Is trouble coming your way? Exploring the neurocognitive mechanisms to assess threatening body language in men

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List of contents

Tables

Figures

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Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas, and contributions from the work of others.

Any ethical clearance for the research presented in this commentary has been approved. Approval has been sought and granted through the Researcher's submission to Northumbria University's Ethics Online System.

I declare that the Word Count of this Thesis is 40,171 words

Name: Connor Leslie

Date:

COVID statement

Before presenting this programme of work, the impact of COVID-19 will be discussed.

The COVID-19 lockdown started five months into my PhD, meaning studies I had initially planned had to be altered or were cancelled. Originally, a qualitative study with police officers was planned, and while two participants were interviewed, recruitment proved to be difficult due to the extra work that was asked of them during the pandemic. Secondly, while stimuli development for study two began prior to the pandemic, fewer men were recruited than planned as in-person data collection could not continue. Finally, due to the lockdowns, all in-person data collection was pushed back until my third year, meaning study three and four’s stimuli development and ratings were still being collected 3 weeks before the submission date, meaning biomechanical analysis was not possible on these data sets.

Abstract

Background and Objectives: Literature from a number of domains suggests that intrasexual selection has been a strong mechanism in shaping men's traits and behaviour. Due to the physical conflict that men have historically engaged in with each other, it is theorised that we have developed cognitive mechanisms to assess physical dominance from a variety of cues. The aims of this thesis are to understand how physical dominance is encoded into the walking gait of men, and investigate how observers decode these cues.

Design: All studies were quantitative and contained two stages, a stimuli creation and ratings of the stimuli. Stimuli creation utilised motion capture techniques to gather movement in a precise and digitised way. This involved placing 39 retroreflective markers on the major joints of the body to capture each body segment with six degrees of freedom. These were transformed into featureless avatars using professional animation software to ensure that anthropometric or other visual features (e.g., build, weight, hair, clothing) were not on display.

Methods: Stimuli was presented to participants across four studies to rate on physical dominance and likelihood of crossing the road to avoid the man.

Results: It was found that ratings of physical dominance had a consistent link with the strength and physical size of the man, where stronger and physically larger men were rated higher in physical dominance and were more likely to be avoided if they approached the observer on a dark night. Preliminary biomechanical analyses suggests that a pendulum-like movement between the mid-hip and mid-back strongly increased perceptions of physical dominance. Participants were also able to differentiate between baseline and threatening walks in studies three and four, suggesting that men alter their movements when confronting an opponent.

Conclusion: Overall, the findings suggest that men alter their movement when acting in a threatening manner, their build is clearly encoded into their gait, and the amount of swing in their motion may be a key factor in observer's perceptions of their dominance. Together, this thesis provides vital new

knowledge into our understanding of how men have evolved to display physical dominance and that we can decode these cues and take action.

Introduction

Charles Darwin's (1859) theory of natural selection permanently changed the face of science. This theory posits that species evolve as an adaption to their environment. Traits that aid survival, no matter how small, are therefore passed to the next generation.

Darwin (1859) however also observed that certain species had traits that did not align with his concept of natural selection. An example of this is the extravagant and physiologically costly male peacock's (*Pavo cristatus)* tail. This hinders both dexterity and speed, therefore making him more vulnerable to predators. Natural selection would suggest that this feature would be phased out as it is clearly costly to produce and maintain, and puts him at a distinct disadvantage when evading predators. Despite this, the tail is selected for which led an initially puzzled Darwin to conclude that separate pressures of mating were at play. Thus, the theory of sexual selection was born. Sexual selection is further divided into two distinct concepts: intersexual selection, and intrasexual selection.

Intersexual selection theorises that the preferences of the opposite-sex are pivotal in the development and continued lineage of traits and behaviours that aid in reproductive fitness. Initially, this was thought to be the primary mechanism that acted upon the development of men's traits (Kordsmeyer et al., 2018). This is further supported by the sheer number of papers citing intersexual selection in the evolutionary psychology literature. Puts (2010) discovered that 55 out of 73 papers published in *Evolution and Human Behaviour* and *Human Nature* from 1997 to 2007 regarding human sexual selection concern focused on human mate choice. However, mathematical modelling by Hill et al., (2013; 2017) suggests that in reality, intrasexual selection (specifically in men) likely plays a more significant role than female choice.

Intrasexual selection involves the competition between members of the same sex, which in turn drives the development of traits and behaviours that aid in such competition. Recent estimates suggest approximately 44% of sexually selected traits are intrasexually selected and used for male contests within the animal kingdom (Wiens & Tuschhoff, 2020). Contests can be viewed as joint displays of male physical dominance, where one can either engage in combat, demonstrate prowess and dominance to force a retreat, or retreat themselves to avoid injury or death. To demonstrate their physical dominance, some species have evolved weapon-like traits. Stags (*Cervidae*) antlers are incredibly costly to produce and maintain (Kodric-Brown & Brown, 1984), with Bubenik (1990) suggests that it takes a staggering 3-5 times more than their standard intake of calcium and phosphorus to produce even a modest set of antlers. While they are costly to maintain, they are clearly beneficial in combat. Antler bone is an incredibly tough material, which makes it difficult to fracture in high-impact collisions that occur in combat (Launey et al., 2010).

Similarly, male fiddler crabs (*Uca annulipes*) have an enlarged claw to threaten potential opponents (Jennions & Backwell, 1996). Furthermore, certain species of lizards, such as the anoles (*Anolis*), perform a 'push-up like' action with their front legs when meeting a potential opponent, showing they are physically fit, capable of inflicting damage, and appearing significantly larger (Rosier & Langkilde, 2011). Chimpanzees (*Pan troglodytes*) and gorillas (*Gorillas*) also display cues of intimidation (Tutin et al., 1991), including lip smacking to make their faces appear more aggressive, and the elongation of their bodies to increase perceived size (Dixson, 1977). These weapons and changes in posture suggest that within the animal kingdom, species have evolved to display their physical dominance to a potential opponent. These intrasexually selected traits are not seen purely within the animal kingdom, but also in humans.

Evidence of the theory of intrasexual selection can be seen in the sexual dimorphism between men and women. Men have on average 61% more muscle mass than women (Lassek & Gaulin, 2009). Specifically, men have 75% more arm muscle mass and 50% more lower-body muscle mass than women (Abe et al., 2003). Translating this to physical strength, on average, men have 90% more upper-body strength, and 65% more lower-body strength than women, showing clear differences between the sexes (Lassek & Gaulin, 2009; Mayhew & Salm, 1990). In fact, Lassek and Gaulin (2009) found when comparing men and women, 99.9% of women in their sample fall below the average man on upper-body muscle mass and strength. Puts (2010, p. 161) summarises this by stating that "men are larger, stronger, faster, and more physically aggressive than women, and the degree of sexual dimorphism in these traits rivals that of species with intense male contests". These sex differences show an evolutionary advantage for men when it comes to combat.

While increased body mass and strength suggests that men are more equipped to engage in physical conflict, sex differences also appear in facial composition which could be beneficial in surviving combat. On average, men have more robust jaws and brow ridges than women, which likely evolved to survive the frequent physical blows to the skull, and to prevent cranial fractures (Carrier & Morgan, 2015; Puts, 2010). Cranial fractures are a common injury for example, Brink (1998) examined 2432 bodily injuries in 1156 men and 325 women over a one-year period in Denmark and found that 69% of the injuries included a craniofacial injury. Therefore, the differences between men and women in their facial structure makes sense, as women are far less likely to engage in physical aggression, and when they do, they sustain fewer cranial injuries than men (Carrier & Morgan, 2015; Daly & Wilson, 1988).

Men and boys are also more physically aggressive than women and girls. In a meta-analysis reviewing the sex differences of aggression, Archer (2004) concluded that sex differences were highest for men in both physical aggression and verbal aggression and these differences are reflected in reported crime statistics. Within England and Wales from the year ending March 2019 to the year ending March 2021, the majority of the suspects (94%) convicted of homicide were men (Office for National Statistics, 2021). Furthermore, this report shows that men who were victims of homicide also increased 50% from the year ending March 2015 to the year ending March 2018. While these numbers have decreased 16% in the last year, the number of men's homicide victims are still at a higher level than women's homicide victims (416 compared to 117 respectively). These statistics are replicated worldwide, with 95% of those convicted of homicide being men (Gibbons, 2013). The authors also show that when looking at homicide rates split by continent, 82% of those convicted in Europe were men, in Asia, men made up 95% of the homicide rates, and 96% in the Americas. Men also make up the majority of homicide victims: in Europe, 72% of victims were men, 71% in Asia, 88% in the Americas, and globally, men were victims of homicide in 79% of the documented cases (Gibbons, 2013).

These gender differences are not only present in homicide. In Australia for example, in men who experienced physical assault, the perpetrators were mostly men (77%), with results echoed for female victims (70%) (Australian Bureau of Statistics, 2022). It is a similar story with threatened assault, as the report shows men being the perpetrator of 80% of the reported face-to-face threatened assaults against men and 65% of the reported face-to-face threatened assaults against women. Furthermore, within the United States, men accounted for 80% of the people arrested for violent crime (FBI, 2014). To summarise, Wright, (1995, p. 72) states, “From an evolutionary point of view, the leading cause of violence is maleness.”

Due to the clear physiological advantages men have with regard to physical combat, it would be advantageous to have cognitive mechanisms with which to assess the physical dominance of opponents. Physical dominance in this context is defined as the ability to win a fight, with those high in physical dominance being more likely to win a fight than those low in physical dominance (Archer, 1988). Engaging in a physical fight, regardless of outcome, can be costly in terms of energy and can result in serious injury, or in extreme cases, death (Hill et al., 2017).

While the majority of conflict involves men on men violence (ONS, 2021), there is still an advantage for women to detect physical dominance in men. Sell et al., (2021) discusses that while most conflict is between men, women’s mate choice may be influenced by factors relating to a mans fighting ability (Fink et al., 2007). As having a mate who can win and survive fights is beneficial, possessing a cognitive mechanism to assess physical dominance would be beneficial for woman. Furthermore, while the majority of violence is men on men, men engaging in physical conflict against women is not unheard of. In the year ending March 2022, 2.2% of men were victims of violent crime, yet 1.6% of women were also victims (a number which the ONS believe to underestimate the amount of women victims, ONS, 2022), further showing the benefit of possessing a cognitive mechanism to assess physical dominance in men.

While it is clear that it would be beneficial for both men and women to possess a cognitive mechanism to assess physical dominance, there may be a difference in how physical dominance is perceived. Literature has repeatedly shown that whilst men are more likely to be a victim of crime in most categories (barring crimes of a sexual nature and domestic violence) women are more fearful of becoming a victim of crime (Fisher, 1995; Jennings et al., 2007; ONS, 2021). Furthermore, Fetchenhaur and Buunk (2006) found that on average, women were more fearful of events that might imply a physical injury compared to men, with Barberet et al., (2004) finding that college-aged women were particularly more fearful of physical violence, sexual assault, and stalking compared to men college students. This could mean that while men and women both possess a cognitive mechanism to detect physical dominance, women may rate physical dominance as higher than men, due to their higher fear. This theory will be examined further within the thesis.

In summary, whilst the animal literature appears to be both extensive and clearly aligned with intrasexual theory, the literature concerning men appears somewhat fragmented with ambiguities in terminology, domain (evolutionary psychology, social psychology, human ethology etc.), and methodology. Therefore, a systematic review was conducted as an attempt to consolidate the relevant research in the area, and gain a better understanding of intrasexual selection's influence on men's traits and our ability to detect them.

Systematic review

Methods

Criteria

The review criterion was studies focusing on physically dominant traits in men. As physical dominance can be a broader term, it was decided to use the traits discussed by Hill et al., (2017) to provide a framework for this search. These terms were dominance, strength, fighting ability, size, and masculinity. To understand our ability to assess these traits in others, search terms relating to the body, face, voice, and movement were used. Papers were required to be written in English and have the full-text available to the researcher.

Search strategy

PsycINFO, Web of Science, and SCOPUS were used as search engines. The terms: 'Dominan*' OR 'Strength*' OR 'Fighting ability' OR 'Size' OR 'Masc*' WITH 'Face' OR 'Body' OR 'Bodily' OR 'Vocal' OR 'Voice' OR 'Movement*' OR 'Biological motion' OR 'Gait' OR 'Body language' were initially searched in December 2021. As a substantial amount of animal studies were returned, 'Human' OR 'Man' OR 'Men' OR 'Male' were added to the search terms.

Literature search

The initial search returned a total of 28,606 papers. After an initial title review by the researcher, this was reduced to 202 papers. An abstract review further reduced this to 89 papers, which had their full texts reviewed in relation to the inclusion criteria and any duplicates were removed. This resulted in 49 papers (which included 114 studies in total), which were then screened by an additional two members of the research team, however no further papers were excluded (See Figure 1 and Appendix A).

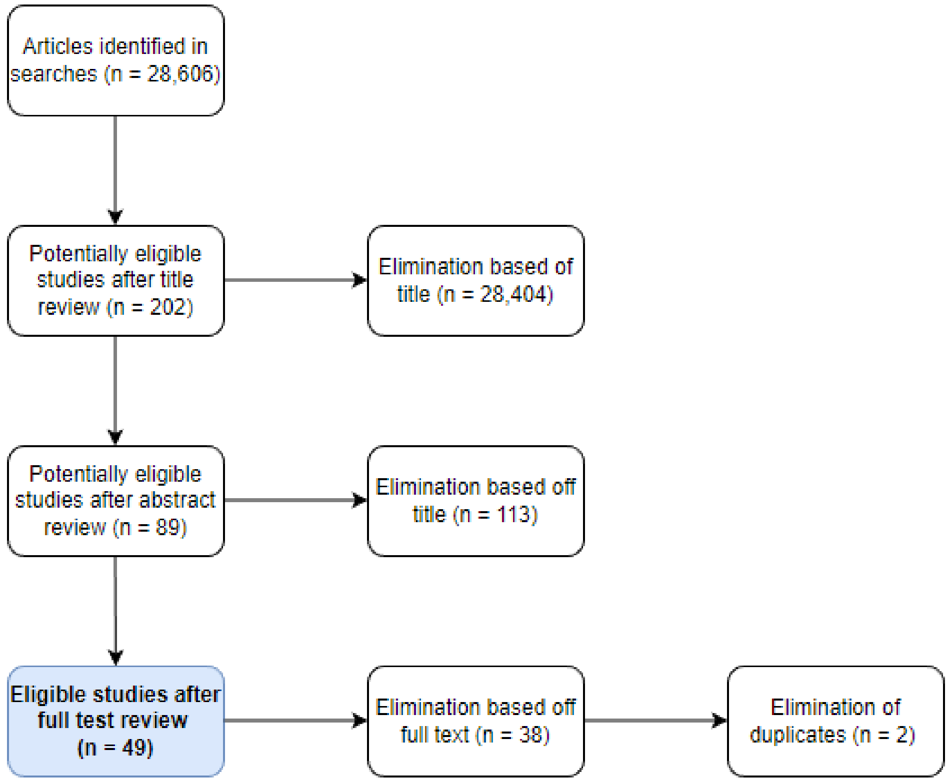

Figure 1: Flow chart of study selection

Results

Vocal stimuli

Nineteen of the papers used vocal stimuli to assess physically dominant traits in men (see Table 1), totalling 38 studies. This involved vocal recordings of both natural (N = 22) and digitally manipulated (N = 16) recordings. Puts et al., (2006) told 111 men they were competing with another man for a lunch date with a woman. The task to win the date was to explain to an unseen opponent why they might be admired or respected, and this speech was recorded to create the stimuli. Naïve participants then rated each voice on how physically dominant the speaker was. Results suggested that speakers with masculine, lower pitched voices received higher ratings of physical dominance compared to those with higher pitched voices. Additionally, the speakers who perceived themselves to be more dominant than their opponent lowered their voice pitch when making their speech, whereas speakers who perceived themselves to be less dominant than their opponent raised their vocal pitch.

The concept that a lowered voice pitch is perceived to be more physically dominant has been supported by other studies with similar methodologies (Hodges-Simeon et al., 2010; Puts et al., 2007). Saxton et al., (2016) investigated dominance ratings from vocal stimuli alongside varying levels of facial hair in facial photos of the speakers. It was found that lower pitched voices were perceived as higher in physical dominance, and that higher levels of facial hair also increased perceptions of dominance. While this study further lends support to the link between lower vocal pitches and higher levels of perceived physical dominance, it also suggests that facial hair may be used as a cue to signal dominance.

Whilst previous research suggests that lower pitch is associated with higher levels of physical dominance, the characteristics of the listener may also influence these ratings. Wolff and Puts (2010) investigated perceptions of men's voices across two studies. The listeners in the study provided a rating of their own dominance as well as testosterone samples. Participants then rated the voices on several dimensions, including physical dominance. Men who rated themselves as high in physical dominance rated the voices of the speakers lower in dominance. Furthermore, there was also found to be an effect of testosterone, wherein men with either naturally high or low levels of circulating testosterone rated speakers as more dominant than men with intermediate levels of testosterone did. These findings suggest that our perceptions of physical dominance do not occur in a void, and that other contextual cues such as the relative dominance of the listener, also play a vital part in these perceptions.

There is also evidence that we can accurately assess strength from vocal recordings (Sell et al., 2010). Vocal recordings from Americans, Tsimane Indians, Argentinians, and Romanians were collected, with the findings showing that perceptions of strength were accurate for both familiar and unfamiliar languages to the listener. This led the researchers to suggest that portrayals of strength from vocal cues may be universal. This would be beneficial to aiding survival in a situation where the listener may be unfamiliar with the language, but they can gain enough cues to assess the potential danger. Further support that strength can be portrayed via vocal cues comes from Raine et al., (2019). Across three studies, different vocal cues were recorded: aggressive speech and non-verbal noises, and dismissive speech and non-verbal noises from 61 men of varying strength. Participants accurately judged differences in strength and did so most effectively from the aggressive voice stimuli (both speech and non-verbal). Furthermore, listeners more accurately judged strength from roars (non-verbal noises) than from aggressive speech. This further supports the notion that men are able to portray their strength via their vocal characteristics.

