, since facial shape is relatively fixed by early adulthood (Carré & McCormick, 2008). On the other hand, a study by Hodges-Simeon, Gurven, Cárdenas, & Gaulin (2013) did not manage to find support for the notion that fWHR is linked to pubertal testosterone concentrations.

Furthermore, one study examined whether fWHR variance may be related to the number of cytosine – adenine – guanine (CAG) repeats in the androgen receptor gene (AR) (Eisenbruch et al., 2017). This polymorphism regulates sensitivity to androgens - either directly or through an interaction with testosterone concentrations. Lower CAG repeats in the AR gene causes greater androgenic effects per unit of testosterone. Thus, it has been hypothesized that individuals with lower CAG repeats might experience enhanced effects from testosterone. The researchers tested this hypothesis and found that CAGn did not predict fWHR variance. Moreover, the researchers found that fWHR did not predict baseline testosterone levels or testosterone reactivity in their full sample. However, fWHR did predict baseline testosterone levels among Caucasian subjects in the study (Eisenbruch et al., 2017).

In sum, there is contradictory evidence regarding a positive relationship between testosterone and fWHR. Physiological factors that may account for individual differences in fWHW as well as how it is linked to aggressiveness and observer judgments are therefore not clear. Eisenbruch et al. (2017) speculated however on two possible mechanisms whereby behaviors may be linked to facial structure: (1) developmental processes that have not yet been explored adjust both fWHR and behavioral tendencies. (2) behavioral tendencies are in part responsive to social treatment from others that is elicited by physical appearance. Future research will be essential to test different estimations regarding how fWHR becomes linked to behavior, testosterone as well as what accounts for individual differences in fWHR.
2.5 Measurement Issues in facial width-to-height ratio research

In the majority of studies where fWHR is assessed, measurements are obtained from 2D photographs of face (Kramer, 2016). Evidence suggest that measurements taken from photographs correlate to a high extent with measures taken directly from the face. The nature of this as a suitable proxy for skull fWHR has not been settled (Kramer, 2016). Furthermore, individuals sometimes vary dramatically in their appearance across images. Photographs in faces often vary in expression, lighting, age and pose and camera parameters (Kramer, 2016). One concern is therefore whether a reliable fWHR can be obtained from 2D photographs.

Although previous research suggests that fWHR decreases with age (Hehman, Leitner, & Freeman, 2014), this is often not controlled for in experiments (Kramer, 2016). Another issue is that turning the head in different directions, has a significant impact on fWHR obtained from photographs (Hehman, Leitner, & Gaertner, 2013). Luckily, most researchers have tended to include only faces that are forward facing, looking directly at the camera without any turning.

In contrast, facial expressions and camera parameters are less well considered (Kramer, 2016). Many researchers exclude photographs showing expressions other than a neutral face, whereas other researchers are less explicit in their inclusion criteria (Haselhuhn & Wong, 2012) or grant that non-neutral images were included (Carré & McCormick, 2008). In addition, no fWHR research appears to have considered the effects of camera parameters (Kramer, 2016). The distance between the face and the camera along with the camera’s focal length alter facial appearance (Banks, Cooper, & Piazza, 2014). Specifically, those photographed closer to the camera appear thinner and therefore of a lower fWHR (Bryan, Perona, & Adolphs, 2012).
According to Kramer (2016), researchers have either failed to consider, or have simply avoided the potential influences of facial expression and camera settings. In addition, he concludes that no research has included measurement of fWHR while methodically varying camera conditions or facial expressions. Consequently, making it difficult to know whether these two factors may influence resulting measures.

