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Social threat processing and emotional arousal

Associations between the Late Positive Potential and aggressive tendencies

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Abstract

Aggressive behaviour can be defined as actions that are believed and intended to cause harm to another individual that does not desire to be the target of such actions. Different situations can warrant aggressive behaviour, such as when an individual is posed with a threat. Aggressive behaviour is one of the ways individuals can deal with threats arising from their environments, and furthermore, aggressive behaviour can also be used to deal with social threats that arise from the interaction between two members of the same species. Aggressive behaviour is correlated with higher emotional arousal, and individuals that illustrate aggressive tendencies should be more sensitive to arousal when confronted with a social threat. This thesis acts upon this notion by hypothesizing that individuals who score higher on a tendency for aggression measurements should exhibit higher emotional arousal when exposed to a cue of social threat. Cues of social threats are thought to be induced by exposing the participant to either an angry face or a face with a high facial width to height ratio. The emotional response is measured with electroencephalography, more specifically looking at the late positive potential. No support for the hypothesis was found between high and low aggression groups. The facial width to height ratios proposed nature of being a cue of social threat becomes contested as the results were conflicting regarding the robustness of the facial width to height ratio's effect. Even if there were no statistically significant differences found between the two groups, it might not be subject for dismissal as the sample population could be considered a low aggression population overall.

Keywords: threat, aggression, anger, late positive potential, social neuroscience

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Introduction

Aggression between human societies and individuals has been occurring for millennia. Although violence is a highly common theme in modern society with widespread fastmoving information on violence, violent fiction and the invention of tools which allow for mass violence attacks, the tendency for aggression has probably not changed much in the last couple of hundred thousand years (Anderson & Huesmann, 2003). Aggression as a phenomenon is probably less prevalent in modern society than what it was in our evolutionary past.

Aggressive behaviour can be considered as the act of harming another individual, such as harming someone physically, condemning an individual's actions or stealing someone's resources. It need not only be considered as acts of violence. Furthermore, aggressive behaviour does not always take the form of a wrongdoer being aggressive towards a victim. The term reactive aggression refers to aggression in direct response to a provocation or something believed to be a threat (Lickley & Sebastian, 2018). The tendency for individuals to engage in aggressive behaviour is also referred to as *trait aggression* (Anderson & Huesmann, 2003).

The dynamics of what is and is not a threat in our social environment might sometimes be hard to distinguish. Thankfully, most organisms seem to have developed heightened sensitivity towards detecting and reacting to threats, something which is also applied to human social settings. One of the more obvious indications of an incoming social threat is an angry face. Research suggests that humans are both faster and more accurate at distinguishing angry faces than other types of expressions within crowds (Hansen & Hansen, 1988). This thesis will also act upon the premise that the facial width to height ratio (FWHR) can serve as a cue of threat. This, since the FWHR is thought to be linked to trait aggression levels within males, and therefore serves as an honest signal of potentially threatening individuals (Geniole, Denson, Dixson, Carré, & McCormick, 2015).

When a threat is present for an organism, it tends to warrant a reaction, i.e. a fight or flight response. The same kinds of reactions are in effect when considering social threats as well. When humans are presented with an incoming social threat, we can choose to either approach or withdraw. The point is, social threats are also something that warrant a reaction from the individual perceiving the threat. This reaction towards a threat can be linked together with *emotional arousal*, as incoming threats are likely to activate the sympathetic nervous system (Siegel & Victoroff, 2009). For this thesis, emotional arousal will refer to a physiological state of higher arousal that can be associated with accompanying emotions, such as anger, fear or euphoria. Furthermore, heightened levels of trait aggression in individuals are also correlated with a tendency for heightened emotional arousal (Buss & Perry, 1992). Thus, it is probable that aggressive individuals are more likely to have higher emotional responses to threats.

This thesis sets out to investigate if trait aggression levels in individuals can be associated with differences in social threat processing. To do this, participants recruited for this study will be exposed to faces which are thought to induce a cue of social threat. The faces presented to participants will be varying across the variables of FWHR and emotional expression. The participants will be grouped in either a relatively high or low trait aggression group based on their aggression scores, using the total score from the short-form Buss-Perry Aggression Questionnaire (sf-BPAQ). For this thesis, when discussing aggression in the context of high and low trait aggression groups, aggression will refer to trait aggression and not aggressive behaviour. The difference in the electrophysiological response to a threatening stimulus between the two groups is the main focal point for this thesis, and the response is hypothesized to be higher for the high aggression group rather than the low aggression group. The results indicated that no significant difference was found between the groups. Although no significance is found between the groups, the effects of FWHR and expression are manifested in different ways. With expression seemingly having a stronger effect on the emotional response than FWHR on the LPP, whereas the effect for FWHR could be seen before the hypothesized emotional response or in conjunction with other factors.

Background

This thesis sets out to investigate associations between self-rated aggression and social threat cues. In order to investigate this, some phenomena will need to be explained. This background will provide justification and explanation for the associations between aggression and social threat mechanisms amongst multiple areas. First off, threat and social threats need a brief introduction in order to find a reliable way to create threatening stimuli. The effects of aggressive behaviour and why such effects occur will be discussed within the context of aggression and anger being tools for social situations and as a direct response to threats themselves. An overview of what can be considered reliable cues of social threat will be discussed in two settings. One instance being angry faces and the other being the FWHR, as both of these instances have in previous literature been illustrated to relate to social threat processes.

Dealing with threats

The ability to swiftly detect and react to threats is thought to have evolutionary benefits to an organism (Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000). This is illustrated by the presence of rapid fight-or-flight responses induced by non-identified stimuli, i.e. reacting to what looks like a snake before acknowledging that it is a snake-looking branch lying on the ground. It seems that threatening stimuli are easier detected and processed more rapidly than other kinds of stimuli (Hansen & Hansen, 1988).

Social threats are a kind of threat that arises from the interaction between two members of the same species, such as competition for resources or potential mates, and this kind of threat is prevalent in humans. In evolutionary history, humans tended to live in groups, and this, in turn, provided benefits to reproductive success (Neuberg & Cottrell, 2008). The benefits of living in groups come with social costs as well, as resources can be protected and more easily maintained by a group, the whole group needs to share what resources are available. This creates a platform for conflict as this resource is desired by many. Humans have thereafter, seemingly, developed mechanisms to better deal with threats posed by the social environment (Hansen & Hansen, 1988).

Different individuals, and individuals from different cultures tend to respond differently to social threats, as the same situation might not be perceived as the same level of threat (Anderson & Huesmann, 2003). One aspect of dealing with threats is the individual’s personal ability to do so. Individuals who believe that they can control threats posed by the environment tend not to be as affected as less assured individuals, as individuals who believe that they are not able to deal with threats experience higher levels of anxiety and stress as a response (Bandura, 1989). Furthermore, gender differences can be seen when posed with a social threat. Women tend to be more sensitive than men when it comes to social cues overall, and this includes threat signals (McClure et al., 2004). When dealing with threats, women tend to exhibit a higher skin-conductance response and are more accurate than men in determining anger within another individual (Goos & Silverman, 2002).

Aggression and anger

A way to deal with threats is through the use of aggressive behaviour, and social threats in both modern and evolutionary society can be considered to have the ability to warrant said behaviour (Lickley & Sebastian, 2018; Neuberg, Kenrick, & Schaller, 2009). Threats concerning resources, such as free-loaders that do not cooperate, or threats to one's own social standing are situations that might provoke and lead to retaliatory action (Anderson & Bushman, 2002; Neuberg et al., 2009).

The emotion of anger is often associated with aggressive behaviour, and it is proposed that anger affects moral reasoning as well as increasing attention spent on a provoking stimulus (Anderson & Bushman, 2002). Anger further justifies aggression and increases arousal within an individual overall and thus can be thought to be involved in conflict resolution, i.e. motivates behaviour towards a provoking stimulus. Sell, Tooby and Cosmides (2009) argue that anger can be used as an instrument to impose one's will upon others, i.e. coming out on top in a conflict of interest. It is hypothesized that individuals with better bargaining traits, such as being strong or attractive, have higher levels of *trait anger*, i.e. the tendency for becoming angry, and that this combination allows for individuals to achieve better results in conflicts of interest. Interestingly, individuals with higher self-esteem seem to more likely to exhibit to higher levels of both trait anger and trait aggression (Anderson & Huesmann, 2003). Considering that better bargaining traits, such as good looks or physical strength, are correlated with trait anger, and these advantageous bargaining traits that might instigate higher self-esteem, allow for anger, as both a trait and emotion, to further the advantage of these traits in disputes. Furthermore, angry faces are rated as more dominant and aggressive than other faces (Oosterhof & Todorov, 2008). Thus, an angry face might serve as a cue for observers that conflict is imminent and might be escalated with angry individuals. A combination of good bargaining traits and using anger as a bargaining tool can also be thought to increase reproductive success within an evolutionary context. This, since a conflict with individuals possessing these traits can be considered as costly, such as direct harm when in conflict with someone more psychically adept or being denied access to good genetic material when in conflict with someone attractive (Scheib, Gangestad, & Thornhill, 1999). Thus, good traits provide an opportunity for trait anger to be selected for in conjunction to further capitalize on already established advantages.

Human aggression can be divided into two different categories: *reactive* and *proactive* aggression (Anderson & Bushman, 2002; Anderson & Huesmann, 2003; Crick & Dodge, 1996). Reactive aggression is referred to as being in response to something provocative or frustrating and is also called affective aggression. Reactive aggression is often associated with being impulsive and emotional whereas proactive aggression is aggressive behaviour in order to achieve a goal. When exposed to an angry face, i.e. a threat, reactive aggression might come as a response. This distinction between two different forms of aggression is further supported by neural evidence from cats (Siegel & Victoroff, 2009). In cats, reactive aggression can be induced with the stimulation of the medial hypothalamus or the dorsolateral areas of the periaqueductal grey whereas proactive aggression can be induced by stimulating lateral hypothalamus or dopamine related regions of the ventral midbrain. Furthermore, proactive aggression in cats is less likely to activate the sympathetic nervous system than reactive aggression and thus suggests lower amounts of emotional arousal (Siegel & Victoroff, 2009). Reactive aggression has also been linked to poor control of autonomous responses, as well as heightened physiological response overall in response stressful stimuli in individuals with high trait aggression, such as higher skin conductance response and increased heart rate (Patrick, 2008).