There has been an extensive body of research conducted into our ability to assess physical size from vocal cues. Early research found that vocal cues can indicate a range of anthropometric features, such as shape, size, and weight (Evans et al., 2006). This was supported by Pisanski et al., (2014), who found that when listening to men's vocal recordings, listeners were able to accurately assess physical size, even though there was no relationship between pitch and physical size. These findings were echoed in another study that found early blind, late blind, and sighted participants were able to accurately assess physical size from vocal cues (Pisanski et al., 2016). Pisanski then built on this by presenting vocal recordings of men to participants and asked them to rate their physical size (Pisanski et al., 2017). Men with lower pitched voices were perceived to be physically larger than those with higher pitched voices, further supporting the concept that men with lower pitched voices are perceived to be higher in physical dominance.

As well as increasing perceptions of physical dominance, lower pitched voices also appear to increase perceptions of masculinity. Masculinity tends to be defined as a social construct (Kimmel, 1987), with Cartei et al., (2014) arguing its connectedness to sexually selected traits, such as large jaws and broader shoulders. Cartei et al., (2014) found that men who were physically taller and had higher levels of circulating testosterone also had lower vocal pitches. Furthermore, these physically larger men were rated as more masculine, a finding supported by Pisanski et al., (2012) who discovered that men's voices that are perceived as more masculine are also perceived as being physically larger.

Similarly, lower pitched voices have been found to have an impact on perceived threat (Zhang et al., 2021). When using the manipulated vocal recordings of one man, participants rated an artificially lower pitched voice as more likely to have aggressive intent than the same man with an artificially higher pitched voice. This finding has been repeated cross-culturally using vocal recordings from American and Hadza populations (Puts et al., 2012). When analysing vocal parameters, it was suggested that individuals are able to portray their threat potential in their voices, as different vocal parameters were found to be related to at least one measure of threat (height, testosterone, physical aggression, weight, and arm strength).

When assessing fighting ability (a term frequently used interchangeably with physical dominance), Aung et al., (2021) presented participants recordings of men's speech patterns. It was found that the speakers height and vocal tract length significantly predicted ratings of fighting ability. Taller men with longer vocal tract lengths were rated as having better fighting ability, suggesting that men's vocal pitch can transmit information about their fighting ability. However, Doll et al., (2014) found that when presenting vocal recordings and facial photographs of men, there was a significant correlation between facial photographs and ratings of fighting ability but not with vocal recordings. These findings are echoed by Han et al., (2017), who presented participants with facial photographs and vocal recordings of men and found that physical size was positively correlated with perceived facial threat, but not vocal threat perceptions. Furthermore, Sebesta et al., (2019) recorded speech and roars from amateur mixed martial arts (MMA) fighters. Participants rated the vocal recordings on perceived formidability (a concept similar to physical dominance, where the traits related to resource holding potential are linked to size and strength, Fessler, 2012), and no link was found between height, weight, physical fitness, or perceived formidability from either vocal recording. There was also no link between perceived formidability and actual fighting success. However, lower pitched speech was rated as more formidable than higher pitched speech, but higher pitched roars were more formidable than lower pitched roars. The findings of these studies suggest that vocal stimuli may not be the most valid or reliable cue to threat, and that facial features may in fact display physically dominant attributes more accurately.

Overall, research suggests a link between lower pitched voices and perceptions of physically dominant traits, and both fundamental frequency (F_0) and formant position (P_f) appearing to be predictors of multiple physically dominant traits (see Appendix A for full details). However, vocal stimuli may not be the most reliable cue when it comes to threat detection (e.g., Doll et al., 2014; Han et al., 2017). In a threatening situation, potential opponents might not speak. Therefore, there may be more reliable and salient cues for us to base our detection of physical dominance on.

Table 1: Findings from vocal stimuli

Study	Focus	Findings
Aung et al., (2021)	Physical dominance	Height and voice pitch significantly predicted ratings of physical dominance
Cartei et al., (2014)	Masculinity	Men who were taller and had higher levels of testosterone have lower F0 and format spacing and were rated as more masculine
Doll et al., (2014)	Fighting ability	Facial photos were predictive of both self and acquaintance reports of fighting ability. Voice ratings were not predictive
Evans et al., (2006)	Size	There was found to be a significant negative correlation between F0 and body ratings, showing that vocal cues can indicate body size, shape, and weight
Han et al., (2017)	Formidability	Men's actual threat potential was significantly correlated with perceived facial threat, but not vocal threat potential
Pisanski and Rendall, (2011)	Masculinity and size	Lower voicers were perceived to belong to physically larger and more masculine voices from either manipulated or natural voices
Pisanski et al., (2012)	Masculinity and size	Men voices that were perceived as masculine were also perceived to be larger
Pisanski et al., (2014)	Size	Individuals were able to assess size from vocal cues and altering pitch did not alter this
Pisanski et al., (2016)	Size	Early blind, late blind, and sighted participants were better than chance at accurately assessing who was a physically larger man
Pisanski et al., (2017)	Size	Individuals with lower pitched voices were perceived as physically larger than those with higher pitches. This can alter depending on location of the sound and listener

Puts et al., (2006)	Physical dominance	Masculine, low pitched voices increased ratings of physical dominance and men alter their vocal pitch when addressing a potential opponent
Puts et al., (2007)	Physical dominance	Lowered voices were perceived as being produced by more physically dominance men
Puts et al., (2012)	Size	Vocal parameters were related to at least one measure of male threat potential
Raine et al., (2019)	Strength	Participants accurately judged strength and height but only in certain speech patterns
Saxton et al., (2016)	Physical dominance	Lower pitched voice and higher levels of beardedness increased ratings of dominance
Sebesta et al., (2019)	Fighting ability	Perceived fighting ability was predicted by different pitches and intensities. Women gave higher ratings of formidability than men
Sell et al., (2010)	Strength	Participants gave accurate assessments of strength from known and unknown languages
Wolff and Puts, (2010)	Physical dominance	Self-rated physical dominance and testosterone levels influence ratings of physical dominance
Zhang et al., (2021)	Aggression	Men with lower pitched voices were perceived as more likely to attack

Static stimuli (face and body photographs)

The majority of the papers included in this section of the review use static stimuli (23 papers), typically involving face and body photographs (both natural and modified, see table 2). Re et al., (2014) for example, used digitally altered masculine and feminine photographs and found that when presenting pairs of faces, ratings of physical dominance can be influenced when paired with other faces. When rating a target face next to a masculine face, ratings of physical dominance decreased compared to when the target face was paired with a feminine face. More recently, Albert et al., (2021) used modified facial photographs to display masculine and feminine traits. The results showed that observers assigned higher dominance ratings to masculinised faces - even after brief exposure. These findings echo Richardson et al., (2021) who also used facial photographs of men and altered them to display masculine and feminine traits. The findings suggest that on average, younger, taller, and stronger men showed greater sensitivity to facial cues of dominance, giving further context to our ability to assess physically dominant traits. As it is men frequently engaging in physical dominance (Archer, 2004), this sensitivity provides an advantage to those engaging in conflict. Participants were also more likely to associate younger masculinised faces with physical dominance compared to older faces. Statistics regarding criminal activity may support why this may be. From March 2019 - March 2020, perpetrators of violent crimes in England and Wales were more likely to be younger men (82% of reported violent crimes had a man as the perpetrator, with 42% of them being aged 25-39 years old, and 28% being aged 16-24 years old, Office for National Statistics, 2020). As perpetrators of violence are more likely to be younger, it would be beneficial for them to be more sensitive to cues of physical dominance to better prepare for a physical fight.

When investigating perceptions of strength from static stimuli, Fink et al., (2007) found a significant, positive correlation between actual strength and ratings of masculinity and dominance. Additionally, Sell et al., (2014) found that when manipulating facial photographs to show signs of aggression, aggressive faces were perceived to be stronger compared to non-aggressive faces. Across two studies, Johnson and Wilson (2019) observed that when presenting full body photographs, men with more upper body strength and larger biceps were rated as stronger. There was a difference in ratings between ethnicities, suggesting that whilst individuals rely on physical information such as strength and bicep size, racial stereotypes are still utilised when making perceptions of strength. This could be problematic for research in the area, as when using facial and body photographs, race is likely to be on display and therefore may interfere with ratings of physical dominance.

Research suggests that strength is encoded into facial features (Butovskaya et al., 2018). In a sample of men from the Maasai tribe of Northern Tanzania, those with higher handgrip strength tended to have wider faces with a lower and broader forehead, a wider distance between the *medial canthi* of the eyes, a wider nose, fuller lips, and a larger, squarer lower facial outline compared with weaker individuals of the same age-sex group. This illustrates anthropometric differences in the face between strong and weak individuals. The idea that facial features provide a cue to strength is further supported by Sell et al., (2009). When presenting facial and body photographs of both American and Argentinian individuals, participants were able to accurately estimate the physical strength of the men from photos of their bodies and faces, largely independent of height, weight, and age. These findings support the notion that strength is displayed through facial cues, and onlookers can accurately assess this.

Kordsmeyer et al., (2019) suggests that physical dominance may be displayed in men’s bodies and faces, as perceived dominance predicts winning success in arm wrestling competitions. Sell et al., (2009) also investigated perceptions of fighting ability and found that they strongly correlated with perceptions of physical strength. When investigating real-life fight outcomes and facial traits, Little et al., (2015) presented participants with pairs of MMA fighters and asked which one would win in a fight. Individuals performed at rates above chance in correctly selecting the winner of MMA fights. It was also found that winners were perceived to be more masculine, stronger, and more aggressive than losers. Furthermore, Trebicky et al., (2013) presented participants with photographs of MMA fighters and asked participants to rate their perceptions of aggression and fighting ability of each fighter. Perceived aggressiveness was positively associated with actual fighting ability, and perceived fighting ability was positively associated with actual fighting ability, however only in heavyweights. These findings somewhat contradict the previous study by Little et al., (2015), as it suggests we are only able to assess fighting ability in heavier men. Trebicky et al., (2019) also found no significant links between actual and perceived fighting ability when presenting photographs of MMA fighters to participants, however, heavier fighters were perceived as having a higher fighting ability. Zilioli et al. (2015) found that face width-to-height-ratio (fWHR) predicts actual fighting ability. fWHR is the distance between the left and right boundary of the face (*zygion* to *zygion*) (width), divided by the distance between the middle upper-lip (*prosthion*) and the highest point of the eyelid (*nasion*) (height), with higher ratios corresponding to broader faces.

Whilst Zilioli et al. (2015) found that fWHR may be a predictor of fighting ability, this may not be the only trait it predicts. Over two studies, fWHR predicted actual aggression, suggesting that individuals have evolved to display their aggression in their facial composition (Carre et al., 2009; Carre & McCormick, 2008). This theory is further supported by Lefevre and Lewis, (2014) who found that when manipulating men and women's facial photographs to increase fWHR and facial masculinity, perceptions of aggression increased. The findings of the research discussed support the idea that aggression is displayed in the face, and onlookers of this can accurately perceive it.

Masculinity may also be a trait portrayed in the face and body. Holzleitner et al., (2014) found that when judging facial photographs of men, morphological masculinity was a significant predictor of perceived masculinity. Furthermore, height and body mass index (BMI) were also significant predictors of perceived masculinity, with physically larger men being rated as more masculine. Fink et al., (2010) adds further support to these results by finding a correlation between ratings of facial masculinity and dominance, and ratings of bodily masculinity and dominance. This suggests that men display these traits in both their faces and bodies.

When viewing facial photographs, facial hair has been shown to influence perceptions. In a study investigating the perceptions of dominance from head hair, men were consistently rated as higher on dominance, confidence, masculinity, and strength when viewing men with a shaved head compared to men with hair (Mannes, 2013). This effect was present with both natural hair and artificially added hair, and when participants were presented with a scenario used to describe a man, where all descriptions were identical except the man's hairstyle. This was further supported by Dixson et al., (2017) who found that men with beards were perceived to be more masculine and dominant compared to clean shaven men. However, while research suggests that men with beards are perceived to be more physically dominant, beards may be a misleading cue. Dixson et al., (2018) analysed facial photographs of MMA fighters and found facial hair had no association with fighting ability, contradicting the previously discussed research. This suggests that while facial hair can increase *perceptions* of physical dominance, *actual* physical dominance may not increase. This is likely due to beards creating the illusion of a wider face while concealing actual bone structure.

Overall, research supports the notion that we can assess physical dominance when using static stimuli. Whilst research into our accuracy in assessing fighting ability is mixed, overall, our ability to assess other physically dominant traits is supported by multiple studies. However, when a threat is incoming, it is unlikely to be static. Furthermore, a recent paper published by Bovet et al., (2022) discussed the limitations of research using facial stimuli, where a systematic review revealed that digitally altered photographs may not be the most methodologically valid tool to use. As with using vocal stimuli as a cue to physical dominance, static stimuli may also not be the most salient of cues. Humans are able to obscure their appearance easily, for example through hairstyles or facial hair, clothing, and different lighting conditions. It may, therefore, be unwise to use static judgements alone when determining if someone could be a threat to us.

Table 2: Findings from static stimuli

Study	Focus	Findings
Albert et al., (2021)	Physical dominance	Masculine faces were rated higher in physical dominance
Butovskaya et al., (2018)	Strength	Those who were stronger displayed different facial features compared to weaker individuals
Carre and McCormick, (2008)	Aggression	fWHR may be a reliable cue of aggression
Carre et al., (2009)	Aggression	fWHR may be a reliable cue of aggression in men
Dixson et al., (2017)	Masculinity	Beards increase ratings of masculinity and dominance
Dixson et al., (2018)	Fighting ability	There was no association between facial hair and fighting ability in UFC fighters
Fink et al., (2007)	Strength	There was a significant correlation between strength and ratings of masculinity and dominance
Fink et al., (2010)	Masculinity and dominance	Ratings of masculinity and dominance correlated between facial and body ratings
Holzleitner et al., (2014)	Masculinity	Morphological masculinity, height and BMI were significant predictors of rated masculinity
Johnson and Wilson (2019)	Strength and size	Stronger men with larger biceps were rated as stronger
Kordsmeyer et al., (2018)	Physical dominance	Physical dominance mediated associations of upper-body size, strength, and perceived vocal and facial dominance
Kordsmeyer et al., (2019)	Strength	Men’s physical strength can be assessed using 3D models
Kordsmeyer et al., (2019)	Physical dominance	Men’s perceived facial and bodily dominance predicts winning an arm-wrestling content
Lefevre and Lewis (2014)	Aggression	Increased fWHR and increased facial masculinity resulted in increased ratings of aggression
Little et al., (2015)	Fighting ability	Participants accurately selected the winner of an MMA fighter more often than chance. Winners were also seen as more masculine, stronger, and aggressive
Mannes (2013)	Physical dominance	Men with shaved heads were perceived to be more dominant, masculine, confident, and stronger
Re et al., (2014)	Physical dominance	Ratings of physical dominance can be altered when other faces are on display

Richardson et al., (2021)	Physical dominance	Younger, masculine faces are perceived as more physically dominant. Younger, taller, and stronger men are also more sensitive to cues of physical dominance
Sell et al., (2014)	Strength	Faces altered to display anger were more likely to be rated as more aggressive and stronger
Sell et al., (2009)	Strength	Participants were accurately able to assess physical strength in men
Trebicky et al., (2019)	Fighting ability	There was no correlation between perceived fighting ability and actual fighting ability in MMA
Trebicky et al., (2013)	Aggression	Perceived aggression was associated with actual fighting ability in MMA fighters. Perceived fighting ability and actual fighting ability only correlated in heavyweights.
Zilioli et al., (2015)	Formidability	fWHR is a predictor of fighting ability in UFC fighters.

Dynamic Stimuli

There are limited findings regarding research investigating our ability to assess physically dominant traits from biological motion. Within this review, only five papers used movement as stimuli, with four of them concerning strength, and one concerning physical size (see Table 3). Veto et al., (2017) used either upright or inverted point light walking stimuli or static point light images to understand our ability to assess physical size. The results showed that upright point light walkers were rated as physically larger than inverted point light walkers, but the static point light images did not show the same effect. While these findings do further our understanding of our ability to assess size from body movement, point light may not be the most ecologically valid of techniques. Firstly, point light does not fully manage to conceal bodily proportions, especially when viewed side by side or in a serial order. The technique requires markers to be attached to physical landmarks on the body, and with point light, the recordings are generally not edited or altered for size, resulting in a lack of standardised proportions. This lack of control has been shown to be a source of perceptual incongruence in the estimation of body size lengths by participants (Linkenauger et al., 2015), presenting an issue when it comes to ratings of traits like dominance from point light stimuli. Controlling for features such as length between joints may be beneficial to obscure absolute size, as this can be inferred from proportions (Pittenger & Todd, 1983).

McCarty et al., (2013) utilised a more modern iteration of this technique by recording motion using a multi-camera motion capture system to record participants dancing in 3D. After this initial recording, each dancer had a featureless, standardised avatar applied to their movements, which meant no physical cues were left on display when shown to raters. This technique ensures that variables such as height, weight, or race are inhibited, and ratings can be based solely on the movement of the participant. The study found that physically stronger men were perceived as being better dancers, despite the absence of anthropometric cues to strength.