In a study Kramer (2016) sought to explore the following (1) the influence of variability in camera parameters on resulting fWHR from images of Hollywood actors (2) variability in camera parameters on resulting fWHR under controlled laboratory conditions and (3) fWHR measures of different facial expressions in controlled conditions. She hypothesized that varying facial expression and camera parameters may have larger effect on fWHR than differences between individuals. The results from the analyses showed that varying the focal length and distance between the camera and face had a relatively small effect on fWHRs in the pictures of the Hollywood actors. More specifically, differences between identities were responsible for a larger proportion of the variation in fWHR than differences within identities. However, when all camera parameters were allowed to vary, the effect size due to identity was larger than photograph selection. Kramer (2016) consequently suggested that varying focal length and distance between camera and face may be less of a problem if uncontrolled in study designs. However, correlation analyses revealed that within-person differences tended to influence the ranking or ordering of faces, which is an issue for the majority of articles on fWHR. Therefore, it is an advantage to collect images taken by different cameras using different settings. (Kramer, 2016). Similar to the photographs of the Hollywood actors, analyses also showed that the distance to the camera together with alterations to focal length had a relatively small effect on fWHR in controlled settings. This was also shown when considering the ranking or ordering of identities based on fWHR.
Lastly, the results also showed that fWHR did change substantially when people posed with four of seven emotional expression compared to neutral faces. Intriguingly, the effect size due to expression was greater than the differences due to identity. It is therefore stressed that there is a great importance in keeping this variable constrained when collecting photograph sets. Kramer (2016) concluded that different head poses (as known from earlier studies) and varying facial expressions are perhaps the most pronounced variables that might provide unreliable measurements. In contrast, focal length and distance between camera and face might not be a significant issue.

3. Rationale for the present study

There is evidence linking fWHR with threatening behaviors in men. A meta-analysis by Haselhuhn et al. (2015) covering most studies on this topic revealed a small but robust link between fWHR and aggressive behaviors. Further, fWHR is thought to be a measure reflecting facial masculinity (Carré & McCormick, 2008) and high sexual dimorphism in males has in turn has been implied as proxy of intra-sexual success, which is often mediated through domineering behaviors (Stirrat et al., 2012).

As noted throughout this thesis, there is also a strong link between perceptions of threat and fWHR. (Geniole et al., 2015). In a meta-analysis by Geniole et al., (2015) using 1,679 males as stimuli, it was reported that ratings of threat were significantly higher for both men and women with greater fWHRs.

Geniole et al., (2015) suggested that fWHR is part of an evolved cueing system of threat. It is therefore of interest in the present study to explore whether judgments of threat based on fWHR map onto observers’ electrophysiological functioning. Since psychological research consistently has shown that third party observers report perceived feelings of threat in response to pictures of high fWHRs compared to low fWHRs it is plausible that these experiences translate into an electrophysiological context. Moreover, considering that
contradicting results regarding fWHR and threat have been reported, adding a neurocognitive perspective to the literature might either reinforce this relationship or speak against it. The present study will therefore use the EEG technique to investigate this.

3.1 LPP as a proxy of emotional arousal

The LPP is an ERP-component that reflects increased activity over centro-parietal areas of the brain and has been implied in the processing of emotional stimuli (Cuthbert et al., 2000). More specifically, in ERP experiments, the LPP amplitudes are greater when a subject passively views both unpleasant and pleasant images, compared to neutral images (Cuthbert et al., 2000; see figure 2). Furthermore, observing threatening faces or facial expressions showing a range of emotions (i.e. happiness or anger, sadness or joy) yield higher LPP amplitudes compared to non-threatening and neutral facial expressions (Hajcak, MacNamara, & Olvet, 2010). In the present study, the LPP is the ERP-component that will be examined.

![Image of LPP graph]

Figure 2. The image shows a typical high emotional arousal LPP vs. a low emotional arousal LPP.

The LPP starts approximately 300-400 ms after stimulus onset and may last for hundreds of milliseconds to seconds, depending on the duration of the emotional stimuli. The maximal amplitude normally occurs at 800–1500 ms following the presentation of the stimuli.
and is observable until the picture offset (Cuthbert et al., 2000). Furthermore, LPP is shown to be independent of stimulus size (De Cesarei & Codispoti, 2006) and is not altered by habituation (Van Strien et al., 2014). Moreover, it is associated with increased amplitudes to images with high evolutionary significance compared with pictures that are of the same valence, but with less evolutionary relevance (Schupp et al., 2006). For instance, Van Strien et al. (2014) found that LPP amplitudes were higher for snake pictures compared to bird pictures. Furthermore, Schupp et al. (2004) found that images with threatening and sexual contents were associated with increased LPP amplitudes compared to image categories that produced the same valence but of less evolutionary significance.