Human males also seem to have higher levels of trait aggression in some respects, such as a tendency for intergroup aggression (Van Vugt, 2009). It is hypothesized that intergroup aggression in our evolutionary past has been for control over significant resources for reproduction, such as mates and food. Thus, aggressive behaviour can be a tool in a competitive environment that allows achieving reproductive success. Intrasexual competition also seems to increase testosterone levels in males irrespective of the nature of the competition as it has been demonstrated across multiple instances, such as chess, video games and judo competition (Anderson & Huesmann, 2003). Anderson and Huesmann (2003) further argue that the increase in testosterone during competition might provide a slight increase in trait aggression.

To measure trait aggression within subjects, one frequently used method is the Buss-Perry Aggression Questionnaire (BPAQ; Buss & Perry, 1992). This questionnaire measures trait aggression among four variables – Physical Aggression, Verbal Aggression, Anger, and Hostility. Physical and verbal aggression represent the physical components of aggressive behaviour, i.e. hurting another individual. Whereas anger and hostility represent its psychological components, with anger being the emotional arousal and preparation for aggression, and hostility refers to the cognitive components, such as jealousy or malicious intent (Bryant & Smith, 2001). The way the BPAQ works is that higher scores on the BPAQ indicate a higher tendency for aggressive behaviour, i.e. a high score on the BPAQ indicates higher trait aggression. In the same way as the entire BPAQ is scored, the sub-categories of the BPAQ is measured, as such there will be a score for physical aggression, verbal aggression, anger and hostility, which together make up the total score of the BPAQ. The BPAQ asks participants questions about their character and past events, such as *I tend to flare up quickly, but get over it quickly*. In the initial study investigating the validity of the BPAQ, it was found that the variable of anger was correlated to all other traits, thus suggesting that trait anger is an integral part of different kinds of aggression. Given the correlation between anger and other sub-categories of aggression, it suggests that individuals prone to aggression are also prone to higher emotional arousal. The BPAQ has further been developed into a short-form that, from initial research, is argued to provide more accurate measurements when compared to the original version (Bryant & Smith, 2001). This short-form was tested for validity among incarcerated individuals with positive results (Diamond & Magaletta, 2006). The sf-BPAQ is usually measured on either a 5-point or a 6-point Likert scale. Bryant and Smith (2001) argue that a 6-point scale is favourable when the point of the measurement is to divide a sample into a high aggression group and a low aggression group, this since a 6-point scale forces participant to choose an answer that points towards a non-aggressive or aggressive tendency where no neutral middle ground can be chosen. The BPAQ has also been investigated in relation to reactive and proactive aggression. The sub-categories of anger and hostility have shown to be stronger connected to reactive aggression tendencies than proactive aggression tendencies (Murray-Close, Ostrov, Nelson, Crick, & Coccaro, 2010). In this study, the range of possible values of the total score of the sf-BPAQ is from 12 points to 72 points.

Trait aggression has been correlated with being prone to increased emotional arousal in some instances. The diagnosis known as *intermittent explosive disorder* is characterized by disproportional reactive aggression and increased anger (Coccaro, McCloskey, Fitzgerald, & Phan, 2007). In a study investigating patients suffering from this condition, participants were exposed to different kinds of emotional faces. It has been demonstrated that angry faces increase amygdala activation in healthy subjects. However, in this study, the patient group exhibited a further increase in this effect. Amygdala activity has in previous literature been correlated with emotional arousal (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012). Thus, suggesting that increased trait aggression and increased emotional arousal might be correlated.

The correlation between trait anger and other sub-categories of aggression, as well as the notion that angry faces can be perceived as cues of threat and a precursor to aggressive behaviour provides evolutionary justification for angry faces being treated differently than other faces (Buss & Perry, 1992; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hansen & Hansen, 1988; Schupp, Öhman, Junghöfer, Weike, Stockburger, & Hamm, 2004). As intergroup competition of resources is thought to be a common occurrence in our evolutionary past and dominance over others leads to more access to said resources, cues of aggression can be thought to be direct threats to reproductive success overall (Van Vugt, 2009). Furthermore, as an expression of anger can be thought as an instrument for winning conflicts of interest, individuals prone to anger also regard themselves as entitled to better treatment, meaning that angry individuals are convinced that they are on the right side of a conflict (Sell et al., 2009). If anger and aggression is a tool for protecting one’s interests in an evolutionary setting, high self-esteem should be a predictor for increased tendencies for aggression.

How trait aggression manifests tends to differ between the sexes, with males having a propensity for costly aggression and females reportedly being more prone to indirect aggression in their adolescent years, reported in a meta-analysis by Archer (2004). Notably, it is further discussed how the emotional component of aggression does not tend to differ between the sexes and reactive aggression, i.e. aggressive behaviour when provoked, tends to decrease observed aggression differences between the sexes. A study conducted by MacLaren, Best, and Bigney (2010) investigated how sex and aggressive tendencies manifest in behavioural responses to threats. In this study, it was found that high aggression and the male sex predicted confrontational responses to threats, in contrast to females and low aggression predicting avoidance responses. Another study investigating what type of emotion predicted what kind of behaviour found that the emotion of anger is a predictor for punishing wrongdoers (Harth, Leach, & Kessler, 2013). Punishment can be considered aggressive-confrontational behaviour and considering the results from these studies together may indicate that trait aggression might predict increased anger responses towards threats posed by the environment.

Given correlations between the emotion anger and aggressive behaviour, and anger’s role in motivating aggressive behaviour, it can be thought that higher trait reactive aggression is more likely to be associated with having a stronger emotional response towards a threatening stimulus (Anderson & Bushman, 2002; Buss & Perry, 1992; Siegel & Victoroff, 2009).

However, there might be some reason to believe that individuals with higher trait aggression might self-rate slightly lower on aggression-measurements than what is accurate due to higher self-esteem (Anderson & Bushman, 2002; Anderson & Huesmann, 2003). This might be a possible limitation when considering aggression as an independent variable within a normal population or small sample size.

Considering the aim of this thesis, trait aggression should be detected by the sf- BPAQ, with a higher score on the sf-BPAQ being manifested as a tendency for higher overall emotional arousal when posed with a threat. Given that aggression towards a social threat is reactive rather than proactive in nature, individuals scoring higher in anger and hostility sub-categories of the sf-BPAQ should be associated with a larger emotional response towards threats.

Deciphering faces as cues of social threat

Threatening faces

In previous literature, an angry face is interpreted as a social threat and is therefore processed differently than other kinds of faces (Hansen & Hansen, 1988). This is demonstrated in a study conducted by Hansen and Hansen (1988), where participants were tasked with detecting the presence of different emotionally valenced faces in a crowd across multiple experiments. In the first experiment, participants were tasked with detecting stand-out faces in a crowd, the faces consisted of either happy, neutral or angry expressions, i.e. if the crowd consisted of happy faces they were tasked to determine if there were faces that had angry or neutral expressions. The results from the first experiment illustrated that participants were both more accurate and faster when the stand-out faces had an angry expression in both happy and neutral crowds than happy faces in angry crowds or neutral faces in angry crowds. However, neutral faces in happy crowds expressed similar effects as angry faces, as well as happy faces being identified similarly fast and accurately in both neutral and angry crowds as neutral faces in happy crowds. Thus, suggesting a bias for novel faces within crowds, with angry faces being processed faster and more accurately than other kinds of faces when unique to their crowd. Interestingly, in trials where there were no stand-out faces, angry crowds yielded in a significantly higher error rate among participants, i.e. participants claiming there were stand-out faces when there were none. In the second experiment, participants were tasked with locating either a happy face in an angry crowd or vice versa. The results from this experiment illustrated that angry faces in happy crowds were easier to locate than happy faces in angry crowds. Thus, the results may indicate that angry faces have an advantage over happy faces in attentional processes. The authors hypothesized that this effect is due to that face-processing favours cues of threat over other kinds of stimuli. To further investigate the effect, a third experiment was conducted, in which they tested multiple key hypothesizes to reinforce the hypothesis of angry faces being favoured in face processing. The experiment was set out to test that angry faces should be identified faster than happy faces regardless of crowd size, that the time to identify angry faces should not be heavily influenced by the number of faces in the crowd as well as the time to identify happy faces should be more influenced by the number of faces in the crowd, and that angry faces would result in a pop-out effect. The pop-out effect should, according to the authors, result in participants learning to adopt a strategy for detecting the presence of an angry face in a crowd, and when this pop-out effect is missing it would be an indication of no angry face. Thus, resulting in the time needed to report a happy crowd with no face should not be substantially influenced by the number of faces in a crowd in later trials. The participants were tasked to determine if a stand-out face was present, i.e. a happy face in an angry crowd or vice versa.

The results reported indicated that all predictions for this experiment were supported. Thus, taking the results from this study provides a robust demonstration of angry faces being favoured over other kinds of faces. To put this in an evolutionary context, it would be favourable for an organism to rapidly detect threats rather than other kinds of stimuli, and that this effect applies to social situations as well, given that angry faces serve as a cue of threat (Hansen & Hansen, 1988). Thus, angry faces can be thought to activate systems used to deal with threats. The effects of angry faces effect on threat-detection mechanisms have been further studied and replicated in multiple instances (Coccaro et al., 2007; Fox et al., 2000; Goos & Silverman, 2002; Schupp et al., 2004; Oosterhof & Todorov, 2008). Thus, angry faces serve as a reliable way to create a threatening social cue that can be displayed to subjects.

Facial width to height ratio

The ratio between the width of a face divided by the distance between the upper lip and between the brows is known as the FWHR. The FWHR has been shown to affect how a face is perceived, especially male faces, and male faces with high FWHR is associated with being perceived as more threatening and dominant by observers (Geniole et al., 2015). High FWHR is both deemed as more masculine and has been associated with higher levels of testosterone in both puberty and adulthood (Gangestad, Thornhill, & Garver-Apgar, 2005; Lefevre, Lewis, Perrett, & Penke, 2013). A possible explanation for this effect can come from an evolutionary setting. Males with a high FWHR tend to be more aggressive and socially dominant, and therefore it is possible that sensitivity towards FWHR has been selected for over time (Carré & McCormick, 2008; Carré, McCormick, & Mondloch, 2009; Haselhuhn, Ormiston, & Wong, 2015). Thus, if high FWHR is a signal of aggressive and dominant behaviour in an individual it can be interpreted as a cue of threat, which implies that FWHR is a significant signal for individuals to react to (Geniole et al., 2015).