Fink et al., used the same featureless avatars stimuli used by McCarty et al., (2013) in their research (Fink et al., 2016; 2017; 2019). Across all three studies, the motion of 80 men was recorded and the walks of the 10 strongest and 10 weakest men were presented to participants to rate on strength. In the first of the studies, both men and women judged stronger male walkers higher on dominance and strength compared to weak walkers. These outcomes suggest that men are able to portray their strength in their movements and this is linked to physical dominance. This finding was repeated in Fink's next study which looked at these perceptions cross-culturally (Fink et al., 2017). The same videos were presented to participants in Germany, Chile, and Russia where strong walkers were judged to be stronger than weaker walkers. These findings, again, lend support to the notion that men portray their strength in their biological motion, even when raters have no other cues. However, Fink et al., then went on to find contradicting results when presenting the movements to members of the Maasai of Tanzania, with stronger men being rated as weaker compared to the weak men. While these findings are unexpected, the researchers suggest that this may be due to the lifestyle of the Maasai, as physical strength (and displays of physical strength) may not be as important compared to other societies.

In summary, given the salient and reliable nature of biological motion, this may be a key cue to assessing vital displays of physical dominance. The little evidence within the area does align to this hypothesis and the possession of this cognitive ability, but research remains limited.

Table 3: Findings from dynamic stimuli

Study	Focus	Finding
Fink et al., (2016)	Strength	Both men and women judged stronger men higher on dominance and strength compared to weak men
Fink et al., (2017)	Strength	Stronger walkers were judged to be stronger compared to weaker walkers
Fink et al., (2019)	Strength	Ratings of strong walkers were judged weaker in strength compared to weak walkers
McCarty et al., (2013)	Strength	Stronger men were perceived as being better dancers
Veto et al., (2017)	Size	Upright PLWs are consistently judged as larger than inverted PLWs

Summary of systematic review

This systematic review lends support to the notion that we are capable of assessing physically dominant traits (such as physical size and strength) in men from a variety of cues. While the systematic review encompassed several different terms relating to dominance such as masculinity, formidability, and strength, we will be using physical dominance as an all-encompassing term. For this thesis, Archer's (1988) definition of physical dominance will be used, which is described as the ability of being able to win in an unarmed, physical fight, with those high in physical dominance being more likely to win in a fight and those lower in physical dominance being more likely to lose.

Perceptions of biological motion

A wide body of literature has consistently found that many species of animals estimate fighting ability from perceptual cues such as visual inspections and vocalisations (Arnott & Elwood, 2009; Huntingford and Turner, 1987). Sell (2021, p.4682) states that "Any animal that can assess, in advance, whether it is likely to win a conflict can make more prudent decisions about whether to instigate, escalate, or retreat during a fight. Therefore, one would predict that natural selection has designed adaptations that perceive cues of fighting ability in others and in oneself and use those estimates to modulate between different behavioural strategies before, during, and after a conflict". As the literature has shown such an overwhelming support for the notion that animals can detect physical dominance in one another to aid in their survival, it would be unusual for this mechanism to not have evolved in humans due how frequent the ancestors of modern humans engaged in conflict (Pinker, 2011).

As previously discussed, there are potential issues with the aforementioned research. For example, assessing physical dominance from vocal recordings may not be the most salient cue in a physical fight, as a potential opponent may never speak during conflict. Similarly, using static photos to assess dominance is problematic, as in real life, our opponent would not be static and would likely have clothing to conceal much of his body. Satchell (2016) supports this notion and argues that using static stimuli misrepresents the information that is present in everyday life. However, some form of motion is likely to be on display, even when vocal and facial cues are not, and are difficult to hide through clothing or make up. Our eyes most likely evolved to detect motion, with Vallortigara et al., (2005) finding that newly hatched chicks showed a preference for biological motion stimuli rather than static stimuli, suggesting that they have an innate mechanism for the detection of biological motion, probably to detect threats. This concept also extends to humans, with 12-week-old infants being able to accurately discriminate between upright and inverted walking motions (Bertenthal et al., 1984), an ability that is fully developed by eight months of age (Hirai & Hiraki, 2005). This suggests that in humans, this preference and ability to detect biological motion is either innate or develops early during cognitive development.

Evidence from the cognitive neuroscience domain also supports the notion that biological motion detection is important. There is a large literature base on specialised areas for processing information such as the superior temporal sulcus (STS), located in the temporal lobe. Allison et al., (2000) discusses how this area is key for both humans and non-human primates for processing important biological motion-based information. Herrington et al., (2011) aimed to gain a better understanding of the STS and its involvement in biological motion perception. When viewing point light walkers, increased activity in the STS was observed compared to viewing a spinning wheel. These findings have also been seen in infants between seven to eight months-old, with increased activity seen in the STS when presenting point light walkers compared to scrambled point light. These discoveries suggest that our ability to detect motion starts from an early age, with the STS being a pivotal region in its processing.

Furthermore, biological motion may be a more accurate cue than static stimuli when gauging judgements, as Troje (2013) argued that humans are less aware of using biological motion to convey information compared to other informational cues (e.g., speech, facial expression). Biological motion is therefore less subjectable to conscious control. The Realistic Accuracy Model (RAM) suggests that an individual uses relevant cues that are available to detect traits and can utilise these to make an assessment (Funder, 1995). This suggests that humans may be able to assess physical dominance from men when their movement is on display. The concept of biological motion being a cue has been supported by research suggesting that humans are able to assess a multitude of traits from viewing the movements of another human, such as gender (Troje, 2013), attractiveness (Klüver et al., 2016), and emotion (Crane & Gross, 2007).

The notion that movement may give honest signals has been found within a range of research. Neave et al., (2011) investigated perceptions of men's dance movements, and concluded that these movements may be an honest cue of a mans vigour. Furthermore, men with stronger handgrip strength (a proxy for upper-body strength) tend to have their dance movements rated as more attractive compared to weaker men (Hugill et al., 2009; McCarty et al., 2013; Weege et al., 2015). More recently, Fink et al., (2021) discussed how mating-related qualities and motives are likely displayed in dance movements, further supporting the notion that honest and important cues can be portrayed in a mans movement. Yet while research into perceptions of strength from dance movements has been undertaken, there has been minimal research into our ability to assess physical dominance from men's biological motion. As this systematic review shows, there are only five papers published investigating this, yet none of these directly examines our ability to detect cues to physical dominance from biological motion.

Summary and aims

To summarise, a wealth of research suggests that men have evolved to engage and survive physical combat, albeit using a multitude of terms to define such abilities (e.g., masculinity, dominance, strength). The research previously discussed also supports the notion that we are able to decode cues to physical dominance in men to garner an accurate picture of their physical prowess. However, the vast majority of this research uses either static or vocal stimuli, which may not be as salient as biological motion. Therefore, the aim of this PhD is to establish whether we possess cognitive mechanisms with which to decode biological motion information for cues of physical dominance. To achieve this, we will answer the following research questions:

1) By using modern motion capture techniques, we will quantify men's movements in a series of controlled experiments to investigate whether we can accurately assess physical dominance as seen in previous research using static and vocal stimuli.
2) Which, if any, kinematic features correlate with perceptions of physical dominance?
3) Women will judge someone's physical dominance as higher than men when viewing biological motion

Study one

Introduction

To summarise the previous chapter, research has argued that men's traits likely saw strong directional pressure by means of intrasexual selection (e.g., Puts, 2010), suggesting that men have evolved to engage effectively in physical combat. For example, men tend to possess heavier brow ridges and more robust jaws than women; this adaptation is thought to have evolved to protect the individual from blows to the head (Puts, 2010). Furthermore, men maintain more upper-body muscle to inflict damage compared to women (Miller et al., 1993, see Sell et al., 2012 for review). These differences therefore suggest that men have adaptations specifically evolved for physical contests.

Humans may also possess a mechanism to cognitively assess physical dominance. Sell et al., (2010) argue that humans possess neurocognitive adaptations specifically evolved to assess a potential opponent's formidability. Several theories have discussed why humans have evolved this mechanism to assess threat. For example, Schaller et al. (2004) proposed that detecting threats from others evolved as a consequence of humans previously living in native, tribe-like communities. During this era, the ability to detect whether other tribe members pose a threat to the individual was thought to lead to a much greater likelihood of survival. By being able to assess whether an approaching man is displaying an intention to harm, this provides the individual with the chance to either prepare for the conflict, or to ensure survival by retreating if the opponent is deemed too threatening.

Research discussed within the introduction suggests that humans may indeed possess this ability, given that traits relating to physical dominance can be assessed from the voices of men, and static photographs of their faces and bodies. For example, numerous studies have suggested a link between face width-to-height ratio (fWHR) and perceptions of physical dominance (Carre et al., 2009; Carre & McCormick, 2008; Haselhuhn et al., 2015; Lefevre & Lewis, 2014; Zilioli et al., 2015), with men with larger fWHR being perceived to have more physically dominant traits. However, an opponent's face may not be the only cue on display, nor the most salient.

Satchell (2016) argues that using static stimuli misrepresents the information that is present in everyday life, as movement is likely to be on show in a real-life setting. Furthermore, individuals can be easily concealed by low lighting and other environmental factors, and appearances can be altered (e.g., using makeup, baggy clothing). Perceptions can also be altered by the presence of a beard. Neave and Shields (2008) for example, found that men with full beards are perceived to be more masculine and aggressive when compared to men with sparce beards.

Perhaps a more salient cue to use when assessing dominance may be biological motion because humans are less aware of using biological motion to communicate information compared to other informational cues (e.g., speech, facial expression). Thus far, there has been minimal research into the assessment of male traits from viewing their biological motion. The Realistic Accuracy Model (RAM) by Funder (1995) suggests that an individual uses relevant cues that are available to detect traits like physical dominance. Satchell et al., (2016) argue that as judgements tend to be made at a distance where facial cues are not always apparent, body movement is key as it is normally on display, even in impoverished situations. Therefore, individuals should be able to make judgements on a potential opponent's physical dominance based on the cues given by an individual's body movement.

Aims

The aims of the current study are to investigate perceptions of physical dominance from biological motion and facial photographs. Furthermore, to establish if perceptions of physical dominance correlate with self-reported measures. The hypotheses of study one are:

1) There will be a significant positive correlation between physically dominant traits and perceptions of physical dominance from facial photographs.
2) There will be a significant positive correlation between physically dominant traits and perceptions of physical dominance from body movements.

3) There will be a significant gender difference between men and women's ratings of the stimuli on physical dominance.

Method

Participants

Sixty men aged between 18-41 years old (mean age = 22.5 years, SD = 3.8 years) were recruited for the stimuli creation aspect of the study. Participants had to be male (as assigned at birth), over the age of 18, and not have any injury or condition that would interfere with their movement. All participants were from the UK.

Questionnaires

Age and injuries that affect gait (to ensure they fit the inclusion criteria) were taken. Participants were also asked what sports they currently played, specifically if they engaged in contact sport. This was done to understand if the participant was accustomed to being in a situation where physical conflict may arise. The categorisation of contact sport and non-contact sport was in line with Conley et al., (2014).

Participants completed the Gough Dominance Scale (Gough et al., 1951), which assessed their dominance through 60 bipolar, agree-disagree statements. Total scores can range from 0 (not dominant), to 60 (very dominant). A Kuder-Richardson formula showed a reliability of .79, showing good reliability. The scale included questions such as "I am usually the leader in my group" and "I usually have to stop and think before I act".

The Aggression Provocation Questionnaire (APQ, O'Connor et al., 2001) was then completed by participants to assess their self-reported aggressive behaviours. The APQ presents 12 hypothetical scenarios which are designed to illicit an emotional response from the participant. An example of one of these scenarios is –

> You have gone out to have a couple of drinks with your partner. Whilst you are at the bar, a stranger approaches your partner

> and grabs her/his backside. On your return, your partner tells you, how you would feel about this situation?

Participants are then asked to identify how angry, frustrated, and irritated they would be on five-point Likert scales ranging from (1) 'not at all' to (5) 'extremely'. Participants are also prompted to select one of five responses to the hypothetical scenario. These vary depending on the scenario, but generally equate to one of five categories of response:

1. Avoiding the situation, denying that something is wrong, or transforming it into something positive

2. Doing nothing, although feel angry

3. Distant anger, indirect, or delayed angry behaviour

4. Assertive behaviour, confronting the provoking person but without overt verbal or physical aggression

5. Aggressive behaviour, direct verbal, or physical aggression

Total scores range from 12 (minimal aggressive tendencies), to 108 (very aggressive tendencies). The APQ has demonstrated good reliability, with a Cronbach's alpha of .92 (O'Connor et al., 2001), which is well within acceptable boundaries (Cortina, 1993; Field, 2013). It was decided to use this questionnaire as it contained ecologically valid scenarios and responses appropriate for day-to-day life.

Stimuli Development

Participants attended a single session at the motion capture lab at Northumbria University. Participants were initially asked to complete the questionnaires discussed above, followed by a facial photograph taken against a neutral background.

All photographs were taken with the same lighting, with the camera at a distance of one metre from the participant. The camera used was a Canon EOS 80D (W), with flash disabled. Photographs were 24.2 mega-pixels. All hair was pushed out of the face with a hairband if necessary, and participants were instructed to have a neutral facial expression as if they were taking a passport photograph (see Figure 2 for example photograph).

Figure 2: Standardised photograph

Participants then had several anthropometric measurements taken in order to build an accurate biomechanical model of their motion. These measurements included: height (mm, Seca stadiometer), weight (kg, Seca digital scales), leg lengths (mm, measuring tape), shoulder circumference (mm, measuring tape), chest circumference (mm, measuring tape), waist circumference (mm, measuring tape), knee widths (mm, callipers), ankle widths (mm, callipers), elbow widths (mm, callipers), and wrist widths (mm, callipers). A dynamometer was used to measure the participants handgrip strength (kg) which was used as a proxy measure of their upper-body strength. The handgrip strength task was done twice on both hands.

Participants then had 39 small plastic retroreflective markers placed on the major joints and areas of the body following the standard Plug-in-Gait full-body marker set (Vicon, Oxford). Markers were attached using hypoallergenic tape, and where possible, placed directly onto the skin of the participant at common anatomical bone protrusion landmarks (see Figure 4 and Appendix B for marker placement). The kinematic approach follows McCarty et al., (2017), with the clinical validation for the accuracy of the marker set established by

Bell et al. (1990). The layout ensures that all body regions can be captured with six degrees of freedom (x, y, and z translations, pitch, roll, and yaw).

Figure 3: Marker Layout

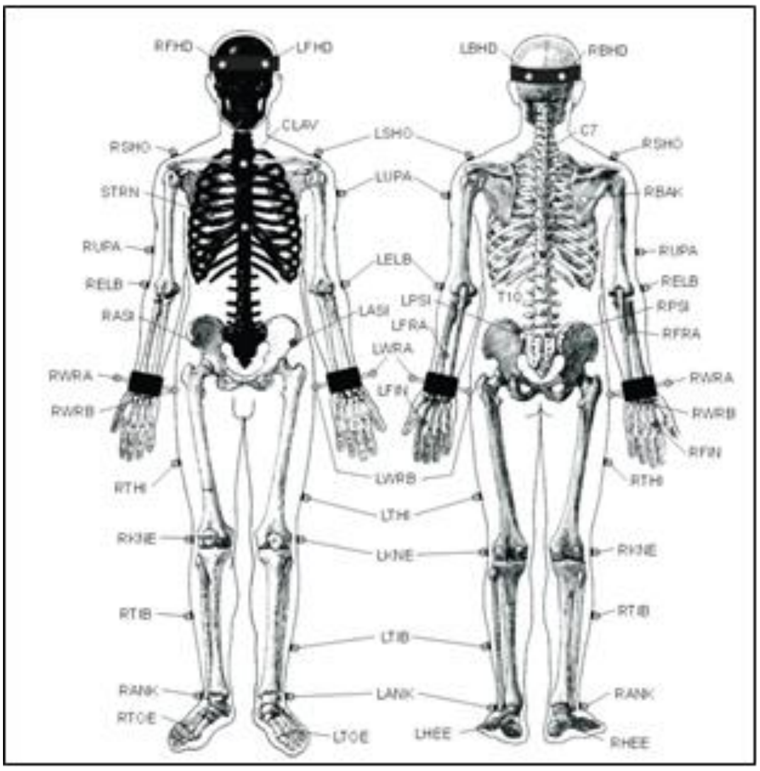

Figure 4: Plug-In Gait marker set layout showing the anatomical locations of each body marker (Vicon, Oxford)

For calibration purposes, participants were required to stand at the point of origin (the point at which x, y, and z coordinates = 0) in the motion capture lab in a T-Pose. A snapshot was taken using Vicon Nexus 2 software (Vicon, Oxford) and labelled to ensure there were no missing or occluded markers. Participants were then asked to walk the length of the room, back and forth, for five minutes under the guise of being part of the calibration process. The goal of this was to ensure that the participants relaxed into their natural gait to prepare for recording their baseline walk. Once the participants seemed suitably relaxed, a recording of them walking from one end of the motion capture lab to the other (5 metres) was captured. Multiple recordings were taken, and the best quality walks were processed.

Data processing

Motion processing

The recorded motion data was processed using Vicon Nexus 2 (Vicon, Oxford), where the reflective markers were labelled (see Figure and Figure 4: Figure in Vicon Nexus 2 showing participant with all 39 markers labelled. At this stage, gaps (an epoch where a marker is occluded from view by all cameras before reappearing further in the recording) and unwanted reflections from objects in the lab were removed. To ensure data accuracy, we only filled gaps that occurred for less than 30 frames (~12% of a second at a capture rate of 250Hz) as this represented the limit of the gap filling algorithm’s ability to realistically interpolate motion without it looking overly artificial. It should also be noted that we exclusively used pattern fills for gaps by copying the trajectory of a marker on the same segment of the body.