In the present study, the main aim is to explore whether fWHRs induce a threat response in subjects. Since people consistently judge faces with high fWHRs as more threatening compared to faces with low fWHRs, there is a possibility that humans have developed a threat- detection-mechanism within the visual monitoring system.

Since previous studies have suggested that the LPP reflects neural processes associated with emotional arousal in response to stimuli with high evolutionary significance, it makes sense to investigate this component as an indicator of feelings of threat. The prediction is then that a relatively higher fWHR face will elicit higher LPP amplitudes compared to faces with lower fWHRs. If this is the case, the LPP may indicate increased focused attention to faces with high fWHRs for threat evaluation, along with an increased arousal response.

4. Method

4.1 Study design

In this study, the data collection was part of a larger study and therefore consisted of an extra experimental task in addition to the one that was specifically designed for the present study.
In the first task, data collection was gathered for both the present study as well as a distinct study. From now on it will be referred to as the *self-regulation task*. The second task was specifically designed for the present study, and will from now on be referred to as the *aggression task*. Both the self-regulation task and aggression task consisted of two parts. In the first part a questionnaire was filled in by the participants and the second part that followed immediately after filling in the questionnaire, was the ERP experiment took place. Next, the study design for the self-regulation task will be described in finer detail. Then, the aggression task will be elaborated on.

For the first part of the self-regulation task, subjects were asked to fill in a paper questionnaire showing photos of 36 different individuals (18 females and 18 males). The faces in the questionnaire were presented in a randomized order for each subject and each individual face was shown twice, once expressing a neutral and once expressing an angry facial expression. Thus, a total of 72 images were presented to the subjects. All faces were by the subjects rated on arousal and valence, using a 9-point likert scale. The highest score on the valence scale corresponded to a negative rating of the portrait, and the highest score on the arousal scale corresponded to a high-intensity rating of the portrait.

For the ERP part in this task (which occurred right after filling in the questionnaire) angry and neutral faces were presented and subjects were asked to employ different emotional regulation strategies using 6 different conditions. The first two conditions represented the baseline: to observe angry and neutral faces. Both conditions were accompanied by the same instruction: ‘Imagine that you are seeing each person in front of you right now on a public train. Just observe their face’.

The other 4 conditions were each accompanied by an instruction designed to drive the participant to reappraise- in the context of different temporal distancing strategies - angry faces after they were presented. The instruction was as follows: ‘Imagine that you are seeing each person in front of you right now on a public train. Their angry face might make you uncomfortable, so imagine that you think to yourself how little their anger will mean to you in 1 Day / 1 Week / 1 Month / 1 Year. Please only apply this strategy after each face is shown, not before.’ The conditions were presented twice pseudo-randomly and never was the first block repeated in the same position in the second round.
As noted on condition in this task also entailed neutral male faces of varying fWHR in which no self-regulation strategies were employed. Instead subjects merely observed the faces in a rather neutral social context (imagine seeing him on a train). Therefore the LPP results from this condition are valuable for comparisons with the LPP data from the aggression task.

The aggression task took place ca. 5-10 minutes after the self-regulation task. Here, data was collected using a different set of stimuli that was specifically selected for this study. For the first part of this task, subjects rated 24 neutral male faces of varying fWHRs on aggressiveness using a 9-point Likert aggressiveness scale. Immediately after the ratings were completed, the ERP recordings took place. Each face that was showed on the monitor was accompanied with specific instructions. Subjects were asked to imagine being threatened by the individual shown, with the following instruction “imagine being threatened by this individual”.

Consequently, for both the aggression and the self-regulation task, the research question is: Will LPP amplitudes vary with high versus low fWHRs, such that higher fWHRs can be correlated with higher LPP amplitudes?

4.3 Subjects

27 subjects were recruited primarily through word of mouth at the campus and at the international student residency. 7 females and 20 males. The subjects were all right-handed, had near normal eyesight, no color blindness and were between 18-40 years of age. They had no record of epilepsy and were not on any type of neuropsychiatric medications. All were students at the University of Skövde and were all fluent in English.