Another possible explanation of why high FWHR is interpreted as a cue of threat is its similarities to an angry face (Carré et al., 2009). When expressing an angry face, the face lowers the brows and raises the upper lip, and therefore increases the FWHR notably. It might be that the effects exhibited by studies regarding FWHR are due to expectations of aggression when exposed to an angry face, as angry faces serve as reliable cues of threat themselves (Hansen & Hansen, 1988). Regardless, FWHR has been noted in modern literature not only to be rated as more threatening and dominant but also predict aggressive behaviour within human males. A study conducted by Carré and McCormick (2008) investigated the FWHRs effect among participants. The results from this study first indicated that FWHR among men predicted reactive aggressive behaviour as well as dominant behaviour. These results were then followed up among hockey players. Among hockey players, aggressive behaviour leads to higher minutes spent in penalty, i.e. temporarily removed from the game. FWHR was correlated positively with the time spent in penalty, and the author then argues that FWHR serves as an honest signal for aggressive tendencies among men. Given that FWHR can predict trait aggression within human males, it seems unlikely that the effect it exhibits on observers would stem solely from its resemblance to an angry face.

Both angry faces and FWHR have been shown to function as reliable signals of social threat. Thus, when an individual is presented with a face that either poses an angry expression or a face with a high FWHR, or a combination of both, threat-related mechanisms within the individual should be activated. Together with aggression literature previously discussed in this thesis, threatening faces should co-occur with a larger emotional response in individuals with higher trait aggression rather than individuals with lower trait aggression.

Emotional arousal and the late positive potential

The late positive potential, often referred to as the LPP, is a late event-related potential (ERP) associated with emotional arousal that appears roughly 300-400 milliseconds (ms) after stimulus onset and is larger at superior and posterior positions on the scalp (Cuthbert et al., 2000). While viewing emotional pictures, subjects exhibit a larger LPP for emotional stimuli regardless of the nature of the emotion in contrast to neutral stimuli, i.e. regardless if it was pleasant or unpleasant images. The same pattern is demonstrated when viewing faces, both angry and happy faces result in augmented LPP amplitudes in subjects when compared to neutral faces (Hajcak, MacNamara, & Olvet, 2010).

The correlation between the LPP and emotional arousal can be seen both from subjective reports and other automatic responses to emotionally arousing stimuli, such as skin conductance and heart rate (Cuthbert et al., 2000). It further seems that augmentation of the LPP follows how emotionally arousing an individual perceives a stimulus, with a larger augmentation following stimuli that are stronger in their emotional content, i.e. results in higher emotional arousal. In a study by Cuthbert et al. (2000) images that were more emotionally arousing, both subjectively rated and exhibited other physiological markers, were images that were high in motivational cues, i.e. violent or erotic images. Furthermore, there is some indication that LPP might be connected to the notion of attention, as emotional stimuli can be thought to be automatically attention capturing (Hajcak et al., 2010; Hajcak & Olvert, 2008). Emotional stimuli seem to increase attentional resources dedicated towards a stimulus when compared to neutral stimuli, and the attention is further sustained when the picture is unpleasant, or negative, in nature (Hajcak & Olvet, 2008). Thus, an augmented LPP can be a result of stimuli that automatically capture attention and is further augmented when said stimuli are high in motivational content. This notion would be true for both positive and negative emotional content, i.e. the LPP is more affected by the arousing properties of a stimulus rather than its emotional valence, however a negativity bias would still be in effect to some extent (Cuthbert et al., 2000; Hajcak & Olvet, 2008).

An advantage with the LPP when measuring autonomous responses to emotional stimuli is its resilience to habituation compared to other measurements of emotional responses, such as skin conductance, heart rate and amygdala activity (Hajcak et al., 2010). Even though there are multiple ways to measure emotional arousal without relying on subjective report paradigms, some research indicates that the LPP and other measurements behave differently from each other (Codispoti, Ferrari, & Bradley, 2006; Ferrari et al., 2016). The reason for LPP being different is in its sensitivity for emotional content, i.e. even if the LPP becomes habituated, or diminished, over repeated stimuli, the effect that emotional stimuli have on it is still present. When comparing this effect to other measurements of emotional arousal, such as skin conductance, it seems that other measurements rapidly habituate over repeated stimulation. In sum, what sets LPP apart from other measurements is that manipulation of the LPP using emotional stimuli does not seem to habituate as much as when compared to other measurements.

However, the LPP and other measurements of emotional arousal is still said to measure the same thing. While the LPP might be a common way to measure the emotional response in electroencephalography (EEG)-studies, amygdala activity along with other neural structures involved in emotional processes is also a common way for cognitive neuroscientists to investigate emotional arousal (Coccaro et al., 2007; Liu et al., 2012). Claimed to be sensitive to emotional stimuli, both the LPP and amygdala activity might intuitively be thought to be two sides of the same coin. However, due to the *inverse problem*, the neural origins of the LPP are in principal impossible to determine by using EEG-data alone. Roughly speaking the inverse problem is a problem for EEG-data, where the EEG-signal, which is the recorded electrical potential on the scalp, cannot be used to calculate where the signal originates from. This is due to a large array of possible origins any EEG-signal might have, and thus it limits the extent to which we can draw conclusions regarding the spatial origins of the EEG-signal (Luck, 2014). Some progress has been made in discovering the neural correlates of the LPP by monitoring both EEG and the blood-oxygen-level-dependent signal (BOLD) at the same time. The BOLD-signal is what is being measured when using functional magnetic resonance imaging (fMRI) to investigate neural activity. Liu et al. (2012) propose that different neural structures generate the LPP-response depending on the emotional nature of the stimuli. As previously mentioned, the LPP seems to be augmented as a response to both positive and negative emotional stimuli. However, depending on the emotional information, the LPP seems to be a result of alternating neural systems depending on the emotional valence. It was found that LPP in response to unpleasant stimuli was coupled with increased activity in the insula and the posterior cingulate and ventrolateral prefrontal cortices. This is in contrast to the LPP in relation to pleasant pictures where it was more associated with activity in occipitotemporal junction, medial prefrontal cortex, amygdala and precuneus (Liu et al., 2012).

It follows that while the LPP seems to be sensitive to emotional information and emotional arousal, it might be the product of different neural structures signaling as a response to the nature of emotional stimuli. While BOLD signals can be more telling about how an individual perceives something, i.e. either pleasant or unpleasant, depending on what neural structures which illustrate higher activity, the LPP will still be augmented as a result.

With the aim of this thesis taken into account, one aspect of high trait aggression individuals might be neglected due to this difference in underlying neural origins of the LPP that can't be dissociated with EEG. This aspect would have been to see if individuals with higher trait aggression process cues of social threat differently than individuals with lower trait aggression.

The notion of angry faces being treated differently than other kinds of faces is further backed up by electrophysiological data (Schupp et al., 2004). Schupp et al., (2004) conducted a study that investigated the differences between threatening, neutral and friendly faces. In piloting stages of this study angry faces were rated with higher emotional arousal within the subjects and higher unpleasantness than other faces. The results from the EEG demonstrated that angry faces augmented the late positive potential (LPP) in contrast to neutral and friendly faces. The link between angry faces inducing higher emotional arousal as well as augmenting the LPP is consistent with previous literature. The LPP has also been illustrated to be augmented with stimuli higher in emotional significance (Cuthbert et al., 2000).

Another aspect of the LPP in addition to its correlation to emotional arousal is its response to evolutionary relevant stimuli. The LPP does seem to be augmented to stimuli relevant in our evolutionary past in contrast to evolutionary irrelevant stimuli regardless of the emotional valence (Schupp, Flaisch, Stockburger, & Junghöfer, 2006; Schupp et al., 2004). Thus, evolutionary relevant emotional stimuli, such as a threatening face, should lead to augmented LPP's. Together with the background for this thesis, the LPP might further be modulated by the subjects' tendencies for aggression. As trait aggression is correlated with sensitivity to emotional arousal, modulation of the LPP, in this case, could be a tendency for emotional arousal in response to threatening social cues which are manifested as increased self-rated trait aggression (Anderson & Huesmann, 2003; Buss & Perry, 1992).

Event-related potentials and aggression

Studies on aggression have shown evidence that aggressive tendencies can be associated with certain neural activities, such as ERPs and fMRI patterns across different kinds of tasks (Bertsch, Böhnke, Kruk, & Naumann, 2009). Induced aggression, i.e. provoked subjects, has been found to increase the amplitude of both early and late positive potentials (P2 and P3, respectively) in subjects when viewing emotional faces. This effect was found for all faces, but the greatest amplitude increase was found in the early positive potential when subjects were exposed to threatening faces. Furthermore, participants more prone to anger show bias towards emotional expressions, which is manifested in slower reaction times. Bertsch et al. (2009) argue that aggression modulates higher level information processing and therefore leads to biases in emotional processing.

This thesis will focus on the LPP as a measurement of emotional arousal. Within the context of the background of this thesis, the LPP should be augmented for a subject scoring high on aggression measurements, especially anger and hostility sub-categories, when exposed to a social threat, i.e. a threatening face.

There also exist some evidence of trait aggression being associated with the P3 in response to aversive stimuli (Patrick, 2008). The P3 is an ERP component often associated with task-relevance. The start of the P3 wave can be observed in the ERPS around 200-400 ms after stimulus onset (Luck, 2014). Individuals exhibiting heightened levels of trait aggression seem to have a diminished P3 when exposed to stimuli of stressful or aversive nature (Patrick, 2008). The possibility exists that individuals scoring high on trait aggression also would have a diminished P3 in response to threatening stimuli since threats should be stressful by definition.

Aim and hypothesis of the present study

The aim of the study is to investigate if higher trait aggression in individuals is associated with higher emotional arousal when exposed to a social threat, this will be done by using the LPP as a proxy for emotional arousal. The rationale behind this is that the LPPs neural origins seem to stem from emotional structures (Liu et al., 2012). To compare levels of trait aggression between participants, the participants will be divided into two groups based on their sf-BPAQ scores by using a median split. The participants will be exposed to cues of social threat in the form of either angry or high FWHR faces, or a combination of the two. The hypothesis for this thesis is that the high trait aggression group’s mean LPP amplitude will be higher than the low trait aggression group’s mean LPP amplitude in response to cues of social threat. Given that no prior research investigates the associations between trait aggression and the LPP in response to cues of social threats, this thesis could provide directions for future research and further the understanding of trait aggressions role in humans.