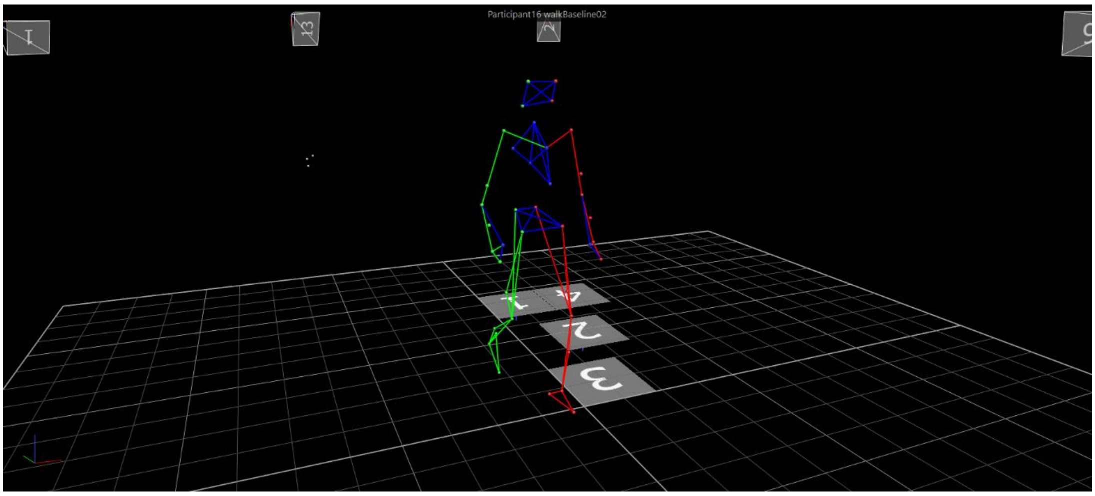

Figure 4: Figure in Vicon Nexus 2 showing participant with all 39 markers labelled

The recordings were then exported to Autodesk MotionBuilder 2017 to create standardised featureless avatars. This ensures features (e.g., gender, height, build, weight, clothing, or facial features) are not on display to rating participants who may take those features into account when rating. Gaps that were unable to be filled in Vicon due to length (those over 30 frames) and participants who had a missing marker were fixed at this stage, by creating a 'rigid body', where two or more markers in close proximity to the missing one were used to fill the gaps. The process of building a featureless avatar is twofold. Step one involves fitting the optical marker data onto an 'actor', based on their T-poses (see Figure 5). This creates a control rig for which a featureless standardised avatar could be driven. The second stage involves applying a 'character' (a featureless avatar) to the scene that is driven by the actor (see Figure 6).

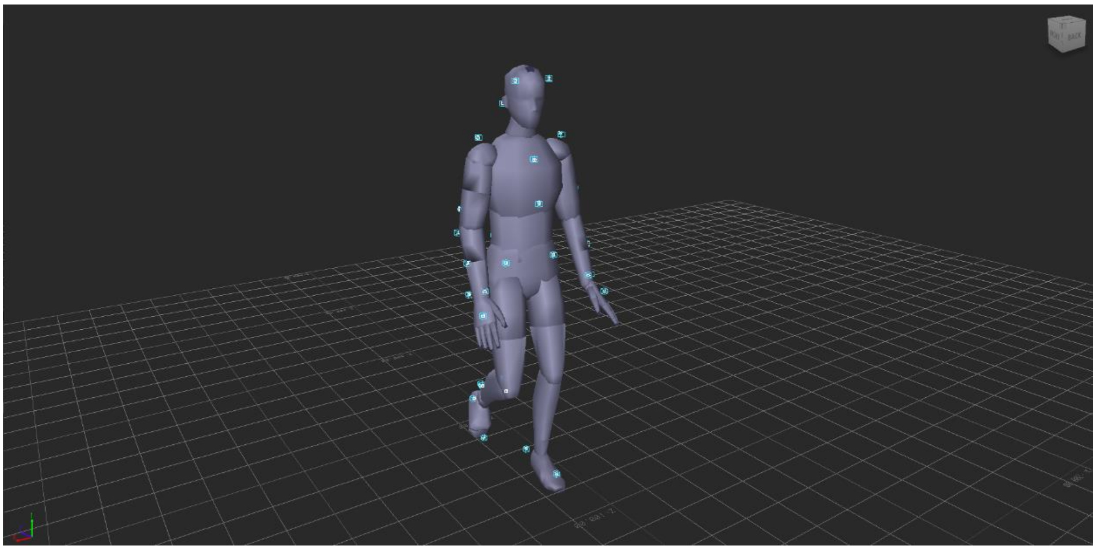

Figure 5: Actor in MotionBuilder

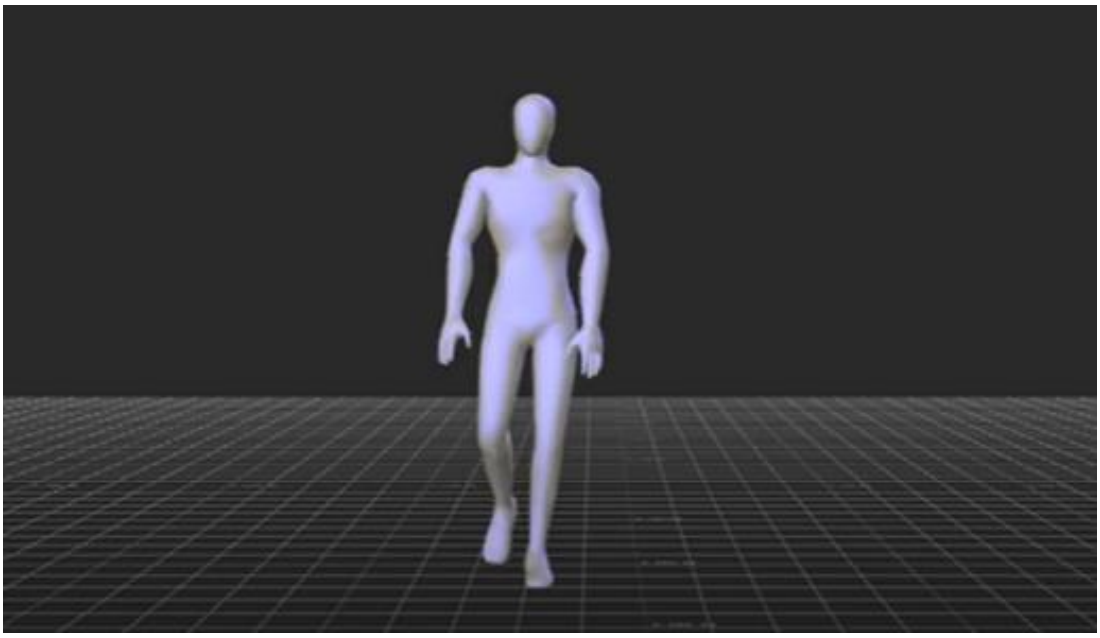

Figure 6: Final featureless character in MotionBuilder

All trials were rendered into .AVI format, with no compression in a 1900x1080 pixel window. The video chosen was the best quality of the recorded trials, and was of the man walking the length of the visible capture space (5 meters) towards the viewer (see Figure 6). The videos of the featureless avatars were uploaded to YouTube, with the videos ranging between 3-4 seconds.

Due to technical issues, only 56 walking videos were generated.

Facial Photographs Processing

Facial width-height-ratio (fWHR) was measured from each photograph following the procedure in (Lefevre et al., 2013) measuring the distance between the left and right boundary of the face (*zygion* to *zygion*) (width), divided by the distance between the middle upper-lip (*prosthion*) and the highest point of the eyelid (*nasion*) (height). Higher ratios correspond to broader faces.

Only 59 facial photographs were useable for ratings as consent for the use of a facial photograph was not obtained for one participant.

Ratings

As two types of analyses were conducted, two *a priori* power analyses were run, suggesting that between 64 (the G-power calculation for the *t*-test) and 71 (the G-power calculation for a correlation) participants were needed for the study to detect a medium effect at 80% power. Thus, 138 participants (71 men, 67 women, and two individuals who did not wish to state their gender) aged between 18-56 years old (mean age = 27.01 years, SD = 8.37 years) were recruited via Prolific (www.prolific.co). Participants were paid £3.13 (the amount suggested by prolific to be a 'good' payment) to compensate for their time. Participants were redirected to the study hosted on Qualtrics (www.qualtrics.com) and shown two blocks of trials in a random order. Block one contained the baseline walk videos, and block two consisted of the facial photographs. Participants were asked to rate *"how physically dominant is this man?"* on a 1-7 Likert scale, (where 1 is 'not physically dominant at all' and 7 is 'very physically dominant') for both the videos and the photographs. Participants were provided with a definition of physical dominance where it was described as the regularities of winning or losing a fight, with those who have higher physical dominance winning more fights (Archer, 1988). The presentation of each photograph/video was also randomised. The study took approximately 25 minutes to complete. Cronbach's alpha was α = .97 for the overall sample, and α = .97 and α = .98 for the ratings of the walking and facial stimuli respectively, suggesting excellent interrater reliability.

Results

All statistics were calculated in IBM SPSS version 26. We calculated ten dominance-relevant variables for each man based on questionnaires and

anthropometrics (see Table 4) and means and standard deviations (SD) for each trait (see
Table 5 and Table 6 for means and SD).

Table 4: Variables and how they were calculated

Variable name	How variable was calculated
Strength	The participants' averaged hand grip strength in kg across both hands. Higher scores indicate greater strength.
Dominance	The sum of their Dominance Scale answers. Higher scores indicate greater self-rated dominance.
Anger, Frustration, Irritation and Reaction	The four components on the Aggression Provocation Questionnaire, where each of the sub-scales were summed. Higher scores indicate greater anger, frustration, and irritation, and a more aggressive reaction to scenarios.
Girth	By combining participants' chest (mm), shoulder (mm), and bicep circumferences (mm), with weight (kg), as seen in Hill et al., (2013). Higher girth indicates a physically larger man.
Facial width-to-height ratio (fWHR)	Measuring the distance between the left and right boundary of the face (zygion to zygion) (width), divided by the distance between the middle upper-lip (prosthion) and the highest point of the eye-lid (nasion) (height).
Walking Stimuli	The average score of physical dominance from the 138 raters on the baseline walks. Higher scores indicate greater perceptions of physical dominance.

Facial Stimuli	The average score of physical dominance from the 138 raters on the facial photographs. Higher scores indicate greater perceptions of physical dominance.

Table 5: Means and standard deviations for the walkers' traits

Trait	Mean (SD)
Dominance	25.90 (6.54) (range: 9 – 38)
Anger	27.83 (8.94) (range: 3 – 43)
Frustration	28.28 (8.70) (range: 4 – 43)
Irritation	32.25 (7.37) (range: 10 – 44)
Reaction	24.77 (5.52) (range: 13 – 34)
Girth	2514.51 (225.56) (range: 2003 – 3137)
Strength	42.60kg (7.59kg) (range: 30kg – 62kg)

fWHR	1.83 (.24) (range: 1.31 – 2.18).
Walking stimuli ratings of physical dominance	3.66 (.69) (range: 2.34 – 5.25).
Facial stimuli ratings of physical dominance	3.64 (.65) (range: 2.26 – 5.05).

Table 6: Means and SD for ratings of physical dominance for the walks and faces on the overall sample (N=140), men (N=71), and women raters (N=67)

	Walk Ratings Mean (SD)	Face Ratings Mean (SD)
All raters	3.66 (.69)	3.64 (.65)
Men raters	3.53 (.68)	3.56 (.64)
Women raters	3.74 (.73)	3.70 (.68)

Principle Component Analysis (PCA)

A PCA was conducted to determine the latent trait(s) of participants' body measurements (shoulder, chest, and bicep circumferences (mm), weight (kg), and height (mm)). Table 7 shows the component loadings. The KMO value was deemed as great in accordance with Sofroniou and Hutcheson, (1999) at .842, suggesting there is an adequate sample size to run the PCA. Furthermore, Bartlett's (1937) test of Sphericity was significant (p < .01), further showing that conducting the PCA is appropriate. Weight, bicep, shoulder, and chest circumferences loaded onto one component, while height loaded onto a second component. Therefore, the participants weight, bicep, shoulder, and chest circumferences were summed to create the component ‘girth’, and height was removed from the component, in line with the findings of Hill et al., (2013). This accounted for 69.24% of the total variance in the participants’ body measurements.

Table 7: Component factor loadings for the weight, bicep, shoulder, chest and height variables

	Component	
	1	2
Weight	.946	-.055
Bicep	.935	-.082
Shoulder	.935	.083
Chest	.900	-.051
Height	.097	.994

Correlations

Pearson’s correlations were then conducted between strength, dominance, Buss Perry aggression scores, the four traits measured by the APQ (anger, frustration, irritation, and reaction), strength, girth, fWHR, and the physical dominance ratings on the faces and walks (see Table 8).

With regards to the face data, a significant, medium strength positive correlation (as per Cohen, 1988) was found between a man’s strength and ratings of his perceived physical dominance: $r(59) = .30$, $p = .02$, where higher ratings of perceived physical dominance correlated with higher strength. A further significant, positive correlation of medium strength was found between a man's girth and ratings of perceived physical dominance: $r(59) = .29$, $p = .02$, where higher ratings of perceived physical dominance correlated with higher girth.

In terms of the walk data, a significant, large strength, positive correlation was found between strength and ratings of perceived physical dominance: $r(56) = .55$, $p < .01$, where higher ratings of perceived physical dominance correlated with higher strength. A further significant, positive correlation with a large effect size was found between girth and ratings of perceived physical dominance: $r(56) = .60$, $p < .01$, where higher ratings of perceived physical dominance correlated with higher girth. Finally, a significant, positive correlation with a medium effect size was found between dominance as measured using the dominance scale and ratings of perceived physical dominance: $r(56) = .35$, $p = .01$, where higher ratings of perceived physical dominance correlated with higher dominance scores measured by the dominance scale. No other significant correlations were observed when looking at correlates for facial and walk ratings (all $p > .05$, see table 8).

Table 8: Correlation for physically dominant traits and walk and face scores

	Buss Perry (BP) Aggression	Anger	Frustration	Irritated	Reaction	Girth	Strength	fWHR	Perceived Dominance Ratings	
									Walking Stimuli	Facial Stimuli
Dominance	.330	.029	-.059	.028	-.010	**.308***	**.271***	-.083	**.348****	.085
BP Aggression		**.299***	.251	.255	.215	-.078	-1.62	-.042	-.180	.002
Anger			**.881****	**.890****	**.261***	-.036	.029	-.047	-.135	.146
Frustration				**.848****	.231	.022	-.059	-.019	-.165	.160
Irritated					**.274***	-.019	.028	.119	-.090	.090
Reaction						.047	-.010	-.012	.214	.179
Girth							**.653****	.115	**.600****	**.290***
Strength								-.015	**.553****	**.295***
fWHR									-.046	-.111

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

Regressions

Due to the significant correlations found (see Table 8), two enter method regressions were conducted, one with the walking stimuli (the averaged score of physical dominance for each of the men) as the outcome variable, the other with the facial stimuli as the outcome variable. The initial regression contained three predictors: self-rated dominance, girth, and strength, with walking stimuli as the outcome variable. The results of the regression suggest the three predictors explain 39.8% of the variance in ratings of physical dominance, $R^2 = .40$, $F(1,52) = 11.89$, $p < .01$.

The findings showed that strength makes a significant contribution to the regression, $\beta = .31$; $t(52) = 2.25$, $p = .03$, as does girth, $\beta = .35$; $t(52) = 2.45$, $p = .02$. However, self-rated dominance, $\beta = .11$; $t(52) = .89$, $p = .38$, was not significant. Therefore, the regression was re-run excluding self-rated dominance. The final two predictors (strength and girth) explained 40.7% of the variance of ratings of physical dominance in the walking stimuli, $R^2 = .41$, $F(1,52) = 17.50$, $p < .01$. Both strength and girth made a significant contribution to the regression ($\beta = .32$; $t(52) = 2.34$, $p = .02$ and $\beta = .39$; $t(52) = 2.85$, $p = .01$ respectively).

In terms of physical dominance ratings for the facial stimuli, there were two significant correlations: strength and girth. An Enter method regression was conducted containing these two traits as predictors, with facial stimuli (the averaged score of physical dominance for each of the men) as the outcome variable. The results of the regression suggest the three predictors explain 8.9% of the variance in ratings of physical dominance, $R^2 = .12$, $F(1,56) = 3.84$, $p =.03$. However, neither strength nor girth contributed a significant amount to the regression ($\beta = .15$; $t(56) = .92$, $p = .36$ and $\beta = .24$; $t(52) = 1.47$, $p = .15$ respectively).

t-tests

A paired samples *t*-test was conducted to investigate a potential gender difference between men and women's ratings of perceived physical dominance. Assumption checks were conducted to ensure that the data was normally distributed and not skewed, where assumptions were met and the analysis conducted. A significant gender difference was found, with women (M

= 3.69, SD = .72) rating physical dominance higher than men (M = 3.53, SD = .76) across all walking stimuli ($t(58) = 4.23$, $p < .01$, $d = .21$). This represented a small effect size by Cohen's (1988) interpretations. There was no significant difference between men and women's ratings of perceived dominance on the facial stimuli ($t(58) = 1.88$, $p = .06$), however it was trending on significant, suggesting that there may still be a link between dominance and facial stimuli. An independent sample *t*-test was conducted to compare the ratings of physical dominance between those who play contact sport, and those who do not. Twenty-seven of the men played contact sport, which included rugby, football, lacrosse, martial arts, American football, and basketball. In regards to ratings of physical dominance on the walking stimuli, there was found to be no significant difference between ratings on men who partook in combat sports (M = 3.78, SD = .55) and those who do not (M = 3.56, SD = .79), $t(54) = -1.20$, $p = .24$. The same was found with ratings on the facial stimuli, where there was no significant difference between men who played contact sports (M = 3.76, SD = .66) and those who do not (M = 3.53, SD = .63), $t(57) = -1.34$, $p = .18$.

Biomechanical Analysis

In an attempt to explore some of the salient kinematic properties that may be driving perceptions, we undertook an exploration exercise by firstly visually investigating the potential differences between the five highest and five lowest rated participant's baseline walks on physical dominance. When viewing the videos of the movements, the team felt that one of the key differences may be a 'swing' or 'swagger' motion. This is best described as the upper body moving in a pendulum-like motion from the hips upward. This motion may be a cue to increase perceptions of physical dominance through swing. By swinging in a pendulum-like motion, this could increase perceptions of the width of the individual, thus being perceived as physically larger.