4.4 Procedure

The subjects were greeted and then asked to read the study description and fill out the informed consent. First the self-regulation task was conducted followed by the aggression task. The first step in the self-regulation task started in which subjects were asked to fill in a paper questionnaire showing photos of 36 different individuals (18 females and 18...
males). The faces in the questionnaire were presented in a randomized order for each subject and each individual face was shown twice, once expressing a neutral and once expressing an angry facial expression. Each face was accompanied with a 9-point Likert valence and arousal scale to rate.

The faces presented in this questionnaire later served as stimuli during ERP-data collection for the self-regulation task. Subjects were introduced to the EEGlab where they were seated on a chair in front of a computer, with the participant’s eyes being approximately 115 cm from the screen. The skull was measured to find vertex, which was marked on top of the scalp. After the electrode cap was fitted and positioned on the head, reference and eye electrodes were attached to the skin using adhesive electrodes. When everything was in place, electrode gel was applied. Next the ERP experiment for the self-regulation task started and subjects were exposed to the faces that were specific for the self-regulation task.

Instantly after the ERP-recordings for the self-regulation the aggression task started. While seated in the chair in the EEG chamber, subjects were asked to fill in a questionnaire where they rated 24 neutral male faces of varying fWHRs on aggressiveness using a 9-point Likert aggressiveness scale. Immediately after the ratings were completed, the ERP recordings were initiated.

4.5 Stimuli

The stimuli were presented on a 24” screen with a 1920×1080p resolution at a frame rate of 60Hz. The stimulus presentation was created using E-Prime (Version 2.0: Psychology Software Tools, Inc., USA). The first sample of images of faces for the self-regulation task, were retrieved from the Umeå University Database of Facial Expressions (Samuelsson, Jarnvik, Heningsson, Andersson, & Carlbring, 2012). The database contained facial images from individuals aged 18-67 and were evenly distributed across sexes. Each
face portrayed both a neutral and an aggressive facial expression. This task consisted of 12 blocks of 36 trials/faces each (18 male, 18 female), of which 2 blocks were neutral and 10 blocks were angry, all presented in a pseudo-random order and each face being displayed lasted for 3,000 ms. It is important to note that each block contained additional instructions regarding various forms of emotion regulation strategies, which are not relevant to the present study. In the analyses, only male faces with a neutral facial expression will be analyzed (18 of 36 trials in two of the 12 blocks). See figure 3 for examples.

The 18 different neutral male faces were divided to either belong to the high or low fWHR categories. Rather than using definitive borders for what constitutes a high or low fWHR, the 9 faces with the highest fWHR were assigned to the “high” category fWHR (M = 2.00, SD = 0.11) and the remaining 9 faces with the lowest fWHR were assigned to the “low” category (M = 1.74, SD = 0.10). In this case the highest fWHR in the low category was 1.88 and the lowest fWHR in the high category 1.93.

Figure 3. Example of faces from the first sample of images (self-regulation task; Umeå University database). The picture on the left is an example of a male with a relatively high fWHR. The picture on the right is an example of a male with relatively low fWHR.

In the aggression task, the sample of faces were retrieved from Dr. Cheryl McCormick, a researcher at Brock University in Canada, who herself has used the pictures in previous studies investigating fWHR (see; Carré et al., 2009; see figure 4 for examples). This
task consisted of five blocks with 24 trials/faces in each block. Each trial lasted for 3000 ms. For both tasks, the time between every trial was 800-1,000 ms. Following the same principle as in the self-regulation task, the 12 faces with the highest fWHRs were assigned to the “high” category (M = 1.97, SD = 0.009). For the remaining 12 faces they were assigned to the “low category” (M = 1.76, SD = 0.08) The highest ratio in the low category was a fWHR of 1.84 and the lowest in the high category a fWHR of 1.86.

Figure 4. Faces from second set of images (aggression task; Brock university). The picture on the left is an example of a relatively high fWHR. The picture on the right is an example of a relatively low fWHR.