Furthermore, individuals scoring higher on anger and hostility sub-categories of the sf-BPAQ should exhibit the strongest manifestation of this co-occurrence, as these two categories seem to correlate the strongest with trait reactive aggression (Buss & Perry, 1992; Coccaro et al., 2007; Murray-Close et al., 2010; Siegel & Victoroff, 2009). Therefore, investigation regarding both total sf-BPAQ and sub-category scores of anger and hostility will be considered as grouping variables.

Materials and methods

Participants

28 participants (12 female, 16 male; mean age ± SD: 26.5 ± 4) were recruited from the University of Skövde. The recruitment was conducted through the use of email lists, social media and word of mouth. The participants were selected using the following inclusion criteria: right-handed, between 18-40 years old, have good sight and be able to clearly see 2 meters ahead with or without sight correction such as glasses, not suffer from epilepsy, not have any current psychiatric or neurological illness or diagnosis, not be colour-blind, speak English and not be dyslexic. The participants were a mix of international and national Swedish students.

Stimulus material

This experiment was conducted as a part of multiple masters-theses, therefore faces, serving as cues of social threat, were created with two levels of three variables. These variables were high and low age, high and low FWHR and no or high emotional valence, i.e. anger, resulting in eight distinct faces. Faces were made in FaceGen Modeller Core 3.18 (For exact values and steps to recreate faces see supplementary material) by Singular Inversions, with a background grey which had an RGB index: 152, 152, 152. The screen used is a 23-inch screen with a 1920 x 1080-pixel resolution and model name HP Compaq LA2306x. The stimuli, which were also 1920 x 1080 in size, were shown for 1500 ms, following a 400 ms fixation point, and followed by a blank screen with a jittered latency of 300-500 ms, for a total stimulus onset asynchrony of 2200-2400 ms.

Measures

Participants were measured for trait aggression with the sf-BPAQ (Bryant & Smith, 2001; see *Supplementary material* for the complete list of questions used). Participants answered the questionnaire using a 6-point Likert scale, ranging from 1 *extremely uncharacteristic of me* to 6 *extremely characteristic of me*. The possible total score of the questionnaire ranged from 12-72. The reliability of the sf-BPAQ for this sample was tested with Cronbach’s alpha, and the trait aggression measurements were found to be relatively low for this sample (12 items; $\alpha = 0.665$). This measurement is done in order to divide participants into a high and low aggression group for comparisons.

The participants also rated all of the 8 faces on the perceived threat levels on a 9-point Likert scale. Where a 1 indicated the lowest level of the perceived threat and a 9 indicated the highest level of perceived threat. This measurement was also tested for reliability with Cronbach's alpha and provided acceptable results (8 items; $\alpha = 0.856$).

Figure 1: Examples of neutral, angry, angry & high FWHR, and old & angry& high FWHR faces.

Procedure

Participants were asked to choose a playlist/artist/album on Spotify to play for the duration of the experiment if they had not provided specifics before arriving. After providing consent, the participant was then instructed to sit down in the experimental room and head measurements were conducted.

After the electrode-cap (g.GAMMAcap) had been placed on the participant's head, participants began the first section of the experiment. This first section (section A) included three questionnaires and a face-rating task. The order of the questionnaires and task was randomized between participants. The order of the questions for each questionnaire was randomized between participants. The questions in the sf-BPAQ were answered using a six-point scale, 1 indicated that the statement was extremely uncharacteristic for the participant and 6 indicated that the statement was extremely characteristic for the participant. The faces for the face-rating task were presented for 1500 ms. Whilst the participants were occupied with the questionnaires, the experimenters gelled the electrodes with conductive gel. The participant answered the questions using the numbers on a keyboard.

When the participants were finished with section A, new instructions were presented to prepare for section B. In section B the same 8 faces as in the face-rating task in section A were presented on the screen. In this section, the participants were given a vigilance task. The vigilance task had the participants pressing a button on a hand controller each time they saw a face with completely closed eyes. The faces with closed eyes were the same faces as the original 8 but with their eyes closed. The frequency of these faces was randomized to occur approximately once in every eight faces. The purpose of this vigilance task was to keep subjects vigilant and maintain a general alertness throughout the experiment. Section B consisted of 12 blocks of trials with 64 trials per block, each face being presented 8 times, plus the (random) number of times the closed eyes were presented. Between each block was a shorter break, the length of which was determined by the participant. The location of the fixation-dot was in between the eyes of the upcoming face. After 6 blocks, the participant was given a longer break and had the opportunity to get up from the chair and walk around or get something to drink. After this break, the remaining six blocks were presented.

EEG recording

Brain activity was recorded using 17 active Ag/AgCl electrodes. 13 of these were placed in a stretchable cap (g.GAMMAcap) and positioned according to the International 10/20 Placement System at the following locations: AF3, AF4, Fz, FC3, FC4, Cz, CP1, CP2, CPz, Pz, P5, P6 and Oz. The other four electrodes were placed at the right and left mastoid (for subsequent offline re-referencing) and at the external canthus and suborbit of the right eye (to capture ocular movements). Electrodes were online referenced to the right mastoid, and FPz served as ground. The active electrode impedances were transformed by the system to output impedance of about 1kOhm.

The EEG data were acquired in MATLAB v8.5.1.281278 (MathWorks, 2019) with a g.USBamp amplifier (g.tec). It was sampled at 256Hz and filtered online with an eighth-order Butterworth lowpass filter with a half-power (-3dB) cutoff at 60 Hz, by an internal digital signal processor within the amplifier.

Data processing

Offline analysis was performed using the toolboxes EEGLAB v13.6.5b (Delorme & Makeig, 2004) and ERPLAB v7.0 (Lopez-Calderon & Luck, 2014) in MATLAB. Continuous EEG data were re-referenced to the average of the mastoids and filtered with a 180th-order stopband notch filter at 50 Hz, to remove line noise.

As a pre-processing step for removing artefacts by Independent Component Analysis (ICA), the data were filtered with a second-order Butterworth bandpass filter with a half-power (-3dB) cutoff at 1 and 30 Hz (the higher highpass filter settings are recommended for ICA analysis). The EEG data were then segmented into epochs of 1900 ms, with a 400 ms pre-stimulus baseline and 1500 ms post-stimulus. Epochs exceeding three standard deviations above the joint electrode probability activity limits were rejected, after which ICA was run. Multiple Artefact Rejection Algorithm (MARA) was used to automatically identify ICA components reflecting artefacts (Winkler, Haufe, & Tangermann, 2011).

The ICA weights were then transferred back onto the pre-processed, unepoched data (that had only been subjected to the notch filter), and the relevant MARA-detected components were removed from this data. Subsequently, this data was filtered with a second-order Butterworth high-pass filter with a half-power (-3dB) cutoff at 0.1 Hz, and was, as before, segmented into epochs of 1900 ms, with 400 ms pre-stimulus baseline and 1500 ms post-stimulus. Step-wise artefact rejection was performed in ERPLAB 7.0 (all epochs containing steplike activity greater than 100 μV in a moving window of 200 ms with a step size of 20 ms were rejected). 2 subjects with an artefact detection rate above 20.0% in total (across all conditions) were rejected from further analysis. For the remaining subjects (n = 25, epochs were averaged for each participant and each experimental condition, and lowpass filtered at 30 Hz to aid visual inspection.

In line with a large body of prior research, which found that the LPP is most pronounced over central-parietal sites (Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2009; Wieser et al., 2014), the LPP was quantified across a cluster of central-parietal electrodes (Cz, CP1, CP2, CPz, Pz) as a function of the condition in two time windows following stimulus onset: 400-1000 ms, and 1000-1500 ms.

Statistical analysis

Statistical analysis was run using IBM SPSS Statistics 25 for mean amplitude data on subjects with adequate data quality. Within-subject conditions were high vs low FWHR, angry vs. neutral expression, P3 vs. early LPP vs. late LPP. Between-subject factors were total aggression scores, measured by the sf-BPAQ, with high vs. low aggression scorers relative to each other. All relevant conditions were subject to a mixed-model 2x2x3x2 repeated-measures ANOVA. Any significant effects involving the between-subjects condition were subject to independent samples t-test as a post-hoc measure. The reasoning behind dividing the LPP into two different time-windows is because of two reasons, to be comparable with other literature in the subject as well as that there is reason to believe that different kinds of stimuli affect different parts of the LPP in different ways, as well as some indication that the P3 might be affected by trait aggression within individuals (Patrick, 2008; Weinberg & Hajcak, 2010). Since the EEG-data should vary over time, the main-effect of Time will not be discussed.

There is also reason to believe that trait reactive aggression would be more associated with the LPP more than trait proactive aggression (Coccaro et al., 2007; Murray-Close et al., 2010; Siegel & Victoroff, 2009). Since sub-categories anger and hostility of the sf-BPAQ seem to be correlated with reactive aggression more than proactive aggression, follow-up analysis will be conducted between high and low scoring groups based on the sum of anger and hostility scores.

Furthermore, as this experiment was the basis for three different master's theses the variable of high and low age for the faces was included in the experiment as a within-subject factor. Given that adequate data exists to investigate possible effects of the interaction between age and aggression group, a similar repeated-measures ANOVA will be conducted to investigate this possible effect (making it a 2x2x2x3x2). As the variable of age is not discussed in the background nor mentioned in the hypothesis, should any interaction effect occur between age, aggression group and any other variable it will be regarded as an exploratory finding for the purpose of this thesis.