Biomechanical analysis began by extracting the x, y, and z coordinates for each marker across each recorded frame (i.e., rows being timeseries) into a data frame. We also marked frames that had 'toe-off' events, which is the frame where the toe leaves the floor, thus marking where each stride starts and ends. In total, 57 data frames, one for each of the participant's baseline walks data, were then imported into SAS version 9.4 (SAS Institute Inc) for statistical analysis.

The first stage of the analysis involved manipulations to standardise the data by stride (i.e., to make each file the same relative length) and to normalise the absolute distance between markers (i.e., standardise the participants size). This would ensure that 'swing' would be more easily identifiable for each stride. Participant's physical size was also standardised, as differences in height may influence swing. Back length was calculated as the distance between the mid hip (the centre between the LPSI (left back hip) and RPSI (right back hip) markers) and T10 (10th thoracic vertebrae). Each participant's back length was up-scaled to the largest participant's, thus resulting in a standardised size. Swing was then calculated as the change in magnitude in the transverse plane (the x-axis) across the trial, relative to walker's pelvis. Swing was then plotted for the five highest and five lowest rated participants in physical dominance (see Figure 7 and Figure 8).

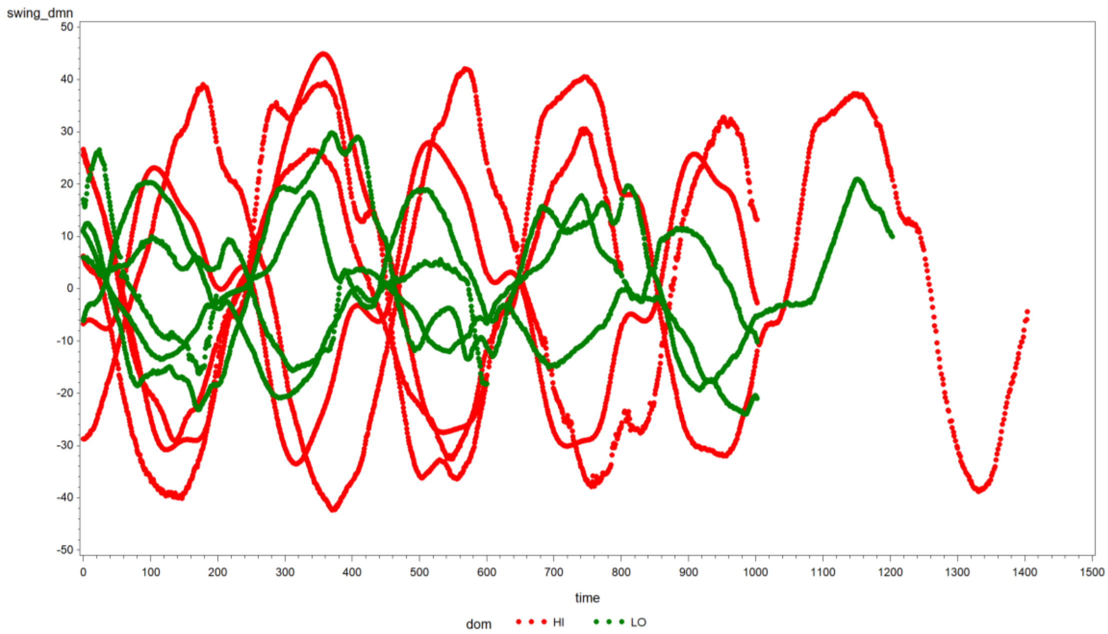

Figure 7: Swing for the 5 highest and 5 lowest physically dominant participants

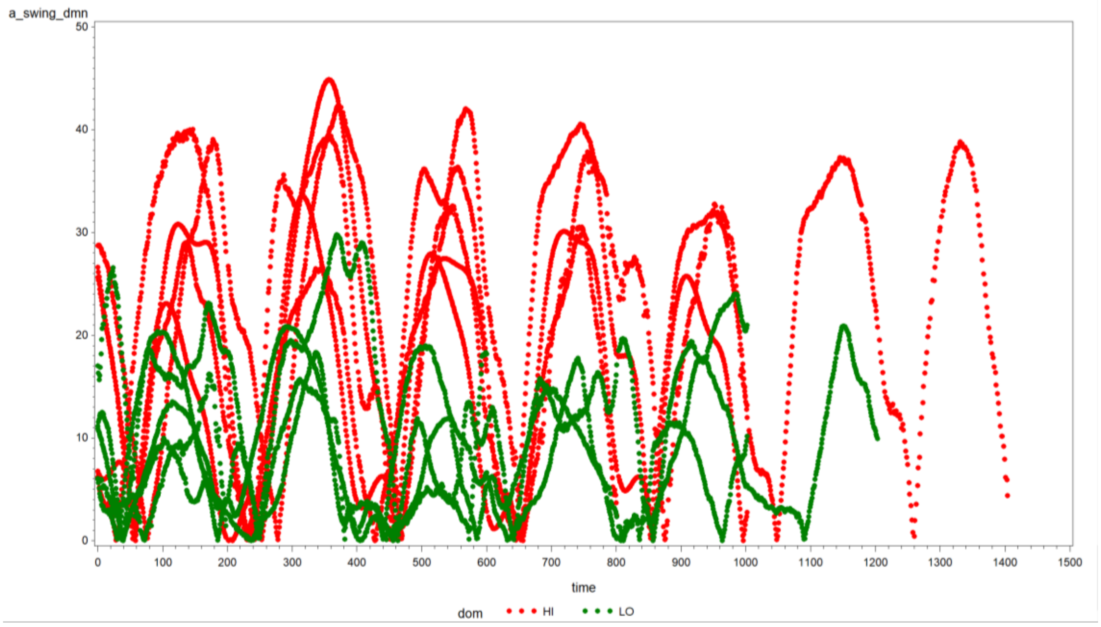

Figure 8: Swing for the 5 highest and 5 lowest physically dominant participants for the absolute value

Figure 7 and Figure 8 suggest that there is a clear difference between the magnitude of swing between participants rated as either high or low in physical dominance. A Pearson's correlation between mean swing values and ratings of physical dominance supports this ($r(56) = .53$, $p < .01$), finding a significant, strong, positive correlation between the two, where men with a higher swing values are rated as more physically dominant (see Figure 9).

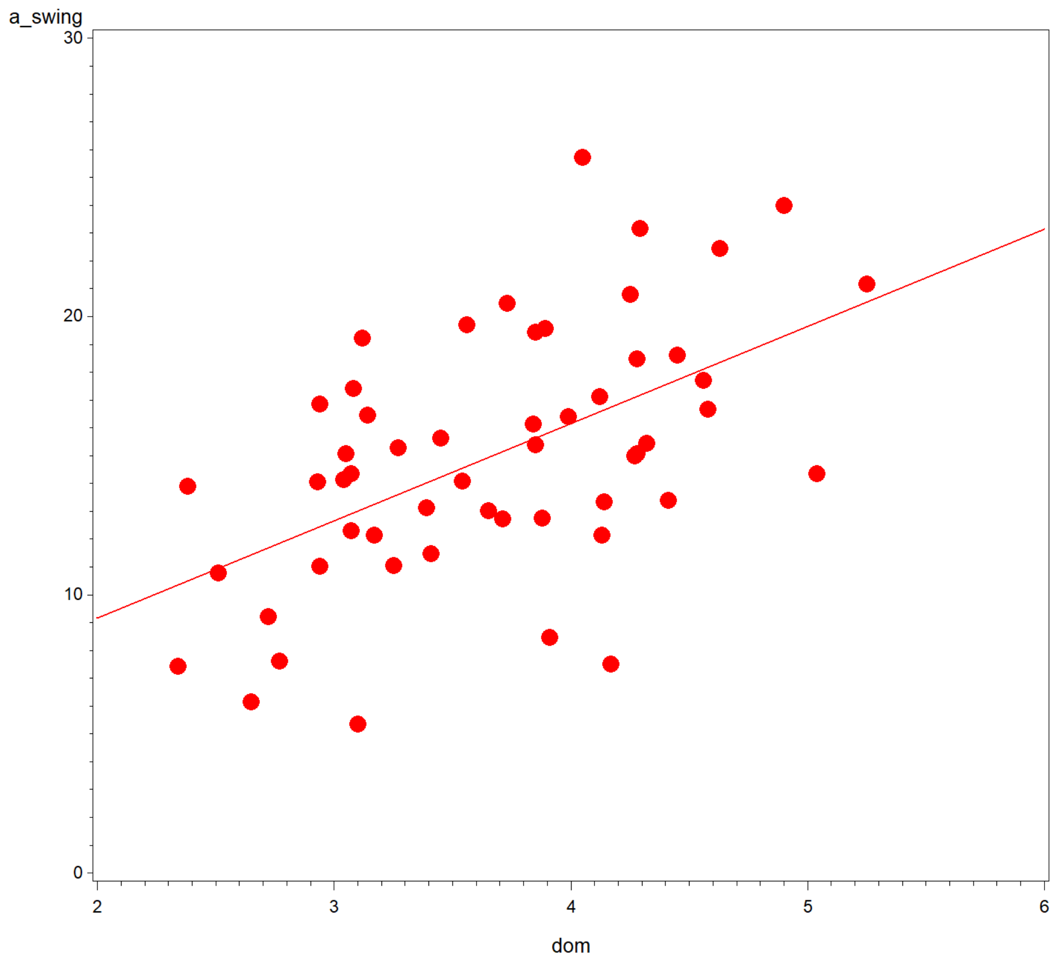

Figure 9: Correlation between mean swing and ratings of physical dominance

Discussion

Summary of findings

The current study aimed to investigate perceptions of physical dominance from viewing baseline walking stimuli and facial photographs, as well as to assess how they correlate with traits (e.g., girth, strength) related to physical dominance. Overall, participants who were physically larger and stronger were rated as higher in perceived physical dominance on both their walks and facial photographs. Furthermore, there was a significant positive correlation between self-rated dominance by the walkers, and perceived physical dominance. This suggests that men are able to portray their dominance through their movements and face.

Hypothesis one: There will be a significant, positive correlation between physically dominant traits and perceptions of physical dominance from facial photographs.

Hypothesis one proposed that there would be a significant, positive correlation between perceived ratings of physical dominance and physically dominant traits encoded into facial photographs. Overall, this hypothesis is partially supported, as whilst there was a significant, positive correlation between perceived physical dominance and girth, and physical dominance and strength, there was no relationship between perceived physical dominance and any of the four components of the Aggression Provocation Questionnaire (anger, frustration, irritation, and reaction, O'Connor et al., 2001), self-rated dominance, or fWHR.

There was a moderate, positive correlation between strength and ratings of physical dominance when viewing the facial photographs, suggesting that stronger men are perceived to be more physically dominant, even when the participants' full build is not on display. These findings support previous findings by Butoyskaya et al., (2018), Sell et al., (2009), and Fink and Neave's (2007) previous research that also found significant correlations between ratings of dominance and strength. As strength is linked to physical dominance, it would be beneficial to portray this to a potential opponent as a warning sign. Both Windhager et al., (2011) and Butoyskaya et al., (2018) found that the physical strength of men was strongly associated with changes of facial shape. These changes could be picked up by others and used as a cue to physical strength.

There was also a positive, significant correlation between girth and physical dominance ratings on the facial stimuli, with physically larger men being rated as higher in physical dominance. Currently there has been minimal research conducted into this relationship. Whilst Johnson and Wilson (2019) investigated perceptions of size, the stimuli they used was of full body photographs. However, the finding that men are able to display their physical size in their face is understandable with regards to combat. As physical size is advantageous during physical conflict, it would be beneficial to portray this in facial features, as if the rest of the body is covered or hidden, it would still give the man another way to portray their physical dominance to a potential opponent.

There was no significant correlation between ratings of perceived physical dominance and fWHR, despite the research discussed within the introduction and systematic review suggesting there may be (Carre et al., 2009; Carre & McCormick, 2008; Haselhuhn et al., 2015; Lefevre & Lewis, 2014; Zilioli et al., 2015). However, these findings could be explained by Wang et al., (2019), who found minimal links between fWHR and various traits relating to anti-social tendencies, arguing an evolutionary mismatch, where traits in an ancestral environment are not linked to a modern environment, as violence is not as prevalent in present times.

Hypothesis two: There will be a significant, positive correlation between physically dominant traits and perceptions of physical dominance from body movements.

Hypothesis two proposed that there would be a significant, positive correlation between ratings of physical dominance and physically dominant traits from baseline walks. Again, this hypothesis is only partially supported, as whilst there was a significant, positive correlation between perceptions of physical dominance and girth, strength, and self-rated dominance, there was no relationship between perceptions of physical dominance and any of the four components on the Aggression Provocation Questionnaire (anger, frustration, irritation, and reaction, O'Connor et al., 2001), self-rated dominance, or fWHR.

Despite their physical size not being on display, physically larger individuals were rated as more physically dominant than physically smaller men. These findings therefore suggest that men are capable of portraying their physical dominance through their biological motion. As discussed in the introduction and systematic review, there has been minimal research using motion capture to assess physical dominance, meaning these findings give novel support to the notion that men can display their physical dominance through motion. However, weight and size must play a role in motion, therefore it must be questioned whether individuals are seeing physical dominance, or are they simply seeing the man's size?

Strength correlated with ratings of physical dominance, which we also saw in ratings of the facial photographs and in previous research. Fink et al., (2016; 2017) used the same motion capture techniques as those used in this study and found a link between perceptions of strength and actual strength, a similar finding to the current study. These findings suggest that men can portray their physical dominance through movement, even when no other cues are on display. A regression suggested strength and size predicted 40% of the variance in physical dominance ratings on the walking stimuli in the current study. This shows the importance of strength and size when it comes to assessing physical dominance.

Unlike ratings of facial photographs, there was a relationship between ratings of perceived physical dominance from the baseline walk and self-rated dominance, where those higher in self-rated dominance were perceived by raters as higher in physical dominance. There has been minimal research into perceptions of dominance from the face and body that does not use unaltered stimuli (such as digitally altered facial photographs). By using unmanipulated stimuli, it supports the notion that men can portray their physical dominance in their movements.

Similar to findings using facial photographs, there was no link between perceptions of physical dominance and any of the traits on the Aggression Provocation Questionnaire (anger, irritation, frustration, and reactions, O'Connor et al., 2001), or fWHR in the walking stimuli. This could be due to the content of the questionnaire as discussed above.

Hypothesis three: There will be a gender difference between men and women and how they rate the stimuli on physical dominance.

A gender difference was found in ratings of physical dominance on the walking stimuli, with women rating the walks as higher in physical dominance compared to men. Literature has repeatedly shown that whilst women are more fearful of becoming a victim of crime, statistics suggest that men are actually more likely to be a victim of crime in most categories, barring crimes of a sexual nature and domestic violence (Fisher, 1995; Jennings et al., 2007; ONS, 2021). Furthermore, Fetchenhaur and Buunk (2006) found that on average, women were more fearful of events that might imply a physical injury compared to men, with Barberet et al., (2004) finding that college-aged women were particularly more fearful of physical violence, sexual assault, and stalking compared to men college students. This increased level of fear may explain why women rate the walks as higher in physical dominance. The women raters may be assuming that the man walking towards them may cause them harm, therefore rating them accordingly. These findings support hypothesis three.

Biomechanical Analysis

The results of the biomechanical analysis suggest that movements rated higher on physical dominance stem from the swing of the participant, a pendulum-like motion of the upper body. As previously discussed, a man's upper-body plays a key role in inflicting damage (Abe et al., 2003; Johnson & Wilson, 2019). Therefore, one technique for the upper-body to appear bigger, ergo more dominant, may be the swing motion seen in the current study.

The notion of exaggerating body size in an aggressive situation has been found within the animal kingdom. A meta-analysis conducted by Palaoro and Peixoto (2022) found that out of the 52 species reviewed, 14 (26.9%) displayed their body size prior to conflict. The researchers summarise by stating "differences in body size might contribute more to contest success because bigger bodies deter most rivals from fighting" (p. 97, Palaoro & Peixoto, 2022).

Evaluation and Future Research

With regard to the questionnaires used within the study, future chapters in the thesis will not use the Gough et al., (1952) dominance scale. This was decided due to the nature of the questionnaire, as upon reviewing the questionnaire, there was a focus on social dominance opposed to physical dominance. The focus of social dominance (where dominance via a social hierarchy is key within a group or society, Pratto & Stewart., 2011) does not involve physical conflict, and therefore not closely related to the current thesis. Therefore, this measure is not reliable in assessing physical dominance, hence the removal of the questionnaire from future research within the thesis.

Overall, the study implemented a robust methodology to record movement. By using motion capture, it ensured that when viewing the walks, perceptions were based solely on the movement, not on any other traits, thus strengthening the findings of the study. However, one issue could be that it we only recorded walks in a baseline state. As stated in the introduction, if a potential physical fight is imminent, it is unlikely that they will display their natural, every day, gait pattern. Therefore, gaining perceptions of physical dominance from baseline walks may not give the full picture on humans' ability to assess a potential threat. Due to this, the next study will record movements of men with the aim of threatening a potential opponent.

Furthermore, while the aim of the thesis is to understand perceptions pf physical dominance, the main concept being examined is being able to assess if a threat is incoming. Therefore, future studies should attempt to assess the reaction to these threatening walks. If an individual is altering their movement to display their physical dominance so that an opponent can either prepare for conflict or to flee, we may see more people avoid men when they are in an agitated state. Future chapters will explore the role of context and state emotional arousal on walking gait.