As noted, in both tasks, the strategy for dividing the faces high and low fWHR categories was a simple division where the top half were assigned to the “high” category and the lowest half to the “low” category. The rationale for this is that there is no clear consensus of what ratio is considered high or low. I have not managed to find a study that states where the boundary for high and low FWHRs lies. In the present study, by dividing the samples in half, we obtain a difference within the sample where the top half has high fWHR in comparison to the lower half. This essentially means that we are comparing the highest fifty percent with the lowest fifty percent in the samples rather than using a predetermined ratio as a border between high and low. This explains why the border for high vs. low fWHR is somewhat different between the self-regulation and the aggression task. Consequently, it might have an effect on both the obtained ratings as well as the subjects LPP amplitudes.
However, since we will be examining the relative difference between the high and low categories, it should not be considered a significant issue to the experiment. If fWHR is an evolved feature, it seems most likely that the proposed effects are linear and not only for an extremely high or extremely low fWHR. An analysis was however conducted to investigate whether there would be any differences in fWHR between the self-regulation and aggression task, which will be revealed in the analyses/results chapter.

4.2 Equipment

The ERP measurements were recorded using two g.GAMMAsys electrode interfaces and two g.USBamp amplifiers (g.tec medical engineering GmbH, Austria). The EEG system transmitted a transformed output signal through two amplifiers with an impedance of 1kOhm. These were connected to the computer where the signals were recorded using MATLAB (version R2015a). A Sampling rate of 512Hz was used, with a 0.01Hz highpass filter and a 30 Hz low-pass filter.

The online reference was chosen to be CPz. Another 4 electrodes were put around the eyes, proximal to the orbicularis oculi muscles; two of which were placed laterally relative to both the left and right eye towards the temples, with the remaining two placed on the dorsal and ventral edges around the right eye, respectively. These recorded any eye-blinks and activity produced by the eye’s rectus muscles. All other electrodes were attached to a cap designed to fit 95% of adult individuals. 32 active AG/AgCl electrodes were positioned according to the international 10-20 placement system. EEG signals at electrode locations (EOG1, EOG2, EOG3, EOG4, F1, F2, FC1, FC2, F7, F8, FZ, FCZ, CP1, CP2, C3, CP3, C4, CP4, CPZ, CZ, P7, P8, POZ, PZ, T7, T8, O1, O2, O9, O10, OZ, RM, LM) were measured with the active EEG electrode system g.GAMMAsys (g.tec medical engineering GmbH, Austria). All EEG recording sites were carefully prepared by injecting conductive electrode
gel. Electrode impedances are transformed by the system to output impedances of about 1kOhm.

The obtained data was processed by using the EEGLAB toolbox (version 13.6.5b) for MATLAB. It was first resampled from 512 Hz down to 256 Hz and referenced to the average of the left and right mastoids. The data was then filtered from 0.1 Hz with a filter and bad channels were automatically removed by computer algorithm. Next, the continuous data was epoched into segments of 500 ms to 3,000ms relative to stimulus onset. The period from ms -500 ms to 0 was then set as the baseline period. Through independent component analysis (ICA), artifacts such as eye blinks and muscle movements were subtracted from the data, without requiring the removal of entire samples. Finally, the previously rejected channels were interpolated from surrounding sources, and the data was run through a final round of artifact detection. Due to poor data quality, 20 unique subjects for the self-regulation and 19 subjects for the aggression task from the original 27, were included. The individual average ERPs, and subsequently the grand average ERP were then computed.

5. Analyses and Results

In regards to potential differences between the stimuli for the self-regulation and aggression task, an independent sample t-test showed no significant difference in fWHR between faces with high fWHRs in the self-regulation vs. aggression task (p = 0.652). Similarly, there was no significant difference in low fWHRs between faces in self-regulation vs. aggression 2 (p = 0.536). Furthermore, additional analyses showed there were highly significant differences between faces with high vs. low fWHRs in both the self-regulation task (p < 0.0001) as well as in the aggression task (p < 0.0001).
5.1 Results from the self-regulation task

5.1.1 Arousal and valence questionnaire

Analysis of the neutral male faces showed that there was no significant difference in arousal and valence ratings based on low or high fWHR (Valence $p = 0.637$ and arousal $p = 0.906$, Kruskal-Wallis test). Despite the non-significant results, faces were on average rated as somewhat more negative for faces with high fWHRs ($M= 4.09, SD= 0.845$) than for low fWHRs ($M= 4.04, SD= 0.728$). Faces with high fWHRs were rated as marginally more arousing ($M = 2.18, SD= 1.896$) than faces with low fWHRs ($M= 2.14, SD= 1.817$).