Results

Descriptive Statistics

The participants not excluded due to poor data quality (n=25) were divided into two groups based on aggression scores, one group of high total aggression scores (n=13) and one group of low total aggression scores (n=12). The division between the two groups was a median split, i.e. all participants with a score higher than the median were selected for the high aggression group and all participants with a score below the median was selected for the low aggression group. The participant with the median score, since a total of 25 participants were subject to analysis, had a score above the entire samples mean score and was therefore included in the high aggression group. Possible scores for the entire sample ranged from 12-72. The low aggression group consisted of 8 male and 4 female participants with a mean age of 26,67 ± 2,43 and the high aggression consisted of 6 males and 7 females with a mean age of 28,25 ± 4,89. To make easier comparisons between the two groups and other studies, the mean and standard deviation for the high and low aggression groups, and for the entire sample were calculated (Buss & Perry, 1992; Diamond & Magaletta, 2006). The aggression scores differed between the two groups with the high aggression group having a mean and standard deviation (SD) of 34.62 ± 2.7 and the low aggression group having a mean and SD of 22.42 ± 5.6. The total aggression scores mean for the sample (N=28) was in between the high and low aggression groups with a mean and SD of 29.9 ± 8.4, and the same can be said for the participants with sufficient data quality (n=25) which had a mean and SD of 28,76 ± 7,5. To make sure the two groups were different enough on aggression scores from each other, an independent t-test was conducted between the two groups. The total aggression scores were shown to be significantly different from each other between the two groups (T(23) = 7.081, P < 0.001). The two groups did significantly differ from each other in mean age (T(22) = -1.006, P = 0.325) or in gender distribution ($\chi^2(1) = 1.51^a$, P = 0.219).

The two groups did not differ significantly in how they rated faces (T(23) = 1.570, P = 0.13), the high aggression group had a mean total sum of scores of 36.7 ± 10.9 and the low aggression group had a mean total sum of scores of 29.8 ± 11. Although the difference between the two groups means were 6.9, high variance in facial ratings makes any other conclusions to be drawn between the two groups unlikely. To test whether any differences between the ratings of individual faces between the groups, a Mann-Whitney U test was conducted. The reason for a non-parametric test is because the data stems from a Likert scale, which would be considered as ordinal data. The Mann-Whitney U test revealed no significant differences on the ratings of each individual face between the groups (P > 0.05).

Inferential statistics

To test the hypothesis a 2x2x3x2 repeated measures ANOVA was first conducted on the LPP between the variables of emotional expression, FWHR, P3 (200-400 ms) vs. early (400-1000 ms) vs. late (1000-1500 ms) LPP and aggression group for the average of the electrode cluster Cz, CP1, CP2, CPz, and Pz. While no significant effects were found for the interaction between aggression group and other variables (P > 0.05), other interactions did show significance. Both the main-effect of expression (F(1,23) = 6,327, P < 0.05) and FWHR (F(1,23) = 7,045, P < 0.05) did show to be significant. Two significant two-way interactions were found, the interaction between time (P3 vs. early vs. late) and expression (F(2,22) = 8,319, P < 0.01), as well as the interaction between FWHR and expression (F(1,23) = 9,365, P < 0.05). One three-way interaction between time, FWHR and expression was significant (F(2,22) = 5,864, P < 0.01).

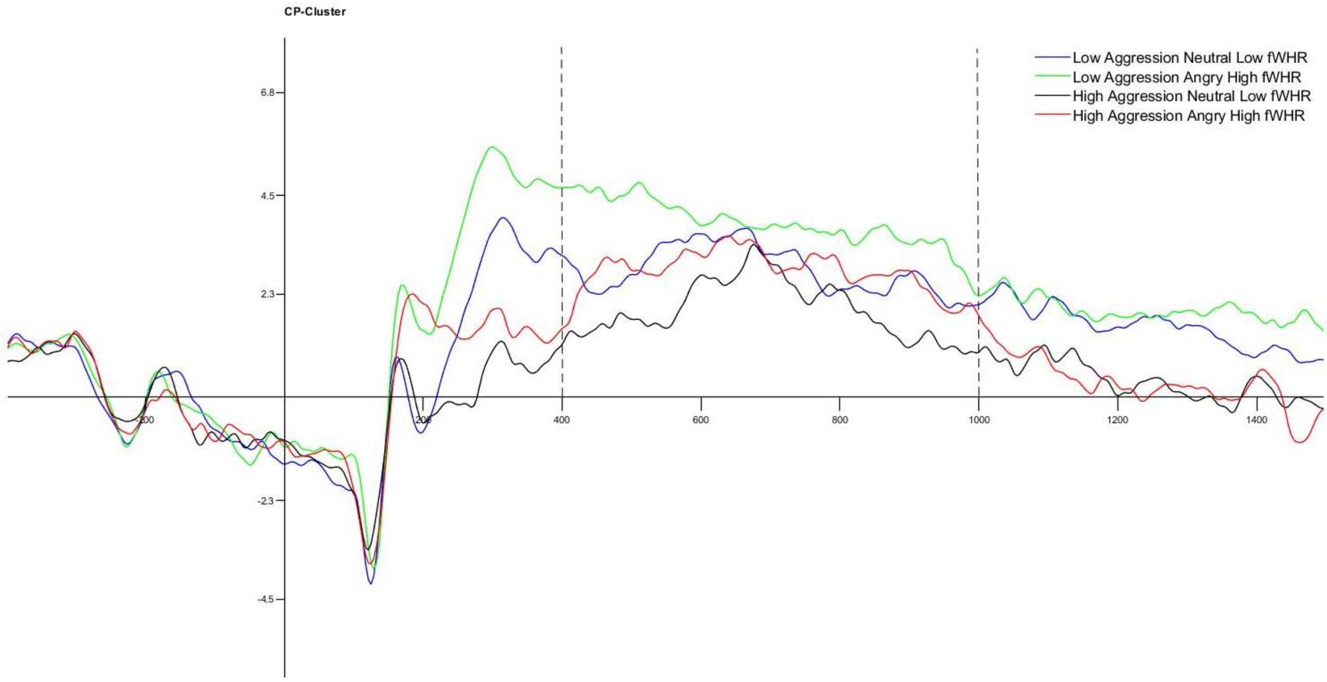

Figure 2: Waveforms across aggression groups for neutral low FWHR faces and angry high FWHR faces. Vertical lines at 400 and 1000 indicate the start of the early and late time windows, respectively.

Since this study also included the variable of age as an independent variable in the stimulus, a second repeated-measures ANOVA was conducted on the LPP (400-1500 ms) between all facial variables (time, age, emotional expression and FWHR), between the high and low aggression groups for the average of the electrode cluster of Cz, CP1, CP2, CPz, Pz. The interaction effect between aggression group and any of the other factors was not found to be significant ($P > 0.05$). However, similar to the first ANOVA conducted other effects did show significance. The two-way interactions between time and age ($F(2,22) = 3{,}828$, $P < 0.05$), FWHR and age ($F(1,23) = 6{,}649$, $P < 0.05$), time and expression ($F(2,22) = 8{,}319$ $P < 0.05$), and FWHR and expression ($F(1,23) = 9{,}365$, $P < 0.05$) were all found to be significant. The only three-way interaction found to be significant was the same interaction between time, FWHR and expression as before ($F(2,22) = 5{,}864$ $P < 0.01$).

Further analysis of the data revealed that the high aggression (mean SD = 4.97) group exhibited approximately three times higher variance within the group than the low aggression group (mean SD = 1.66) for the total LPP mean amplitude values across all conditions.

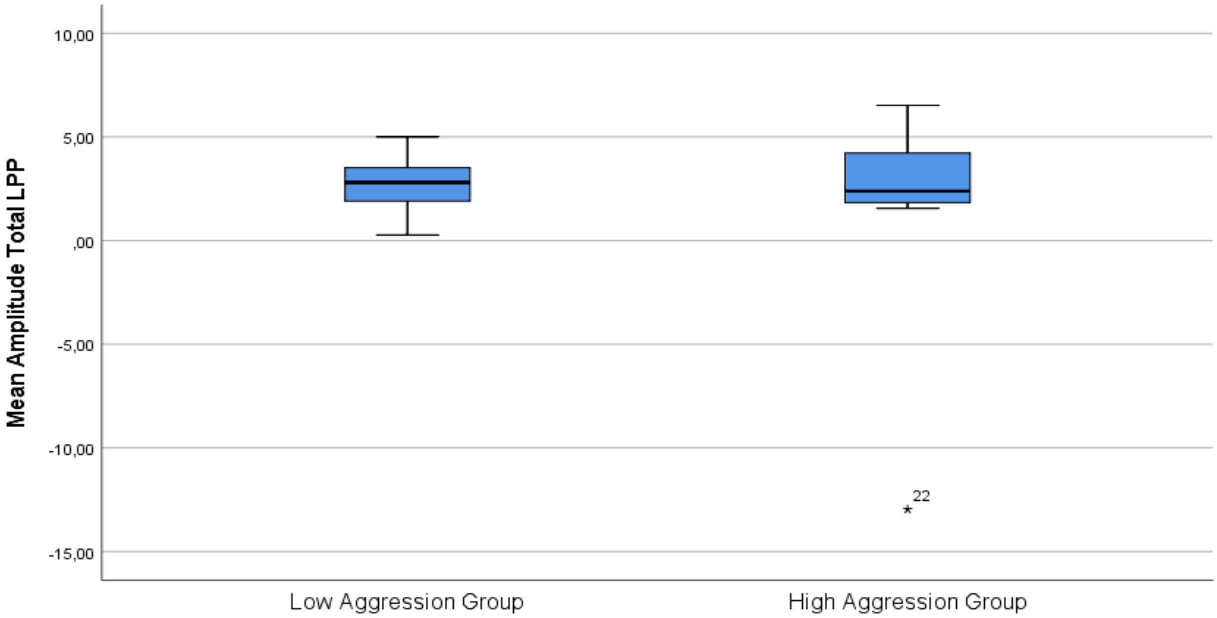

Figure 3 Mean amplitude for the entire LPP between low and high aggression group, asterisk implies subject with a mean more than 3 IQR away from group median.

Plotting revealed one of the subjects in the high aggression group to be considered an extreme outlier and is therefore thought to potentially skew the data. All subjects with a mean more than 2 SD from group mean (n=1) were removed from the analysis and previous tests were repeated to check for potentially changed results. With the subject removed the SD for the mean amplitude for the entire LPP between subjects for the low aggression group (SD = 1.39) and high aggression group (SD = 1.77) became more similar to each other. To retest the hypothesis a repeated measures ANOVA between the variables of FWHR, emotional expression, time and aggression group. Given the previous reasoning behind the exploration of the P3 between high and low aggression groups, this time-window was also included in re-testing after the outlier was removed. The ANOVA was conducted on mean amplitude values for the Cz, CP1, CP, CPz, Pz-cluster. No significant results were found for the interaction between aggression group and other variables ($P > 0.05$). The same interaction effects as the non-corrected version did show significance. When running the corrected repeated-measures

ANOVA including the variable of age, no differences in the results were found.