Conclusion

This study aimed to use motion data and facial photographs to understand perceptions of physical dominance. After collecting ratings from 146 participants viewing 56 walking videos and 59 facial photographs, it was found that men whose walks were rated as higher in physical dominance were both stronger and larger than those who were rated lower in physical dominance. Additionally, men whose facial photographs were rated as higher in dominance, were stronger than those rated as lower in physical dominance. These findings show support for the concept that men have evolved to display their physical dominance through their biological motion and faces. Furthermore, biomechanical analysis suggests that a pendulum-like upper-body motion may be vital to displaying a high level of physical dominance to observers.

Study two

Introduction

Study 1 recorded the walks of men in a baseline state and no instructions were given on how they should move. However, when a threat is incoming, it is unlikely a potential foe would be moving towards you in such a relaxed state. Instead, it is likely that their body movements will be somewhat different and dependent on the emotional/arousal state they find themselves in, as well as demonstrating their capabilities.

The concept of altering body movements when threatening a potential opponent is evidenced across the animal kingdom, where certain species such as armadillo lizards (*Cordylus cataphractus*), chimpanzees (*Pan troglodytes*), and gorillas (*Gorillas*) alter their movements to intimidate a potential opponent (leMouton et al., 1999; Rosier & Langkilde, 2011; Tutin & Fernandez, 1991). These findings show that certain species of social animals present a wide variety of movements to both intimidate an opponent, and to prevent physical conflict from occurring.

In humans, there has been minimal research regarding the idea of a man altering their movements when aiming to intimidate or threaten. As the cost of engaging in a physical fight can be high, it would therefore be beneficial to both present our physical dominance in the lead up to a physical conflict to deter rivals, and for us to have cognitive mechanisms that can accurately and quickly recognise these threats so we can take appropriate action.

Aims

The aims of the current study is to investigate if men alter their movements when approaching potential opponents, with the intent of confrontation, and if these alterations are perceived as being more physically dominant than their baseline walk (i.e., they exaggerate their dominance). Furthermore, the study aims to understand if these movements are effective at deterring a potential opponent. Therefore, the hypothesis of study two are:

1) There will be a significant, positive correlation between physically dominant traits and perceived ratings of physical dominance based on body movements in both the baseline and threatening walks.

2) Participants will rate threatening walks as higher in physical dominance compared to baseline walks.
3) Participants will be more likely to cross the street to avoid the men who are performing threatening walks compared to the baseline walks.
4) There will be a gender difference between men and women and how they rate the stimuli on physical dominance.

Method

Participants

An opportunity sample of 19 males were recruited via email and social media to take part in the stimuli creation portion of the study. The participants were aged between 20-37 years old (Mean age = 26.02 years, SD = 5.22 years). Inclusion criteria required participants to be over the age of 18 years old, be male (as assigned at birth), and not have any injury or condition that would interfere with their movement.

Materials

Age and injuries that affect gait (to ensure they fit the inclusion criteria) were taken. Participants were again asked what sports they currently played (which was categorised into contact and non-contact sport in line with Conley et al., 2014), as well as if they had ever been involved in a physical fight. These questions were to assess if there was a difference in how those who may engage in combat are perceived compared to those who do not.

The Aggression Provocation Questionnaire (O'Connor et al., 2001) was used in this study (as discussed in study one). In addition to this, a body opponent bag (BOB, see Figure 10) was used as a potential opponent for the participants. The BOB was placed 5 metres from the start point of the participants threatening walk and was adjusted to the participants height. Research has previously suggested that individuals may not want to engage with a physically larger (Felson, 1996), or smaller than themselves (Lawler, 1986), therefore by height adjusting the BOB, it goes some ways to avoid such issues.

Figure 10: Body opponent bag (BOB)

Procedure

The motion capture calibration of this study followed the same procedure as study one. Participants had the same physical measurements taken and completed the Aggressive Provocation Study (O'Connor et al., 2001). However, when filling this out, the participants were instructed to pick one scenario that would invoke the biggest reaction out of them should it happen in a real-life setting (see Table 9). This was later used to motivate their threatening walk.

Once they performed their T-pose to help identify possible issues with marker positioning, the participant walked the length of the lab (5 meters) for five minutes to ensure they adopted their natural gait. This natural walk was recorded to establish their 'baseline' walk. The participant was then asked to stand at the top of the motion capture lab and face the BOB. The scenario they chose to provoke them was read aloud, with details embellished and personalised to try and create a situation the participant could imagine themselves in. For example, if the participant had chosen the scenario about their partner in a pub, the participant was asked what their local pub is called and what drink they might order. If the participant chose a scenario regarding a driving incident, they were asked what car they have, and where they were travelling to. Once the scenario had been read aloud, the participant was asked to approach the BOB as if he was the man in the scenario. This walk was then recorded as their threatening walk. The study lasted approximately 1 hour.

Table 9: Scenarios picked from the Aggression Provocation Questionnaire (O'Connor et al., 2001)

Scenario	Times Chosen
You find out from a friend that your partner has been unfaithful to you on one occasion, after a works Christmas party.	7
You have gone out to have a couple of drinks with your partner. Whilst you are at the bar, a stranger approaches your partner and grabs her/his backside. On your return, your partner tells you.	6
You are driving down the motorway. As you are in the process of changing to a slower lane, a reckless driver speeds out from the inside lane, cutting you off, causing you to slam on your brakes, swerve, and nearly lose control of your car.	3
You are in a great hurry and right in front of you a car stops. A man gets out but he carries on talking to the driver, blatantly ignoring your calls for him to move. You cannot get past the car.	2
You're sat on a train quietly reading the newspaper. A couple of football supporters are sitting a few seats in front shouting, swearing, and generally being obnoxious. Suddenly, one of them throws an empty beer can in the air and it accidentally hits you.	1

Treatment of data

In line with the previous study, motion data was processed using Vicon Nexus 2 (Vicon, Oxford) and then exported to MotionBuilder (2017) to create standardised, featureless avatars. Upon completion of the avatars, all trials were rendered into .AVI format, with no compression in a 1900x1080 pixel window. This meant each of the 19 participants had videos of two walks: a baseline walk, and a threatening walk. Three of the participants punched the BOB, however this aspect of the walk was cut from the videos to ensure that ratings were made on the movement prior to the physical aggression starting. The video chosen was the best quality of the recorded trials , and was of the man walking the length of the lab (5 metres) towards the viewer (see Figure 6). The videos of the featureless avatars were uploaded to YouTube, with the videos ranging between 3-4 seconds in length.

Ratings

As two types of analyses were planned, two *a priori* power analyses were calculated, suggesting that between 64 (the G-power calculation for the *t*-test) and 71 (the G-power calculation for a Pearson's correlation) participants were needed for the study to detect a medium effect at 80% power. Therefore, 156 participants (77 men, 79 women) aged between 18-50 (mean age = 24.85 years, SD = 6.54 years) were recruited via Prolific (www.prolific.co) to take part in the study hosted on the survey platform Qualtrics (www.qualtrics.com). Participants were paid £3.13 which is the amount suggested by Prolific to be a 'good' payment to compensate for their time. The funding for this was a grant from the European Human Behaviour and Evolution Association awarded in 2021.

Participants were shown the 19 baseline walks and 19 threatening walks three times, totalling 114 videos shown across three blocks. Block one consisted of asking participants to rate '"*how physically dominant is this man?*" on a 1-7 Likert scale (where 1 is 'not very physically dominant', and 7 is 'very physically dominant'). They were given the same definition of physical dominance as the previous study: "*the regularities of winning or losing a fight, with those who have higher physical dominance winning more fights"* (Archer, 1988). Block two consisted of asking the participants to imagine that they were walking alone down a street and see this man walking towards them. They then rated each video on how likely they would be to cross the street to avoid the man. Ratings were on a 1-7 Likert Scale, with 1 being 'not very likely to cross the street' and 7 being 'very likely to cross the street'. Finally, block three asked participants to rate 'how creative is this man?' on a 1-7 Likert scale, (where 1 is 'not very creative' and 7 is 'very creative') and were given the definition of creativity as 'having the ability to produce original ideas'. A control question was decided upon to ensure that participants were not randomly selecting answers. By using creativity there should be no relationship between the ratings of creativity and ratings of physical dominance and crossing the street, to ensure that participants were not randomly allocating ratings to the traits.

There were also two attention checks per block as discussed in Oppenheimer et al., (2009), as a way to ensure participants are paying full attention to their ratings. This involved the participant selecting a specific number on the scale when instructed, and if participants failed the attention check, they were removed from the study, however, none failed the attention checks.

The presentation of each question block was randomised as well as the videos presented within each block. The study took approximately 25 minutes to complete. Cronbach's alpha was α = .96 for the overall study, showing that there was excellent interrater reliability.

Results

All statistics were calculated in SPSS version 26. The 19 men who participated in the motion capture had scores calculated on seven variables (see Table 10) where means and standard deviations were calculated for each trait (see Table 11).

Table 10: The seven traits calculated for the 19 men

Variable name	How variable was calculated
Strength	The participants' averaged hand grip strength in kg. Higher scores indicate greater strength.

Anger, Frustration, Irritation, and Reaction	The four components on the Aggression Provocation Questionnaire, where each of the sub-scales were summed. Higher scores indicate greater anger, frustration, and irritation, and a more aggressive reaction to scenarios.
Girth	By combining participants' chest (mm), shoulder (mm), and bicep circumferences (mm), with weight (kg), as seen in Hill et al., (2013). Higher girth indicates a physically larger man.
Baseline Walk: Physical Dominance	The average score of physical dominance from the 156 raters on the baseline walks. Higher scores indicate greater perceptions of physical dominance.
Threatening Walk: Physical Dominance	The average score of physical dominance from the 156 raters on the threatening walks. Higher scores indicate greater perceptions of physical dominance.
Baseline Walk: Street Crossing	The average score of how likely they would be to cross the street to avoid the man from the 156 raters on the baseline walks. Higher scores indicate greater perceptions of physical dominance.
Threatening Walk: Street Crossing	The average score of how likely they would be to cross the street to avoid the man from the 156 raters on the threatening walks. Higher scores indicate greater perceptions of physical dominance.

Table 11: Means and standard deviation for each measure

Measure		Mean (SD)
Strength		41.00kg (7.73kg) (range: 30kg – 57kg).
APQ	Anger	27.53 (10.92) (range: 10-42)
	Frustrated	27.58 (9.44) (range: 8-42)
	Irritated	29.63 (8.35) (range: 14-42)
	Reaction	35.58 (6.83) (range: 25-51)
Girth		2383.82 (172.98) (range: 2163 – 2822).
Perceived physical dominance	Baseline	3.70 (.77) (range: 2.43 – 5.29).
	Threatening	3.94 (.73) (range: 2.31 – 4.85).
Crossing street	Baseline	3.08 (.38) (range: 3.21 – 4.36).
	Threatening	3.70 (.74) (range: 3.28 – 4.35).

Creativity	Baseline	3.79 (.27) (range: 3.21 – 4.36)
	Threatening	3.89 (.30) (range: 3.28 – 4.35)

Principle Component Analysis (PCA)

In line with Hill et al., (2013) and the findings from the previous study, a PCA was conducted to determine the underlying components(s) of participants' body measurements (shoulder, chest, and bicep circumferences (mm), and weight (kg). Table 12 shows the component loadings per latent variable. The KMO was deemed as good in accordance with (Sofroniou & Hutcheson, 1999) at .760, showing there is an adequate sample size to run the PCA. Furthermore, the Bartlett's test of Sphericity (1937) was significant (p <. 01), further showing that conducting the PCA was appropriate. Weight, bicep, shoulder, and chest circumferences loaded onto one component. Therefore, these were summed to create the component 'girth', containing the same variables (chest, shoulder, and bicep circumference (mm) and weight (kg)) as study one. This accounted for 73.94% of the total variance in the participants' body measurements.

Table 12: Component factor loadings for the weight, bicep, shoulder, and chest variables

Measure	Component 1
Chest	.942
Weight	.890
Shoulder	.807
Bicep	.942

t-tests

Paired sample *t*-tests were conducted to investigate if ratings of physical dominance increased from viewing the baseline walk to viewing the threatening walk, as well as if the likelihood of crossing the street increased from viewing the baseline walk to viewing the threatening walk. When running assumption checks, the data was not normally distributed for the threatening walks. However, as discussed in Havlicek and Peterson (1974), this does not alter the robustness of the *t*-test, therefore the analysis was conducted.

Table 13: Mean and standard deviations for physical dominance scores on both walks

	Physical Dominance Ratings	
	Baseline Walks Mean (SD)	Threatening Walks Mean (SD)
Overall sample (n=156)	3.70 (.77)	3.94 (.73)
Women (n=79)	3.66 (.79)	3.83 (.72)
Men (n=77)	3.75 (.78)	4.05 (.77)

A paired samples *t*-test revealed there was no significant difference between baseline (M = 3.70, SD = .77) and threatening walks (M = 3.94, SD = .73) on perceived physical dominance ratings: $t(18) = 1.62$, $p = .124$. There was no significant difference between men (M = 3.75, SD = .78) and women's (M = 3.66, SD = .79) ratings of perceived physical dominance on the baseline walk: $t(18) = 1.54$, $p = .140$. However there was a significant difference for the threatening walk: $t(18) = 2.93$, $p = .01$, $d = .30$, showing a small effect size, with men rating the walks as higher in physical dominance (M = 4.05, SD = .08) compared to women (M = 3.83, SD = .72).

Table 14: Mean and standard deviations for crossing the street likelihood on both walks

	Crossing the street	
	Baseline walks mean (SD)	Threatening walks mean (SD)
Overall sample (n=156)	3.08 (.38)	3.70 (.74)
Women (n=79)	3.37 (.37)	3.86 (.66)
Men (n=77)	2.78 (.41)	3.05 (.83)

When comparing the likelihood of crossing the street on the baseline and threatening walks, there was a significant increase in likelihood of crossing the street when viewing the threatening walk (M = 3.70, SD = .74) compared to the baseline walk (M = 3.08, SD = .38) in the overall sample, $t(18) = 5.25$, $p < .01$, $d = 1.05$. Using Cohen's (1988) conventions, this is a large effect.

When investigating if there was a gender difference between men and women's likelihood of crossing the street, it was found that women were significantly more likely to cross the street than men, when viewing both the baseline walk ($t(153)$, = 14.90, $p < .01$, $d = 1.51$, M = 3.37, SD = .37 for women, and M = 2.78, SD = .41 for men) and the threatening walk ($t(153)$, = 6.13, $p <.01$, $d = 1.08$, M = 3.86, SD = .66 for women, and M = 3.05, SD = .53 for men), with both again showing a large effect size.

An independent sample *t*-test was conducted to compare the ratings of physical dominance and likelihood of crossing the street, between those who played contact sport, and those who do not. Five of the men played combat sport, which included rugby and football. In regards to ratings of physical dominance on the baseline walks, there was no significant difference between ratings on men who played contact sports (M = 3.89, SD = .71) and those who do not (M = 3.63, SD = .81), $t(17) = -.62$, $p = .54$. The same was found with ratings on the threatening walks, where there was no significant difference between men who played contact sports (M = 4.26, SD = .40) and those who do not (M = 3.83, SD = .80), $t(17) = -1.13$, $p = .27$. These findings were mirrored when investigating ratings of crossing the street, where again it was found that there was no significant difference in ratings on the baseline walk between those who played contact sports (M = 3.00, SD = .23) and those who do not (M = 3.11, SD = .42), $t(17) = .56$, $p = .58$, or the threatening walk (M = 3.50, SD = .54 for men who played contact sports, M = 3.77, SD = .80 for men who do not partake in contact sport), $t(17) = .51$, $p = .50$.

An independent sample *t*-test was also conducted to compare ratings of physical dominance and likelihood of crossing the street, between those who had been involved in a physical fight at some point in their lives, and those who had not, with nine men having been involved in a physical fight. For ratings of physical dominance on the baseline walks, there was no significant difference between ratings on men who had been in a physical fight (M = 4.00, SD = .80) and those who have not (M = 3.40, SD = .65), $t(17) = -1.70$, $p = .10$. The same was found with ratings on the threatening walks, where there was no significant difference between men had been involved in a physical fight (M = 4.00, SD = .60) and those who had not (M = 3.84, SD = .88), $t(17) = -.58$, $p = .57$. These findings were replicated when investigating ratings of crossing the street, as there was no significant difference in ratings on the baseline walk between those who had been involved in a physical fight (M = 3.09, SD = .39) and those who have not (M = 3.07, SD = .40), $t(17) = -.14$, $p = .87$, or the threatening walk (M = 3.77, SD = .84 for men who had engaged in a physical fight, M = 3.62, SD = .64 for men who had not), $t(17) = .43$, $p = .67$.

Correlations

Pearson's correlations were then conducted between strength, girth, anger, frustration, irritation, reaction (the four components from the aggression provocation questionnaire, O'Connor et al., 2001), and physical dominance ratings on the baseline and threatening walks (see Table 15) and the street crossing scores on the baseline and threatening walks (see Table 16).

Table 15: Correlation between traits and perceived physical dominance ratings

							Dominance ratings per walk	
	Anger	Frustration	Irritated	Reaction	Girth	Strength	Baseline	Threatening
Anger		**.861****	**.922****	.282	-.048	.201	.280	.167
Frustration			**.897****	.262	-.104	.145	.138	.183
Irritated				.331	.046	.107	.305	.318
Reaction					.399	.120	.317	.153
Girth						**.569***	**.577****	.271
Strength							**.495***	.245

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

Table 16: Correlation between traits and likelihood of crossing the street

							Street crossing ratings per walk	
	Anger	Frustration	Irritated	Reaction	Girth	Strength	Baseline	Threatening
Anger		**.861****	**.922****	.282	-.048	.201	-.276	-.183
Frustration			**.897****	.262	-.104	.145	-.240	-.014
Irritated				.331	.046	.107	-.126	-.014
Reaction					.399	.120	.120	.153
Girth						**.569***	**.602****	**.538***
Strength							.281	.361

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

A significant correlation was found between scores of physical dominance ratings and strength in the baseline walks, $r(17) = .50$, $p = .03$; physical dominance ratings and girth in the baseline walks, $r(17) = .58$, $p = .01$; crossing the street and girth in the baseline walks, $r(17) = .60$, $p = .01$; and crossing the street and girth in the threatening walks, $r(17) = .54$, $p = .02$. All of these correlations were strong, positive correlations (Cohen, 1988). In addition, there were strong, positive correlations between dominance ratings in the baseline walks and dominance ratings in the threatening walks, $r(17) = .64$, $p = .01$, and likelihood of crossing the street in the baseline walks and likelihood of crossing the street in the threatening walks, $r(17) = .76$, $p < .01$.