5.1.2 ERP experiment

Analyses showed that there was no statistical significant difference in subjects LPP amplitudes when observing faces with high versus low fWHRs. A paired sample t-test however showed a trend towards significance ($p = 0.128$, $t = 1.591$, df 19) where subjects on average yielded higher positive amplitude areas for faces with high fWHRs (see figure 5) ($M = 14.01 \mu V, SD = 14.1$) than for low fWHRs ($M = 8.35 \mu V, SD = 7.71$).

As can be observed in figure 4, the discrepancy between the LPP amplitudes for low and high fWHR becomes more pronounced over time. A separate analysis for the late periods of the late LPP (between 1,500-3,000 ms) was consequently conducted. The results showed no statistical significant differences in LPP amplitudes for high ($M= 8.18 \mu V, SD = 9.1$) vs. low fWHRs low fWHRs ($M = 3.96 \mu V, SD = 1.1$; $p = 0.109$, $t = 1.680$, df 19).
5.2 Results from the aggression task

5.2.1 Aggression questionnaires

Analyses showed that subjects rated faces with high fWHRs as more aggressive than faces with low fWHRs ($p < 0.001$, Kruskal-Wallis test). Faces with High fWHRs received average ratings of ($M= 4.20, SD= 2.12$) and Low fWHRs ($M= 2.70, SD= 1.72$). Spearman’s rank coefficient showed a positive correlation between aggression scores and fWHR ($r_s = 0.332, p < 0.001$).

5.2.2 ERP experiment

A paired sample t-test revealed that subjects yielded significantly greater LPP amplitudes when observing faces with high fWHRs compared to faces with low fWHRs ($t=3.133, df=18, p = 0.006$). On average, the within-subjects difference was substantially greater for faces with high fWHRs ($M= 9.12 \mu V, SD=7.23$) compared to low fWHRs ($M= 3.94 \mu V, SD =3.59$). As can be noted in figure 6, the differences between LPP amplitudes for high and low fWHRs appear more pronounced in the late LPP. An additional analysis of the late LPP (1,500-3,000 ms) did also show that late LPP amplitudes were higher when observing faces with high fWHRs ($M = 4.87 \mu V, SD = 4.52$) compared to low fWHRs ($M = 1.46 \mu V, SD = 1.91$; ($t=3.011, df=19, p = 0.007$).
**Figure 6. Grand average for neutral male high vs. low fWHRs, from the Brock University database.**

### 6. Discussion

Several studies have found that males with higher fWHRs are more prone to aggressive and dominant behaviors (Geniole et al., 2015). In line with this, faces with relatively high fWHRs are consistently perceived as more threatening. Intriguingly, no prior study has explored how this experience in observers translate into an electrophysiological context, in the form of an ERP-experiment.

Therefore, the main aim of this study was to investigate whether images of men with different fWHRs would elicit distinct neural activity that could be observed in the resulting ERP. Specifically, I wanted to investigate whether subjects would show different LPP amplitudes when observing men with high versus low fWHRs. The LPP is thought to reflect emotional arousal to evolutionary salient stimuli, such as threats. Thus, the hypothesis was that faces with higher fWHRs would elicit greater LPP amplitudes in subjects as a reflection of negative arousal. In the present study, there were two experimental tasks referred to as the self-regulation task and aggression task. These two will first be discussed separately followed by a general discussion.

#### 6.1 Discussion on the self-regulation task

Results showed that subjective ratings of arousal and valence of the faces were not significantly affected by fWHR. This is rather surprising as we would expect that arousal would be higher and valence lower for faces with high fWHR. In relation to this, there are a few issues worth noting. Several subjects reported that they felt that it took a long time to fill in the questionnaire. A few of them also stated that they felt rushed as they wanted to commence the ERP-experiment as soon as possible. This could have affected the accuracy of the ratings. Furthermore, the neutral male faces in the questionnaire were embedded with
faces showing very angry facial expressions. There is a possibility that this had a desensitizing effect on the ratings for the neutral faces. Lastly, it could be that ‘arousal’ and ‘valence’ do not effectively encompass all dimensions of threat as effectively as pure aggression ratings.