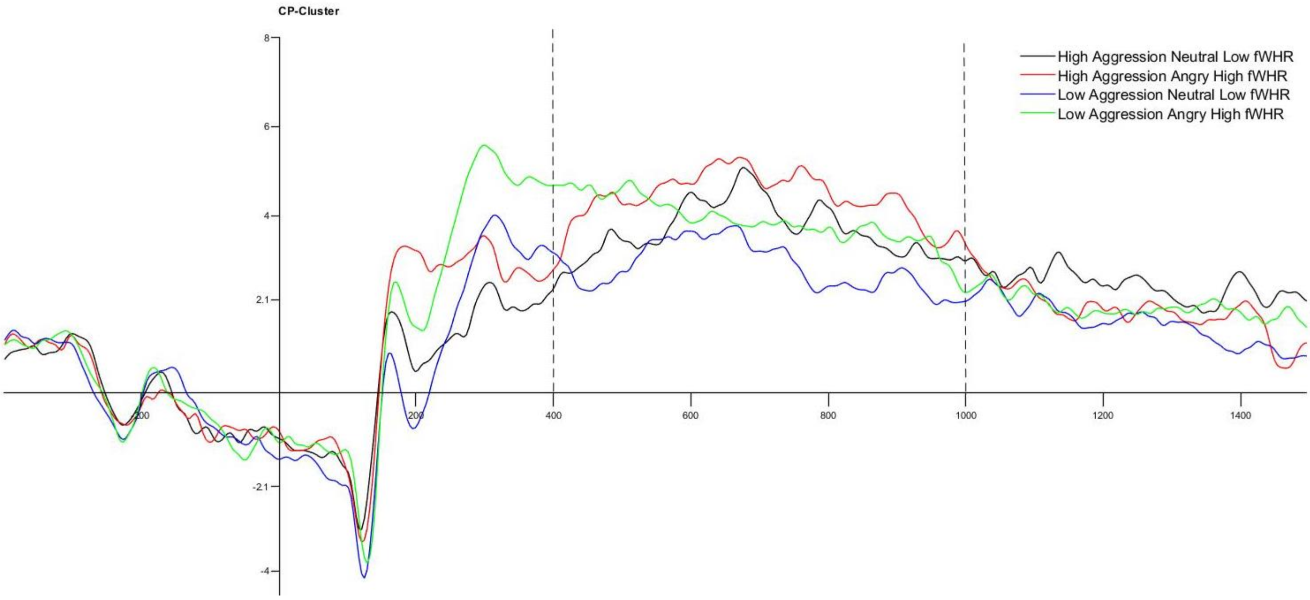

Figure 4: Waveforms across aggression groups for neutral low FWHR faces and angry high FWHR faces with outliers removed. Vertical lines at 400 and 1000 indicate the start of the early and late time windows, respectively.

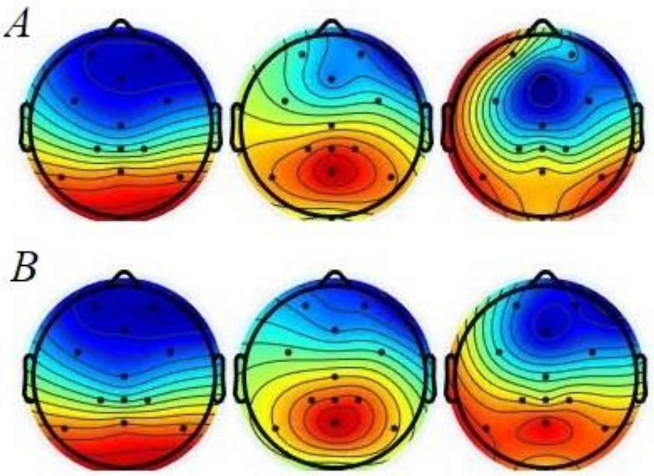

Figure 5 A: Scalp distribution across all subjects for all threatening faces for time-windows: 0-400 ms, 400-1000 ms, 1000-1500 ms. B: Scalp distribution across all subjects for all threatening faces for time-windows: 0-400 ms, 400-1000 ms, 1000-1500 ms with outliers removed.

Effect	F-value	Degrees of freedom	P-value
Time	33,952	2, 21	< 0,001 *
Time x Aggression Group	1,384	2, 21	0,272
FWHR	4,616	1, 22	0,043 *
FWHR x Aggression Group	1,259	1, 22	0,274
Expression	8,103	1, 22	0,009 *
Expression x Aggression Group	0,527	1, 22	0,475
Time x FWHR	9,798	2, 21	0,001 *
Time x FWHR x Aggression group	1,464	2, 21	0,254
Time x Expression	7,303	2, 21	0,004 *
Time x Expression x Aggression Group	1,012	2, 21	0,38
FWHR x Expression	10,732	1, 22	0,003 *
FWHR x Expression x Aggression Group	2,056	1, 22	0,166
Time x FWHR x Expression	5,899	2, 21	0,009 *
Time x FWHR x Expression x Aggression Group	0,015	2, 21	0,985

Table 1: Results from the 2x2x3x2 repeated-measures ANOVA with the outlier removed. Asterisk indicates significant results.

Post-hoc testing revealed that the main-effect of FWHR was not present when only analysing the LPP (early vs. late), rather its effects were expressed in the P3-time window resulting in it being significant as a main effect. Paired t-test with Bonferroni corrections was run to test the effect within each time-window (P3, early, & late) of the low vs. high FWHR conditions (adjusted critical $\alpha = 0.01666\ldots$). In both the early ($T(23) = 1.545$, $P = 0.136$) and late ($T(23) = 0.366$, $P = 0.717$) time-windows the low vs. high FWHR revealed no significant results. However, in the P3 time-window the paired t-test did show significance ($T(23) = 4{,}570$, $P < 0.001$).

The same post-hoc testing was used to investigate the effect of expression with the same corrected critical α value (adjusted critical $\alpha = 0.01666\ldots$). In this post-hoc test only the late window revealed no significance for the differences between neutral vs. angry expression

(T(23) = -1.197, P = 0.243), whereas the effect was significant in both the P3 (T(23) = -4.637, P < 0.001) and the early T(23) = -2.994, P < 0.01) time-window.

In line with the background of this thesis, grouping the participants based on their scores of anger and hostility scores from the sf-BPAQ, referred to as high and low *reactive aggression groups*, was thought to be warranted. The analysis was redone on the dataset following the exclusion of the outlier, and similar time-windows (early and late LPP, & P3), variables and tests were conducted. The repeated measures ANOVA revealed no significant interaction effects between high and low reactive aggression groups and other variables.

Discussion

The aim of this thesis is to investigate if higher trait aggression in individuals could be associated with higher emotional arousal when exposed to a cue of social threat. This has been done by using the LPP as a proxy for emotional arousal. Cues of social threats have been presented to participants by exposing them to faces exhibiting two, supposedly, threat inducing variables – angry expression and high FWHR. Furthermore, the results from the statistical testing run after the removal of outlier will be discussed in favour of any analysis prior to the exclusion of the subject. The reasoning for this can be seen across comparisons between *Figure 2* and *Figure 4*, as well as in *Figure 5*.

The results

The effects which did show significance were a bit surprising. The premise that the FWHR can serve as an honest cue of threat seems to be partially supported by these results. With the two variables which supposedly should serve as a cue of threat, anger and FWHR, only the angry vs neutral expression showed significance as an effect on the LPP. If FWHR is a cue of threat, these results indicate that the effect is smaller than the effect of emotional expression as it was only significant in the P3 time-window. The variable of FWHR showed to have significant interaction effects with both time and expression as well as a three-way interaction between time, FWHR and expression. Given that expression seems to have a more robust effect than FWHR, the interaction between the two might suggest an exaggeration of the already established threat cue from expression. This is a plausible hypothesis, because an angry face has been shown to be a reliable way of inducing a cue of threat across multiple studies (Fox et al., 2000; Hansen & Hansen, 1988; Oosterhof & Todorov, 2008; Schupp et al., 2004). The possibility also exists that FWHR is a cue of threat and that an angry high FWHR individual is more threatening than either an angry low FWHR individual or a neutral high FWHR individual.

In support of the validity of this experiment, the effect of expression did reveal to be significant, which was highly expected given that it is frequently utilised as a way of inducing social threat. The interaction between time and expression is further support of this. Similar studies investigating the early and late LPP suggests that differences between a neutral and a threatening condition are more likely to occur in the early LPP time window rather than the late (Weinberg & Hajcak, 2010). The variable of time was involved in five out of the total eight significant effects. Therefore, the stimuli used in this experiment can be thought to have had the expected effect on participants within the context of threatening stimuli evoking differences in the early time window rather than the late. Furthermore, the waveforms in *Figure 4* illustrate this claim quite nicely, where visual inspection suggests that effects exhibited by the stimuli occur more in the early window rather than the late.

Within the context of this thesis, one of the more exploratory findings was the supposed effect of facial age. The facial age of the face stimuli proved to have significant interaction effects with time and FWHR. Given that the main theme of this experiment has been threat, there are different kinds of explanations of why the perceived facial age has had an effect. One is the older faces might exhibit a demonstration of genetic superiority. This, however, is outside the scope of this thesis and would require follow-up studies to investigate what kind of an effect that might be present.