There were no significant correlations between any variables and ratings of creativity, supporting its use as a control question. This therefore suggests participants did not randomly assign ratings to the questions, giving strength to the findings. No other significant correlations were observed when looking at correlates for physical dominance and likelihood of crossing the street (all $p > .05$).

Regression

Due to the significant correlations found between girth, strength, and ratings of physical dominance on the baseline walks (see Table 15), an enter method regression was conducted. The initial regression contained two predictors, girth and strength, with the ratings of physical dominance on the baseline walks as the outcome variable. The results of the regression suggest these two predictors explain 37.4% of the variance in ratings of physical dominance, $R^2 = .37$, $F(1,16) = 4.77$, $p = .02$. When viewing each of the two predictors separately, neither girth (β= .44; $t(16) = 1.81$, $p = .08$) nor strength (β= .25; $t(16) = 1.03$, $p = .32$) were significant predictors. However, as girth neared significance, the regression was re-ran removing strength as a predictor. The regression was therefore conducted with girth as the predictor variable and the ratings of physical dominance on the baseline walks as the outcome variable. Girth explained 33.2% of the variance in ratings of physical dominance: $R^2 = .33$, $F(1,16) = 8.47$, $p = .01$, and girth was a significant predictor, (β= .57; $t(16) = 2.91$, $p = .01$).

Two further regressions were conducted based off the correlations for crossing the street (see Table 16). The initial regression had girth as a predictor variable and the likelihood of crossing the street in the baseline walks as the outcome variable. Girth explained 36.2% of the variance in ratings of physical dominance: $R^2 = .36$, $F(1,16) = 9.64$, $p = .01$, and girth was a significant predictor: (β= .60; $t(16) = 3.10$, $p = .01$). A final regression was conducted with girth as a predictor variable and the likelihood of crossing the street to avoid the man in the threatening walks as the outcome variable. Girth explained 29.0% of the variance in ratings of physical dominance: $R^2 = .29$, $F(1,16) = 6.93$, $p = .02$, and girth was again a significant predictor, (β= .54; $t(16) = 2.63$, $p = .02$).

Discussion

Summary of Findings

The current study aimed to understand if men move differently when approaching a potential opponent in order to exaggerate their dominance, and if onlookers of this movement can accurately assess this. There were four hypotheses to the study: i) that there will be a significant, positive correlation between physically dominant traits and perceptions of physical dominance from body movements; ii) that participants will rate threatening walks as higher in physical dominance compared to baseline walks; iii) that participants will be more likely to cross the street to avoid the man on the threatening walks compared to the baseline walks; and iv)there will be a gender difference between men and women and how they rate the stimuli on physical dominance.

Overall, girth and strength correlated with ratings of physical dominance on the baseline walks, where physically larger and stronger men were rated higher on physical dominance. There was no significant difference between the baseline walks compared to threatening walks in terms of perceived dominance. Furthermore, girth significantly correlated with both the baseline and threatening walks in likelihood of crossing the street, where physically larger men were significantly more likely to be avoided. There was a significant difference between baseline and threatening walks on participant’s likelihood of crossing the street, with participants being significantly more likely to cross the street to avoid a man in an agitated state compared to when he was at baseline.

Hypothesis one: There will be a significant, positive correlation between physically dominant traits and perceived ratings of physical dominance based on body movements in both the baseline and threatening walks.

Hypothesis one suggested that there would be a significant, positive correlation between physically dominant traits and ratings of physical dominance and physically dominant traits and street crossing likelihood. There was a link between girth, strength, in both ratings of physical dominance and likelihood of crossing the street, however no correlations between the four traits of the APQ were found. Therefore, the hypothesis can only be partially supported. There was a significant, positive correlation between strength and girth and ratings of physical dominance on the baseline walks, where physically larger and stronger men were rated higher in physical dominance compared to physically smaller and weaker men. This echoes the findings in study one, where physically larger and stronger men were rated as significantly higher in physical dominance on their baseline walk. As discussed within study one, the link between higher ratings of physical dominance and strength and size is not surprising, with multiple studies finding a link between the attributes and physical dominance (e.g., Fink et al., 2016; 2017). These findings further support the notion that men are able to portray these attributes via their movement, leading to an advantage when engaging in combat to portray their physical dominance to a potential foe. However, the link between strength and girth was only found within baseline walks, not the threatening walks, suggesting that there is another factor being observed when assessing threatening walks. For example, men could be portraying other traits, such as aggression (a trait not measured within the current study), when acting in a threatening manner.

There was a significant, positive correlation between girth and likelihood of crossing the street in both the baseline and threatening walks, with people being more likely to cross the street when facing a physically larger man. This correlation reiterates what has been found previously, in that girth plays a key role in physical dominance and this can have an impact on behaviour (e.g., avoiding the man). However, while a correlation was found between ratings of physical dominance and strength, there was found to be no significant relationship between strength and likelihood of crossing the street. One explanation for this may be why people are crossing the street to avoid the person. Within the UK, one in two women and one in seven men felt unsafe when walking alone after dark (ONS, 2021). This unsafe feeling may not be due to a physical threat, where assessment of strength would be important. For example, three out of five women aged 16-34 years experienced some form of harassment in the year 2020-2021, with 44% of women having experienced catcalls or unwanted sexual comments. The fear of verbal harassment may be why people are crossing the street to avoid the man and why strength may not be as much of an important factor when deciding upon what action to take.

Hypothesis two: Participants will rate threatening walks as higher in physical dominance compared to baseline walks

Hypothesis two predicted a significant difference between ratings of physical dominance between the baseline and threatening walk, with threatening walks being rated as higher in physical dominance compared to the baseline walk. Whilst there was a marginal increase in perceptions of physical dominance, it was not a significant increase therefore not supporting hypothesis two. These findings, whilst unexpected, could potentially be explained by the low numbers of men who partook in the stimuli creation. Nineteen participants is considerably lower than study one and other research in the area (e.g., Fink et al, 2016; 2017), which could explain the null findings. This is supported from the variability of ratings of physical dominance. For both baseline and threatening walks, a standard deviation of .77 and .73 was found respectively, suggesting low variance in the ratings of physical dominance. When viewing the range of the scores, the data suggests that the men in the study were not particularly physically dominant, as 53% of the participants had a physical dominance score between 2.43 – 3.58 out of a possible score of 7 on the baseline walks, with a total range of 2.43-5.29 out of a possible score of 7 for all 19 participants. Furthermore, 53% of the participants had a physical dominance score between 2.31-3.97 out of a possible score of 7 on the threatening walks, with an overall range of 2.31-4.85. As the ratings of physical dominance was so low, it may suggest that a spectrum of physically dominant men was not present within the study. By gaining more participants for stimuli creation, it may increase the chances of getting physically dominant men at both ends of the spectrum.

Hypothesis three: Participants will be more likely to cross the street to avoid the men who are performing threatening walks compared to the baseline walks.

Hypothesis three stated that there would be a significant difference between participants' likelihood of crossing the street to avoid the man on the two walks, with the threatening walks being rated higher in likelihood of crossing the street compared to baseline walks. The study showed that participants were more likely to cross the street and avoid the man when viewing the threatening walk compared to the baseline walk. These findings suggest that men walk differently when approaching an opponent for an altercation and may do this with the aim to threaten an individual. Additionally, onlookers of this movement are able to differentiate between a threatening and non-threatening walk and take further action, therefore supporting hypothesis three. As it is beneficial to avoid physical conflict due to the potentially high cost (Davies & Krebs, 1984), it suggests that the threatening walks are successful in deterring a potential opponent, as both the men and women were more likely to cross the street to avoid the men's threatening walk. As there was a significant difference between baseline and threatening walks for crossing the street but not for physical dominance, it could suggest that it is not physical dominance being demonstrated through motion, yet the aim of deterring an opponent to reduce the cost of engaging physical conflict is still achieved.

Hypothesis four: There will be a gender difference between men and women and how they rate the stimuli on physical dominance.

For ratings of physical dominance, the results showed a gender difference with men rating the walks as more physically dominant compared to women, but only when viewing the threatening walks. As men are more likely to engage in intrasexual conflict (Buss & Shackleford, 1997) and be involved physically violent crimes (Daly & Wilson, 1988; Gottfredson & Hirschi, 1990), it may be beneficial to overestimate an opponent's physical dominance in order to avoid a physical conflict. This is supported by Damasio's (1994) Somatic Marker Hypothesis and Haselton and Buss (2009) Error Management Theory, which state that humans are more likely to overestimate the level of threat posed to ensure maximum chance of survival. This notion is supported in the animal kingdom, where if an opponent is deemed too much of a potential threat, the animal will withdraw from a fight and avoid the damage that would have been inflicted (Clutton-Brock et al., 1979).

The data also showed gender differences between men and women's likelihood of crossing the street. Women were significantly more likely to cross the street to avoid the men at both baseline walk and threatening walk. As previously discussed, women are less likely to be a victim of violent crime (excluding sexual offences and domestic abuse) than men, but are more fearful of becoming a victim of crime (Fisher, 1995; Hale, 1996; Jennings et al., 2007; ONS, 2021). The recent ONS (2021) report does support these findings, where one in every two woman felt unsafe when walking alone after dark compared to one in seven men feeling fearful. While historically it was men that were more likely to engage in intrasexual competition of resources and mating opportunities (Buss & Shackelford, 1997), it has been argued that it is more important for women to have a higher level of fearfulness, enabling them to avoid danger and ensuring the survival of offspring.

Evaluation and Future Research

We found no significant difference between ratings of physical dominance when viewing the baseline walks and threatening walks, which could be due to a methodological issue with the study, such as the low sample size for the stimuli set. However, as there was a significant difference between street crossing on the two walks, it suggests that men are moving differently, perhaps to deter a potential opponent. Observers can see the difference and adapt their path accordingly. However, it was not possible to conduct biomechanical analysis (as seen within study one) on the current data due to time restraints, therefore the exact movement that is being portrayed is still unknown. Biomechanical analysis will be conducted on the data set at a later date to give a clearer picture as to what threatening movements are being portrayed, and if it is the same swing seen in study one. As minimal research has used biological motion as stimuli, and even less investigate perceptions of both baseline and threatening walks, it gives new evidence to support the theory of intrasexual selection and that men are able to portray their threatening intent to a potential foe.

For future research, recruiting more men to take part as stimuli would be beneficial to ensure there is a wider range of movements on display. Due to COVID-19, it was not possible to recruit more men to take part in the study. Another problem with the study was the lack of understanding of the men's own physical dominance. As discussed, the dominance scale used in study one may not have been the most valid to use in the context of this research, however in this study no alternative was used as the researchers felt no suitable questionnaire were available to assess self-rated physical dominance. Future studies will assess men's physical dominance through self-report to understand if there is a relationship between self-reported physical dominance and perceptions of physical dominance.

Conclusion

The study aimed to establish whether men move differently according to whether they are at baseline or when approaching an opponent in an altercation. We also sought to investigate if observers rated men's threatening movements as more dominant, which would suggest the presence of an intimidation or exaggeration of their dominance. The results showed that ratings of physical dominance did not increase when viewing the baseline walks compared to the threatening walks, however men were more likely to rate the threatening walks as more physically dominant compared to women. When asked how likely they would be to cross the street to avoid the man walking towards them, likelihoods increased when viewing the baseline walks compared to the threatening walks. Furthermore, women were more likely to cross the street compared to men when viewing both the baseline and threatening walks. These findings support the notion that men are able to deter a potential opponent with their biological motion.

Study three

Introduction

As discussed within the introduction, it is estimated that approximately 44% of men's sexually selected traits are used for intrasexual contests in the animal kingdom (Wiens & Tuschhoff, 2020). These can include weapon-like features, such as the enlarged claws of fiddler crabs (*Uca annulipes*) or the elongated horns of rhinoceros beetles (*Dynastinae*, Emberts et al., 2021). These weapons can provide an advantage when engaging in conflict, something that humans also utilise.

Research into historic cranial trauma examining the skeletal remains of individuals from 80,000 to 20,000 years ago found a higher prevalence of trauma in men compared to women (Beier et al., 2018; Beier et al., 2021). These studies comprised a sample of 234 individual crania with 1,285 cranial bones, and suggested that men were more at risk of neurocrania injuries (the upper and back section of the skull) compared to women. Skeletal differences between men and women have long been found, with a range of research showing that skeletal remains of men are more likely to show injuries compared to the skeletal remains of women (Cohen et al., 2014; Fibiger et al., 2013; Milner et al., 2015). A recent study examined calvaria (upper skull) injuries from 30,000 years ago (Kranioti et al., 2019). One injury, a depressed and inwardly displaced cranial fragment, has a semi-circle shape and after extensive testing, the researchers concluded that the cause was unlikely due to an environmental accident, but from a rounded object, such as a club. Further these findings suggest that weapons may have been used in historic conflicts between men (Kranioti et al., 2019).

The use of more modern weapons, such as spears, have been evidenced as far back as 7500 years ago (Hughes, 1998), and perhaps longer (Christenson, 1986).Weapon use is still highly prominent in current times. In the year March 2021 to April 2022, there were approximately 49,094 possession of a weapon offences recorded by the police in England and Wales, the highest figure in the past 20 years (Office for National Statistics, 2022). Furthermore, the report states that for all offences in England and Wales over the past 20 years, between 0.4% and 0.2% involved a firearm. With regards to knife and offensive weapon offences in England and Wales, 2022 saw a 5% increase to 19,555 offences compared to 2021. Furthermore, when viewing homicides by method of killing in England and Wales in 2020/2021, 40% involved a sharp instrument and 5% used a blunt instrument.

Blunt weapons come in many forms but in modern times, perhaps the first one to come to mind is a baseball bat. The baseball bat has long been used as a weapon, with Adair (1994) discussing how the instrument has been used for both domestic and street violence. In a study investigating 90 documented baseball bat injuries between June 1997 to June 2000 there were 39 cranial fractures, showing the potential severity of being involved in a conflict where the opponent has a bat (Dujovny et al., 2009). In an American study investigating self-defence methods in the home, it was found that only two participants had used a gun, with the majority of participants reporting using another weapon. Specifically, nine participants said they used a baseball bat, two used a stick, and two used a club (Azrael & Hemenway, 2000).

Aims

Whilst the previous studies have supported the notion of detecting physical dominance in men, no research to date has investigated the impact carrying a weapon, specifically a baseball bat, can have on how an onlooker perceives their movements. As a weapon can cause additional physical damage, it would be beneficial to possess a cognitive mechanism to assess this. Therefore, five hypotheses were formulated, following the method of the prior chapters, but with the addition of the men holding baseball bats during their threatening walks.

1) There will be a significant positive correlation between physically dominant traits and ratings of physical dominance.
2) There will be a significant positive correlation between physically dominant traits and likelihood of crossing the street.
3) There will be a significant difference between ratings of the baseline walk and threatening walks, with threatening walks (including the ones involving a weapon) as being rated as higher in physical dominance.

4) There will be a significant difference between ratings of the baseline walk and threatening walks (including the ones involving a weapon), with people being more likely to cross the street to avoid the person on threatening walks.
5) There will be a gender difference between men and women and how they rate the stimuli on physical dominance.

Method

Participants

Thirty-seven men (aged 18 – 56, mean age = 25.3 years old, SD = 5.3 years old) were recruited to take part in the motion capture aspect of the study, however three participants had to be excluded: two for having faulty motion capture data, and one for later disclosing they had an injury that affected their movement. The recruitment of the participants was on a convenience sampling basis through social media, with the inclusion criteria being that they are at least 18 years old, have no current or previous injuries that affect their gait, and being male (assigned at birth).

Materials

The same questionnaires discussed in study two were used, in addition to a question to assess their own physical dominance. This question asked if they were to engage in a physical fight win a man of a similar size to them, how likely are they to win on a 1 – 7 scale (1 being ‘not very likely at all’, 7 being ‘extremely likely’). As in previous studies, participants were asked to indicate which scenario from the Aggression Provocation Questionnaire (O’Connor et al., 2001) would provoke a reaction out of them the most.

Procedure

The motion capture procedure was the same discussed in study one.

Participants were asked to walk up and down the room for five minutes to ensure their natural gait was apparent. This was then recorded to establish their baseline walking gait pattern. The BOB (as seen in study two) was then placed in line with the participant, five meters away on the other side of the room and adjusted to match the participants height. The chosen scenario was then read to the participants and embellished (see Table 17 for scenarios).