For the ERP experiment, results showed no significant difference in LPP amplitudes in subjects upon observing faces with high versus low fWHR. There was however a trend towards significance and subjects did on average elicit higher LPP amplitudes in response to faces with high fWHRs. In addition, a separate analysis on the late LPP (1,500-3,000 ms) did not show either a significant difference.

There are some possible reasons in particular that may explain why the results from the ERP experiment did not reach significance. Firstly, the variance between subjects was quite large. In addition, the sample consisted of relatively few subjects whose data quality was sufficiently good for analyses (n = 20). Moreover, there were only two blocks with 18 trials of neutral male faces, for a total of 36 stimuli per subject. This can be compared to the aggression task, where subjects watched a total of 120 stimuli per subject. Taken together, these are shortcomings that have quite possibly compromised the power of the self-regulation task. Unfortunately, however, it was not practically feasible to change this aspect of the self-regulation task, insofar as it was run as part of another (broader) study.

In sum, the results from the self-regulation task did not provide support the hypothesis, despite a noteworthy mean difference in LPP amplitudes in subjects. Earlier studies such as Carré et al. (2009), have primed subjects on aggression when conducting experiments measuring aggression scores based on fHWR. In the self-regulation task, no priming during the ERP-experiment was introduced since it was part of a larger study that had another main focus. The rationale for priming is that, for instance, urging subjects to imagine ‘being threatened’ by the individual shown, should decrease the feeling of being in a laboratory and merely observing faces of strangers, and instead increase the feeling of having
a real encounter with the person. Consequently, possibly increasing the ecological validity somewhat. On the other hand, there are reasons to assume that any evolutionarily salient stimuli such as a face would elicit significant responses with or without priming.

### 6.2 Discussion on the aggression task

Consistent with the greater LPP amplitudes for faces with higher fWHRs, subjects rated the same faces prior to the experiment as more aggressive than the faces with lower fWHRs ($p < 0.001$). However, despite higher aggression ratings for faces with high fWHRs, the average rating was only 4.20 on a scale ranging from 1 (“not aggressive at all”), 5 (“somewhat aggressive”) to 9 (“extremely aggressive”). Although faces with high fWHRs received higher ratings than faces with low fWHRs, they were on an average rated as less aggressive than ‘somewhat aggressive’, meaning that they were not judged as specifically threatening. The reason for this could be that the ratings followed immediately after the self-regulation task, where subjects had repeatedly observed faces showing angry facial expressions. Consequently, this could have had a desensitizing effect when rating the faces showing neutral facial expressions.

The main finding in the aggression task is that subjects yielded significantly greater LPP amplitudes when observing faces with higher fWHRs compared to faces with relatively low fWHRs ($p = 0.006$). This effect was also apparent in the late LPP ($p = 0.007$).

Lastly, unlike the self-regulation task, subjects were primed for aggression by being instructed to imagine being threatened by the individual shown. Whether this may have aided the results to reach statistical significance is hard to establish but nonetheless a possibility.

### 6.3 General discussion

Previous studies show that men with high fWHRs behave in more threatening ways and observers can accurately predict this. The present study did replicate previous
findings in the aggression task, in which faces with high fWHRs were judged as more aggressive than faces with low fWHRs. However, faces with high fWHRs were not rated as significantly more arousing in the self-regulation task nor lower in valence. Consequently, this calls the link between arousal/valence and threat into question.

Moreover, in the self-regulation task, previous findings were extended by finding that faces with high fWHRs elicited greater LPP amplitudes compared to faces with low fWHR in the subjects. This indicates that feelings of increased arousal upon observing faces with high fWHRs do translate into an observable electrophysiological context. This is the first time this has been reported in the literature. Moreover, a noteworthy finding is that the discrepancy between LPP amplitudes for high vs. low fWHR appears especially pronounced over time in both tasks. In the Late LPP (1,500-3,000 ms), the amplitudes for low fWHRs goes down to almost non-existing levels whereas the amplitudes for high fWHRs remain relatively high throughout the whole LPP. Perhaps, the continued high amplitudes elicited by a face of high fWHR indicate that the stimulus reached a level of evolutionary significance that required the subject to sustain his or her attention. Conversely, for faces with low fWHRs, it only elicited attention in the beginning. As the facial features were assessed, perhaps it was not considered a threat and therefore attention towards the stimuli decreased.