The P3 time window did, however, exhibit the strongest effects of the stimuli, with both expression and FWHR and the interaction between them resulting in significant results. Even if the main effect of FWHR was not supported in the post-hoc analysis of the LPP as it was only significant in the P3 time-window. While the P3 is outside of the scope of this thesis in regard to its hypothesis and background, it is still interesting to bring up as a point because of the conflicting results between the P3 and the LPP. If this study's result gives conflicting support for the FWHR as an honest signal of cue of threat in the LPP, but an effect is occurring in the P3, it might mean that the FWHR has another kind of effect than previously thought. Going on just the post-hoc analysis of the main effect results, it can be interpreted that FWHR has an effect in the earlier stages of face processing. This, since what we can be fairly certain is a cue of threat, the angry face, is seen to have an effect from the P3 and onwards while the FWHR only has interaction effects in the LPP but the main effect is supported in the P3. This might indicate that the FWHR is not a signal of threat but something else, what this something else might be is subject for future research and investigation. Continuing on the P3, visual inspection of the waveform (*Figure 4; Figure 6*) seems to be consistent with previous literature regarding the P3 and individuals with higher trait aggression (Patrick, 2008). This is because the P3 for the high aggression group seems to be diminished when compared to the low aggression group, as well as the early LPP seem to be more augmented for the high aggression group. Even though the effect of either aggression group or reactive aggression group (group assignment based on anger & hostility sub-categories) was not found to be significant for the P3, the waveform seems to be in the direction expected when comparing to other literature within the subject.

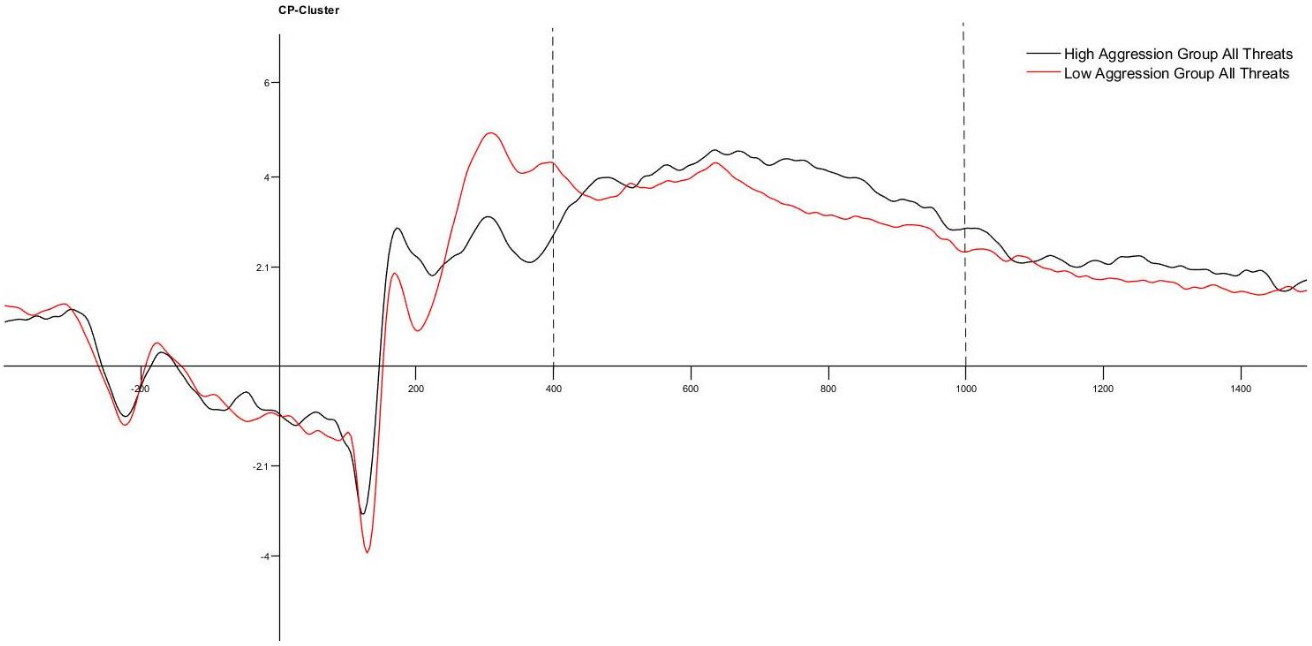

Figure 6: Waveforms across aggression groups for all threatening faces (anger, high FWHR, or both present) with outliers removed. Vertical lines at 400 and 1000 indicate the start of the early and late time windows, respectively.

Distinguishing the P3 away from the LPP might seem somewhat counterintuitive, as the P3 is often associated with the LPP in terms that an augmented P3 should follow emotional stimuli preceding an augmented LPP (Hajcak et al., 2010). However, this does not necessarily mean that the P3 is an ERP component sensitive to emotional information. It is argued that the P3 is augmented in response to attention catching stimuli, such as when something novel is introduced, or it is relevant to a task (Luck, 2014). Furthermore, the P3 is not augmented when a stimulus fails to capture attention (Hajcak et al., 2010). Hajcak et al (2010) argue that emotional stimuli are automatically attention capturing, thus emotional stimuli should elicit an augmented P3. To equate the LPP as an extension of the P3 even more, similar scalp regions are of interest when investigating the P3, i.e. central and parietal areas, thus making the distinction between them more vague, as one might say that the LPP is just an extended P3 (Hajcak, 2010; Luck, 2014). However, the neural origins of the two ERP components seem to only differ slightly from each other. While previously discussed in the background, the different neural origins of the LPP seem to be driven by emotional processes in frontal, temporal and parietal areas, while the P3 has been associated with attention-related frontal and attention-related temporoparietal regions (Liu et al., 2012; Polich, 2007). Arguably, it is possible that the neural origins of the P3 and the LPP stem from similar neural systems, or at the very least systems with close proximity to each other. The aspect that would separate them is the correlation of the P3 with attention, as the LPP is not typically associated with paradigms investigating the attention aspects of the P3, such as the *oddball paradigm* (Luck, 2014). The case of high trait aggression individuals might provide some further insights into this distinction. Furthermore, it is argued that individuals with higher trait aggression should exhibit diminished P3 responses towards aversive stimuli and that the same individuals are more sensitive to the same kind of stimuli, i.e. stronger emotional responses (Anderson & Huesmann, 2003; Patrick, 2008). This distinction between P3 and LPP would have been made even stronger should the results from this thesis have been significant between the aggression groups. Looking at *Figure 6*, the high aggression group waveform follows this pattern of diminished P3 but augmented LPP. Therefore, future investigations of trait aggression might provide further insight into how both the P3 and LPP relate to each other as trait aggression might co-occur with one component in one way opposite to the other.

The non-significant effect between reactive aggression groups did not follow what could be expected based on previous literature. If previous literature is correct, then the strongest associations should be seen between individuals exhibiting the highest scores on anger and hostility sub-categories rather than the lowest scorers on the same categories (Buss & Perry, 1992; Coccaro et al., 2007; Murray-Close et al., 2010; Patrick, 2008; Siegel & Victoroff, 2009). Given that no effect regarding trait aggression was seen to be significant across the entire analysis, it is hard to determine whether this notion should reach significance or not. It is possible that the same reason as to why the main hypothesis was not supported is present when changing the grouping variable from total score to sub-score.

The hypothesis – why was it not supported?

There are multiple possible explanations as to why the hypothesis was not supported by the data collected. The first explanation as to why no significance was reached in the analysis is because of the sample. As already previously discussed there is reason to believe that the high aggression group in this experiment might not have been a *true* high aggression group. Therefore, the co-occurrence expected to be exhibited by the hypothesis is too small for statistical analysis to support it. The sample might also have not been optimal for grouping using aggression as a factor, as students are not stereotypically aggressive the entire sample might be considered as a low aggression population. Given the high variance that comes with electrophysiological data together with a plausibly weak association can have resulted in a false negative.

Another explanation is that the association stated by the hypothesis is much smaller than expected. Should the association be a very weak association with the LPP it need not matter that the sample might be considered as low aggression sample, rather a higher number of participants would be required to achieve the statistical power needed for the association to show any significance. This point, together with the section previously mentioned goes hand in hand. As the sample increases in size, the samples aggression scores will have a better distribution around the *true* mean rather than being skewed in one direction. This is, of course, relative to if the sample can be considered to be skewed to begin with.

A final explanation might be that the hypothesis is inherently false. That the response towards social cues of threat does not differ between on an individual’s aggressive tendencies or that it is in the opposite direction towards what the hypothesis states. As it has also been sown that a low baseline emotional arousal seems to lead an individual to behave more aggressively (Anderson & Huesmann, 2003). However, higher trait aggression seems to imply both lower baseline arousal as well as an increased sensitivity to incoming aversive stimuli (Patrick, 2008). It is hard to imagine that the response expected to be expressed by the high aggression group for this experiment, or any high aggression group, to be nullified by a lower overall baseline level of emotional arousal. The waveforms in *Figure 4* seem to be in-line with what can be expected from a high aggression group, i.e. a diminished P3 followed by an augmented LPP. Therefore, it suggests that the reasons as to why no significance was found lies at the statistical level rather than the non-existence of the proposed co-occurrence stated by the hypothesis.

Outlier

Electrophysiological data might be under less scrutiny when it comes to statistical outliers, such as the one discovered in *Figure 3*, as electrophysiological data usually undergoes several processing steps, such as ICA and MARA, which is thought to counteract possible confounds that might skew the data. However, in this study, it seems like one participant did skew the data significantly. An intuitive inspection of *Figure 2* suggests that a possible interaction effect of aggression group might be in effect, although in the opposite direction of the hypothesis which is not problematic in and of itself. The corrected waveform in *Figure 4* suggests that if any significant effects were able to be found the direction of the effect would be opposite of *Figure 2*. Furthermore, scalp distribution for the LPP, *Figure 5*, suggests that the outlier was skewing data in a way that was atypical for the LPP. Scalp distribution for *Figure 5: A* shows typical LPP progression of the LPP up until the late (1000-1500 ms) portion of the LPP, where the scalp distribution revealed that the highest activity was recorded 3 quarters of the circumference around the edge of the head (clockwise from right ear to the nose). *Figure 5: B* pre- (0-400 ms) and early (400-1000 ms) LPP is similar to *Figure 5: A* but differs in the late window. The *Figure 5: B*'s late portion can be considered a more representative scalp distribution for the LPP in line with previous research than *Figure 5: A*'s late scalp distribution (Schupp et al., 2004**)**.

Sample

The next point for discussion is the level of trait aggression within the sample. To be able to make comparisons to other studies the total score of other studies, that have been using the full 29-question version or a five-point scale, or both, has been translated to be comparable with this thesis. However, caution is advised in these comparisons as a five-point scale allows for a neutral middle whereas a six-point scale used in this thesis forces the participant to either choose an answer indicating aggressive or non-aggressive tendencies. There are reasons to use either, however, given the forced decision a six-point scale implies it allows for an easier distinction between high and low-aggression groups (Bryant & Smith, 2001).