However, whether the LPP exclusively reflects genuine feelings of threat or some other form of arousal is present cannot be established with absolute certainty. On the one hand, the fact that all subjects rated faces with high fWHRs as more aggressive in the aggression task could be an indicator that the LPP amplitudes is directly linked to feelings of threat. Moreover, earlier studies have found a robust link between fWHR and threat. On the other hand, the increased LPP amplitude could reflect some other form of arousal in some of the subjects. As noted earlier in this thesis, females are more attracted to males faces with high sexual dimorphism during ovulation. This could mean that the LPP amplitudes of some
female subjects reflected positive arousal rather than feelings of threat, or perhaps a mix of both. This is, however, very speculative and would need to be investigated through a more elaborate study design.

Another thing to consider in future studies would be to investigate whether subject’s own FWHR might influence their aggression ratings as well as their electrophysiological responses to men with high versus low FWHRs. As noted earlier in this thesis, FWHR is thought to partly have been driven by intra-sexual competition. Studies suggest that FWHR is predictive of aggression, formidability and fighting success. Thus, there are reasons to believe that men with high sexual dimorphism such as a high FWHR, are less sensitive to other men with high FWHRs. Consequently, the interaction between one’s own FWHR and another individuals FWHR should be explored in future studies.

In the present study, there are some limitations. Firstly, the number of subjects partaking in the study was relatively few (n=27). In addition, good quality ERP-data could only be retrieved for 20 subjects in the self-regulation task and 19 subjects in the aggression task, which means that a significant number of subject’s data had to be discarded. Second, the present sample consisted of both male and female subjects. Since FWHR is thought to primarily serve as an intra-sex competition signal of formidability and threat among men, there are good reasons to recruit only males. In a similar vein, a female-only sample could serve to investigate whether female reactions follow a distinct pattern as well as a comparison to a male-only sample. Lastly, and perhaps the main limitation which primarily applies to the self-regulation task, is the few block and trials with neutral male faces. Ideally, in an ERP experiment, roughly 40-60 good trials per subject are preferred (Luck, 2014). In the self-regulation task, there were only 18 trials/faces across two blocks (for 36 total) compared 24 trials/faces across 5 blocks in the aggression task (for 120 total). This is an enormous difference in this context, and may be the main reason why the results in the self-regulation
task did not reach statistical significance. All things considered, future studies could benefit from taking the limitations in the present study into consideration.

7. Conclusion

Results from the aggression task showed that subjects rated high fWHR faces as more aggressive. Moreover, when instructed to imagine being threatened by the face shown, subjects yielded higher LPP amplitudes upon observing high fWHR faces compared to faces with low fWHR. This possibly reflects greater feelings of threat in subjects when focusing on faces with high fWHRs. Thus, the findings from the aggression task provide support to the possibility that humans have evolved a specific mechanism to promptly detect potential threat in the male face, based on fWHR. However, as found in the self-regulation task, when only imagining seeing the male on a public train, the differences in LPP amplitudes for high fWHRs vs. low fWHRs did not reach statistical significance, although a trend towards significance was apparent. In addition, subjects did not rate faces with high fWHRs as more arousing or lower in valence.

Taken together, the present findings provide relatively modest support for the theory that fWHR serves as an evolved cue of threat. As this is the first ERP study investigating the effects of fWHR in observers’ electrophysiological functioning, there is great potential to improve the experimental design used in this study. Especially it would be of great benefit to increase statistical power through more blocks/trials.

Regardless, results from the present study did manage to show that male faces with high fWHRs are judged as more threatening, when subjects were instructed to imagine being threatened by the different male individuals. If faces with high fWHRs indeed are perceived as more threatening, whether it is in a neutral or threatening setting, it may provide further insight in how judgements of the male face are formed. As noted in the beginning of this thesis, appearance may have a significant impact on the outcome of a social situation.
One example is in job interviews. Therefore, knowing that fWHR may influence how we are perceived, could help us guide our own strategies in important social interactions.
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