When presenting means during this discussion that stem from another article, it will be the translated value that will be presented, which is not entirely accurate for reasons given above. The mean aggression score for this sample was 29.9 ± 8.4 whereas other samples, when translated, has been at 36.24 and 30.648 (Buss & Perry, 1992; Diamond & Magaletta, 2006). To make a strict comparison, this sample's high aggression scorers (mean ± SD: 34.64 ± 2.) mean is lower than Buss & Perry's (1992) total mean (36.24). This calls the validity of this thesis' high aggression group into question as one can regard the entire sample as being low in trait aggression when comparing it to another sample.

However, Diamond and Magaletta's (2006) samples mean (30.648) is close to this samples mean (29.9), and even though they are close in total score, the sample populations' overall trait aggression can be thought to differ. In this thesis the sample consisted of both Swedish and international students, and the 2006 sample discussed by Diamond and Magaletta (2006) consisted of newly incarcerated federal offenders. Taking the sample population into account, this thesis sample aggression level is similar to trait aggression levels of criminals. This might give reason to believe that the sample recruited for this thesis is disproportionally aggressive as compared to other samples. Intuitively, there should be an expected difference in aggression levels between these two sample populations with higher aggression levels exhibited by federal offenders. There are however methodological differences between the samples which might affect cognitive aspects behind the reasoning for each question on the questionnaire. In the Diamond and Magaletta (2006) study the aggression questionnaire was part of a larger mental health survey. If aggression is within the context of mental health for a person which her mental condition is a basis for the levels of freedom within a freedom-constrained environment, there is reason to believe that motivation to willingly score lower might come into effect. However, the same thing can be considered using this thesis sample. Intuitively, there might be negative conjugations for people to score high on questions that measure aggression, especially for socially sensitive young adults (Blakemore & Mills, 2014).

There might also have been linguistic reasons as to why trait aggression levels within this sample are within scrutiny. In the Diamond and Magaletta (2006) study, the differences between the questions *Given enough provocation, I may hit another person* (mean: 2.61) and *There are people who have pushed me so far that we have come to blows* (mean: 3.02) are not as big as exhibited within this thesis's sample (mean: 1.59 & 2.74 respectively). These two questions are very similar, but they differ in their temporal nature. The former of the two questions is before the fact and forces the participant to appraise if the stated action fits with their character in response to provocation. The latter question is after the fact, i.e. that the situation described has happened to them. However, the stimuli described in both questions are similar to each other as they are both in response to some kind of provocation. Given that the questionnaire was given in a language which is likely the native language in the Diamond and Magaletta (2006) study and was not the native language of any participant in this thesis sample might give rise differences in English-speaking skills. It might be the case that English-speaking skills have interfered with the validity of the aggression questionnaire for this thesis sample and therefore larger differences in similar questions, such as the two stated above, is displayed. Additional evidence for language effects on the questionnaire exists, anecdotally, from some participants failing to perform the task during the EEG-section of the experiment even though unambiguous written instructions were given. However, since participants were recruited on the basis of being students, domestic or international, the degree of English-skills should exhibit a floor-effect due to English-skills required to partake in higher education.

Regardless of plausible critiques of the validity of the aggression scores for this sample, the total aggression scores did differ significantly between the two groups ($P < 0.001$) and can hence be thought to differ from each other on the accounts of trait aggression between the groups. Thus, the categorization of high vs. low aggression groups might, therefore, be the concept under scrutiny, as the high aggression group cannot be validated as being a true high aggression group, rather it is a relatively high aggression group.

Limitations

There are several possible limitations to this study. First is that the alleged high and low aggression groups are not true high and low aggression groups could have an effect on the results. Given the generally low reliability of the sf-BPAQ in this sample when tested (12 items; $\alpha = 0.665$), the validity of the groups becomes compromised. This, together with the discussion of the sample under the section *Sample* provides a basis for scepticism of the proposed high and low aggression groups.

Participants were also allowed to listen to preferred music during the EEG-recording, which might provide possible confounds regarding the results. There is however a tradeoff between allowing music and boredom. Luck (2014) argues that the potential confounds brought by boredom and tiredness that arise when participating in an EEG-experiment are larger than the possible confounds introduced when allowing participants to listen to music. Therefore, the possible confounds should be mitigated when allowing participants to listen to music during the experiment in contrast to possible confounds brought on by boredom.

All of the faces presented to the participants during this experiment was artificially generated through the use of a computer program. This might result in a lack of authenticity of the stimuli. Previous studies have more commonly utilized photographs of real people when inducing a cue of threat in participants (Fox et al., 2000; Hansen & Hansen, 1988; Schupp et al., 2004). It is possible that the association hypothesized in this thesis did not achieve statistical significance due to the effect being mitigated by non-authentic cues of threat.

The presence of the outlier (*Figure 3*) provides further possible limitations. When comparing to previous studies, the scalp distribution in the late time window in *Figure 5: A* looks atypical for the LPP (Schupp et al., 2004). It is hard to know if this atypical scalp distribution was the result of an atypical participant or if it was an error in data-processing steps. If it was the former, rejecting this participants data should make the average scalp distribution across all participants look closer to the expected pattern, which it did (see *Figure 5: B*). If it was the latter, it might be that the entire sample's data had been skewed and the rejection of the participant did not matter as the entire sample's data was affected by the same type of error in data-processing steps.

The existence of gender differences was discussed in the background response towards threats as well as general trait aggression (Goos & Silverman, 2002; McClure et al., 2004; Van Vugt, 2009). However, for the current hypothesis, gender differences were neglected in favour of sf-BPAQ scores. A better way to control for possible effects arising from the differences between males and females would have been to distribute the two genders equally across the two groups.

Since this study favoured sf-BPAQ scores and a median split of those scores and neglected the background variables of the participants it is possible that gender and age are possible confounds. While the mean age between the two groups used in this study were fairly similar, 26,67 and 28,25, the gender distribution was not optimal. The low aggression group contained eight males and four females while the high aggression group contained five, originally six but one was removed due to being an outlier, males and seven females. To minimize any confounding effect of gender differences it would have been better to have made median splits for each gender group individually on sf-BPAQ scores and after that assigned the highest scoring females and highest scoring males to the high scoring group. Given that the total number of males were 13 and the total number of females were 11, the optimal groups would have been seven males and five females in one group and six males and six females in the other. Although the gender distribution did not differ significantly, there is still the possibility that it could have affected the results and the group division could have been conducted in a more optimal way.

A limitation that can be seen quite clearly in *Figure 4* is possible overlap effects. The baseline period of the waveform is quite steep approaching the stimulus onset and might therefore affect the subsequent waveform. Research literature indicates that the late positive potential can extend up to several seconds after stimulus onset, thus possible overlap effects are quite likely occurring in this experiment (Hajcak et al., 2010).

Conclusion and direction for the future

To conclude, I suggest that there is some reason not to throw away the hypothesis all together since the group sizes were relatively small for comparisons with electrophysiological data and psychological distinctions between high and low aggression groups. Looking at the waveform in *Figure 4* there might be possible effects occurring especially in the P3 time window. However, should such an effect be explored the method for it ought to differ from the one used in this thesis as there are probably more efficient ways to induce cues of social threat when focusing on the P3. However, should an effect not be found where aggressive tendencies are associated with the LPP or P3 as responses of cues of social threat, the emotional and functional components of aggression might need to be reconsidered. As aggression is one way to deal with threats arising from our environment and emotional arousal is also correlated with being exposed to threats, the non-existence of any co-occurrences stated by the hypothesis sounds unlikely as aggression and emotional arousal seem too related to each other to not be associated with each other in any direction (Lickley & Sebastian, 2018).

Further investigation within the field of FWHR is also suggested. Given that post-hoc analysis of the main effect for FWHR was not found to be significant within the LPP time-window but was significant for the P3 time-window, its robustness as a cue of threat comes into question. It is, furthermore, likely that the hypothesis for this experiment would be better investigated neglecting FWHR altogether because it might be that FWHR is not as a strong of cue of social threat as emotional expression and therefore would require to be more thoroughly investigated without other experimental variables such as age or expression.

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Supplementary material

Aggression Questionnaire questions:

1. Physical Aggression:

    1.1. Given enough provocation, I may hit another person.

    1.2. There are people who pushed me so far that we came to blows.

    1.3. I have threatened people I know.

2. Verbal Aggression:

    2.1. I often find myself disagreeing with people.

    2.2. I can’t help getting into arguments when people disagree with me.

    2.3. My friends say that I’m somewhat argumentative.

3. Anger:

    3.1. I flare up quickly but get over it quickly.

    3.2. Sometimes I fly off the handle for no good reason.

    3.3. I have trouble controlling my temper.

4. Hostility:

    4.1. At times I feel I have gotten a raw deal out of life.

    4.2. Other people always seem to get the breaks.

    4.3. I wonder why sometimes I feel so bitter about things.

Faces:

All faces were created based on the same face, each variable were then added upon previous variables in this order: Default face → FWHR → Angry Expression → Age. To create faces without a specific variable changed, example low FWHR young angry face, skip irrelevant steps.

Steps in Facegen Modeller Core 3.18:

Neutral face/base for other faces:

Use the average settings that follows from [new] [racial - any] [male] with skin texture nr. 24.

High FWHR:

Step 1. Set “brow ridge high/low” to 6
Step 2. Set “brow ridge inner” to -6
Step 3. Set “brow ridge outer” to 4
Step 4. Set “Jaw - thin/wide” to 2

Step 5. Set “Jawline - concave/convex” to -2
Step 6. Set “Cheekbones - thin/wide” to -5
Step 7. Set “Cheekbones - thin/wide” to 4

All of these steps change the values of other variables, do it in specified order to achieve the metrics used.

Angry Expression:

Brow Lowerer = 5

Upper lid raiser = 10

Lips toward each other = 6

Nose wrinkler = 4

Upper lip raiser = 3

Lip tightener = 4

Jaw clencher = 10

Expression anger = 2

Expression sneer = 2

Modifier browIn left = 1

Modifier browIn right = 1

Modifier eyes wide = 10

Phoneme BMP = 3

The values for expression do not change when another value is altered, and the order of when which is altered can be at random.

Age:
Set the Age-slider to its maximum and change the skin texture to texture nr. 24.