Table 17: Scenarios chosen for study three

Scenario	Times Chosen
You find out from a friend that your partner has been unfaithful to you on one occasion, after a works Christmas party.	13
You have gone out to have a couple of drinks with your partner. Whilst you are at the bar, a stranger approaches your partner and grabs her/his backside. On your return, your partner tells you.	5
Your boss believes you have made a minor mistake at work. In the presence of all your work mates, he embarrasses you by calling you an incompetent imbecile.	5
You are driving down the motorway. As you are in the process of changing to a slower lane, a reckless driver speeds out from the inside lane, cutting you off, causing you to slam on your brakes, swerve, and nearly lose control of your car.	4
You are in a great hurry and right in front of you a car stops. A man gets out but he carries on talking to the driver, blatantly ignoring your calls for him to move. You cannot get past the car.	2
It is Saturday afternoon and you are looking for a parking space in the centre of town. You drive into a car park and just as you are about to reverse into one of the few remaining spaces another car speeds into your space.	2

You are walking down the street on your way to an interview for a new job. As you turn the corner, a window cleaner nearby, accidentally spills soapy, hot water on your newly dry-cleaned suit.	1
You’re sat on a train quietly reading the newspaper. A couple of football supporters are sitting a few seats in front shouting, swearing and generally being obnoxious. Suddenly, one of them throws an empty beer can in the air and it accidentally hits you.	1
You are in the cinema watching a movie. Behind you two lads are talking, laughing loudly and kicking the back of your seat all the time.	1

Participants were then either given nothing (an unarmed, but threatening walk), an umbrella, or a baseball bat (the order each threatening walk was given was randomised for every participant) and asked to approach the BOB with their subsequent motion recorded. This was then repeated for the other two items (the same scenario being read and embellished each time), meaning participants had four recordings in total: a baseline walk, unarmed walk, umbrella walk, and a bat walk. The participants were not instructed how to pick up the weapon and were free to handle it anyway they wanted. This was done to try and ensure that participants felt comfortable, as well as increase ecological validity.

A bat was used as the weapon for two reasons. One, due to damage that could be inflicted, as discussed within the introduction, and secondly for ethical reasons to ensure the safety of the researchers. The umbrella was used as a control for the bat, as while an umbrella can still be used as a weapon, it is unlikely to inflict the same level of damage as a bat. Furthermore, an umbrella is likely to be held in a similar manner to a baseball bat, ensuring that the videos are not too visually distinct from one another, potentially altering the perceptions of the movements, as well as being a similar size and shape to one another.

The study took approximately one hour, and participants were given a £20 Amazon voucher, funded by Northumbria University.

Treatment of data

The motion capture data was treated in the same way as discussed in study one. However, due to the participant holding an item in some conditions, 'characters' were not used in this study, and instead the 'actor' was presented to participants (see Figure 5). This decision was made because when the motion data was rigged onto the character, the resulting animation looked unusual and distracting. This could alter perceptions of the movement as attention may be drawn to it. Using the 'actor' somewhat fixed these visual anomalies, but at the cost of de-standardising the build of the participant. To attempt to counterbalance this, the videos were rendered at the walker's eye height. It was also decided to hide the umbrella and baseball bat from the animations so viewers could make judgements based on the movement of the men, not on the item they were holding. Overall, this was found to be successful, with the end results leaving viewers unable to discern if the walker was carrying a weapon (see Figure 11, Figure 12, Figure 13, and Figure 14 for frames of each type of walk).

Figure 11: video showing a participants baseline walk

Figure 12: video showing a participants' unarmed walk

Figure 13: video showing a participants umbrella walk

Figure *14*: video showing a participants bat walk

The 34 participants each had four walks rendered (baseline, unarmed, umbrella, and bat walks), resulting in a total of 136 videos. In a similar fashion to study two, if a participant struck the BOB in any way, the video was cut before that point to ensure that the judgements were made on the movement alone. In total, on the unarmed walks ten participants (29.4%) engaged in physical violence, with eight participants punching the BOB and two pushing the BOB. Twelve participants (35.3%) engaged in physical violence when using the umbrella, with all 12 hitting the BOB with the umbrella. Finally, 11 participants (32.4%) engaged in physical violence when using the baseball bat, with six participants hitting the BOB with the bat, three poking the BOB with the bat, and two dropping the bat and punching the BOB. All of these movements were removed from the videos. Five videos needed to be removed due to technical problems with the Vicon data recordings (three bat walks and two umbrella walks), and a further three umbrella videos needed to be removed due to being too short (less than a second long). This resulted in a total of 128 videos: 34 baseline walks, 34 unarmed walks, 29 umbrella walks, and 31 bat walks.

Method – Raters

Participants

As two types of analyses were planned, two *a priori* power analyses were run, suggesting that between 64 (the G-Power calculation for the *t*-test) and 71 (the G-Power calculation for a correlation) for the study to detect a medium effect at 80% power. Therefore, 154 participants (75 men, 77 women, one non-binary individual, and one individual who did not give their gender) aged between 18-52 (mean age = 26.3 years, SD = 7.2 years) were recruited via prolific (www.prolific.co) to take part in the study hosted on Qualtrics (www.qualtrics.com). Participants were paid £3.13 (the amount suggested by prolific to be a ‘good’ payment) to compensate for their time. This money was awarded through a grant from the European Human Behaviour and Evolution Association in 2022.

Procedure

Participants were randomly allocated to one of three blocks which contained either 44 or 41 videos of baseline, unarmed, umbrella, and bat walks. It was decided to use three blocks to ensure the study took a reasonable time to complete, as research suggests an online study should be no more than 28 minutes long (Revilla & Höhne, 2020). The participants viewed the 44 or 41 videos three times (resulting in participants seeing a total of either 132 or 123 videos, depending on the block they were allocated), each time with a different question present. The questions used were the same as study two: “*how physically dominant is this man?*” on a 1-7 Likert scale, (where 1 is ‘not very physically dominant’, and 7 is ‘very physically dominant’), *“how likely would* *you be to cross the street to avoid the man?",* on a 1-7 Likert Scale, (where 1 being 'not very likely to cross the street' and 7 being 'very likely to cross the street'), and "*how creative is this man?*" on a 1-7 Likert scale, (where 1 is 'not very creative' and 7 is 'very creative'). The allocation to each block was randomised, as were the order of the videos and questions. The study took approximately 25 minutes to complete.

Results

All statistics were calculated in SPSS version 26. The 37 men who participated in the motion capture had scores calculated on 12 variables (Table 18) where means and standard deviations were calculated for each trait (see
Table 19).

Table 18: Variables and how they were calculated for study three and four

Variable name	How variable was calculated
Strength	The participants' averaged hand grip strength in kg. Higher scores indicate greater strength.
Anger, Frustration, Irritation and Reaction	The four components on the Aggression Provocation Questionnaire, where each of the sub-scales were summed. Higher scores indicate greater anger, frustration, and irritation, and a more aggressive reaction to scenarios.
Girth	By combining participants' chest (mm), shoulder (mm), and bicep circumferences (mm), with weight (kg), as seen in Hill et al., (2013). Higher girth indicates a physically larger man.
Self Rated Dominance	Participants score on rating themselves on how likely they would win a physical fight on a 1 (not very likely) to 7 (very likely) scale.

Baseline Walk:Physical Dominance	The average score of physical dominance from the 154 raters on the baseline walks. Higher scores indicate greater perceptions of physical dominance.
Unarmed Walk: Physical Dominance	The average score of physical dominance from the 154 raters on the unarmed threatening walks. Higher scores indicate greater perceptions of physical dominance.
Umbrella Walk: Physical Dominance	The average score of physical dominance from the 154 raters on the umbrella threatening walks. Higher scores indicate greater perceptions of physical dominance.
Bat Walk: Physical Dominance	The average score of physical dominance from the 154 raters on the bat threatening walks. Higher scores indicate greater perceptions of physical dominance.
Baseline Walk: Street Crossing	The average score of how likely they would be to cross the street to avoid the man from the 154 raters on the baseline walks. Higher scores indicate greater perceptions of physical dominance.
Unarmed Walks: Street Crossing	The average score of how likely they would be to cross the street to avoid the man from the 154 raters on the unarmed threatening walks. Higher scores indicate greater perceptions of physical dominance.
Umbrella Walk: Street Crossing	The average score of how likely they would be to cross the street to avoid the man from the 154 raters on the umbrella threatening walks. Higher scores indicate greater perceptions of physical dominance.

Bat Walk: Street Crossing	The average score of how likely they would be to cross the street to avoid the man from the 154 raters on the bat threatening walks. Higher scores indicate greater perceptions of physical dominance.

Table 19: Means and standard deviation for each measure

Measure		Mean (SD)
Strength		45.09kg (7.90kg) (range: 33.5kg – 76kg)
APQ	Anger	28.26 (8.13) (range: 10 – 42)
	Frustrated	30.03 (8.86) (range: 10 – 42)
	Irritated	31.79 (8.12) (range: 14 – 42)
	Reaction	36.88 (4.60) (range: 25 – 51)
Girth		2916.72 (258.32) (range: 2054 – 3601)
Self rated physical dominance		4.56 (1.31) (range: 1-7)
Perceived Physical Dominance	Baseline	3.15 (.73) (range: 2.04 – 4.52)

	Unarmed	3.85 (.95) (range: 2.26 – 5.88)
	Umbrella	3.79 (1.12) (range: 2.10 – 6.44)
	Bat	3.54 (1.00) (range: 2.15 – 5.65)
Street Crossing	Baseline	2.92 (.58) (range: 1.78 – 3.79).
	Unarmed	3.77 (.97) (range: 1.90 – 6.48)
	Umbrella	3.77 (1.06) (range: 2.22 – 6.46)
	Bat	3.55 (.91) (range: 2.02 – 5.62)
Creativity	Baseline	3.40 (.29) (range: 2.02 – 5.62)
	Unarmed	3.27 (.42) (range: 2.47 – 4.35)
	Umbrella	3.45 (.38) (range: 2.68 – 4.55)
	Bat	3.27 (.40) (range: 2.30 – 4.05)

Principal Component Analysis (PCA)

In line with Hill et al., (2013) and the findings from the previous study, a PCA was conducted to determine the underlying variable(s) of participants' body measurements (shoulder, chest, bicep circumferences (mm), and weight (kg)). shows the component loadings per latent variable (see Table 20). The KMO was deemed as good in accordance with Hutcheson and Sofronious (1999) at .791, showing there is an adequate sample to run the PCA. Furthermore, Bartlett's test of Sphericity (1937) was significant ($p < .01$), further showing that conducting the PCA is appropriate. Weight, bicep, shoulder, and chest circumferences loaded onto one component. Therefore, these were summed to create the component 'girth'. Again, this was in line with study one and two and Hill et al., (2013). This accounted for 86.67% of the total variance in the participants' body measurements.

Table 20: Component factor loadings for the weight, bicep, shoulder, and chest variables

Measure	Component 1
Chest	.981
Weight	.935
Shoulder	.958
Bicep	.845

Correlations

All traits were calculated as discussed in SPSS. Pearson's correlations were conducted between strength, self-rated dominance, anger, frustration, irritation, reaction, strength, girth (see Table 21 for mean scores), and the physical dominance ratings and street crossing ratings on walks on all four of the participants walks (see Table 22 for mean scores). Correlations were also run between creativity ratings and physical dominance and street crossing, where no significant correlations were found (p >.05), supporting its use as a control question in the study, as discussed within study two.

Table 21: Means and standard deviations for each trait

Trait	Mean (SD)
Self-rated Dominance	4.56 (1.31)
Anger	28.26 (8.12)
Frustration	30.03 (8.86)
Irritation	31.79 (8.16)
Reaction	36.88 (4.60)
Girth	2916.79 (258.32)
Strength	45.09kg (7.70kg)

Table 22: Means and standard deviations for ratings on the baseline, unarmed, umbrella, and bat walks for physical dominance ratings and likelihood of crossing the street

	Dominance Ratings Means (SD)	Street Crossing Ratings Means (SD)
Baseline	3.15 (.73)	2.92 (.58)
Unarmed	3.85 (.95)	3.77 (.98)
Umbrella	3.79 (1.12)	3.77 (1.06)
Bat	3.54 (1.00)	3.56 (.91)

Table 23: Correlation between traits and physical dominance ratings

	Anger	Frustration	Irritated	Reaction	Girth	Strength	Dominance ratings per walk			
							Baseline	Unarmed	Umbrella	Bat
Self-rated dominance	-.037	.004	.000	.243	**.555****	**.513****	.189	**.372***	**.455****	.318
Anger		**.882****	**.835****	**.483****	-.077	-.177	.197	.101	.179	.108
Frustration			**.923****	.510**	-.001	-.139	.234	.115	.210	.151
Irritated				**.615****	.064	-.085	.204	.102	.153	.140
Reaction					.166	.196	.122	.088	.136	-.014
Girth						**.678****	**.445****	.291	.295	.195
Strength							.323	.266	.265	.169

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

Table 24: Correlation between traits and crossing the street ratings

	Anger	Frustration	Irritated	Reaction	Girth	Strength	Street crossing ratings per walk			
							Baseline	Unarmed	Umbrella	Bat
Self-rated dominance	-.037	.004	.000	.243	**.555****	**.513****	.133	.098	.236	.012
Anger		**.882****	**.835****	**.483****	-.077	-.177	-.036	.287	.124	.090
Frustration			**.923****	**.510****	-.001	-.139	.062	.268	.188	.154
Irritated				**.615****	.064	-.085	-.008	.201	.139	.098
Reaction					.166	.196	.047	.038	-.159	-.244
Girth						**.678****	-.021	.144	.290	.102
Strength							.195	.046	.050	-.042

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

There was found to be significant, positive correlations of large strength according to Cohen (1988) between self-rated dominance and ratings of physical dominance on the unarmed and umbrella walk ($r(32) = .37$, $p = .03$ and $r(32) = .46$, $p = .01$ respectively), where men who rated themselves as being higher in physical dominance were perceived that way by raters watching their unarmed and umbrella walks. There was also a significant, positive correlation of large strength between girth and ratings of physical dominance on the baseline walks ($r(32) = .45$, $p = .01$), where physically larger men were rated as higher in physical dominance compared to physically smaller men.

There we no other significant correlations between the men's traits and perceptions of physical dominance or likelihood of crossing the street.

Regression

Due to the significant correlations found between girth and ratings of physical dominance on the baseline, unarmed, and umbrella walks (see Table 8: Correlation for physically dominant traits and walk and face scoresTable 23), an enter method regression was ran. The initial regression contained the predictor variable of girth and ratings of physical dominance on the baseline walks as the outcome variable. The results of the regression suggest that girth explains 19.8% of the variance in ratings of physical dominance, $R^2 = .20$, $F(1,32) = 7.89$, $p = .01$, with girth ($\beta = .45$; $t(32) = 2.81$, $p = .01$) being a significant predictor. A second regression was run with the predictor variable of self-rated dominance and ratings of physical dominance on the unarmed walks as the outcome variable. The results of the regression suggest that self-rated dominance explains 13.9% of the variance in ratings of physical dominance, $R^2 = .14$, $F(1,32) = 5.15$, $p = .03$, with self-rated dominance ($\beta = .37$; $t(32) = 2.27$, $p = .03$) being a significant predictor. A final regression was run with the predictor variable of self-rated dominance and ratings of physical dominance on the umbrella walks as the outcome variable. The results of the regression suggest that self-rated dominance explains 20.7% of the variance in ratings of physical dominance, $R^2 = .21$, $F(1,30) = 7.85$, $p = .01$, with self-rated dominance ($\beta = .46$; $t(30) = 2.80$, $p = .01$) being a significant predictor.

ANOVA

To ensure the data was suitable for a repeated measures ANOVA, three assumption checks were conducted. Independence of observations and normality of the DVs (by viewing Q-Q plots) were sufficient. However, Mauchly's test of Sphericity was significant for both physical dominance ($\chi^2(5) = 14.23$, $p = .01$) and street crossing ($\chi^2(5) = 14.67$, $p = .01$), therefore a one-way repeated measures ANOVA (with adjusted degrees of freedom using the Greenhouse-Geisser method) was conducted.

The first one-way repeated measures ANOVA revealed a significant effect of walk type on dominance ratings ($F(2.16, 25.14) = 7.26$, $p < .01$, $\eta_p^2 = .29$, a large effect size as discussed by Miles & Shevlin, 2001). Pairwise post-hoc comparisons revealed that baseline (M = 3.15, SD = .73) and unarmed (M = 3.85, SD = .95) walks differed significantly ($p = .01$, $d = .83$, a large effect size as discussed by Cohen, 1988), with unarmed walks being rated as significantly more dominant. Furthermore, baseline (M = 3.15, SD = .73) and bat (M = 3.54, SD = 1.00) walks differed significantly ($p = .05$, $d = .40$, a medium effect size as discussed by Cohen, 1988).

The second one-way repeated measures ANOVA revealed a significant effect of walk type on street crossing ratings ($F(2.27, 59.02) = 9.27$, $p < .01$, $\eta_p^2 = .21$, showing a large effect size). Pairwise post-hoc comparisons revealed three significant differences between the walking types, with baseline walks (M = 2.92, SD = .58) being rated as significantly less likely to be avoided compared to unarmed (M = 3.77, SD = .98; $p < .01$, $d = 1.06$), umbrella (M = 3.77, SD = 1.06; $p < .01$, $d = 1.00$), and bat (M = 3.56, SD = .91; $p < .01$, $d = .84$) walks, with all walks showing a large effect size (Cohen, 1988).

t-tests

Paired sample *t*-tests were run to investigate a gender differences between raters on perceptions of physical dominance and likelihood of crossing the street (see Table 25 and Table 26 for means and standard deviations for both questions).

Table 25: Means and standard deviations for men and women for physical dominance ratings

	Men Mean (SD)	Women Mean (SD)
Baseline	2.97 (.86)	3.37 (.64)
Unarmed	3.63 (.94)	4.08 (1.01)
Umbrella	3.55 (1.14)	4.03 (1.16)
Bat	3.25 (1.03)	3.83 (1.02)

Table 26: Means and standard deviations for men and women for likelihood of crossing the street scores

	Men Mean (SD)	Women Mean (SD)
Baseline	2.62 (.75)	3.26 (.61)
Unarmed	3.43 (.97)	4.10 (1.11)
Umbrella	3.46 (1.08)	4.05 (1.20)
Bat	3.21 (.87)	3.84 (1.05)

There was found to be a significant difference between men and women on all questions. For the ratings of physical dominance, there was a significant difference between as women rated the baseline walks (M = 3.37, SD = .64; $t(33) = 6.06$, $p < .01$, $d = .53$), unarmed walks (M = 4.08, SD = 1.01; $t(33) = 6.10$, $p < .01$, $d = .46$), umbrella walks (M = 4.03, SD = 1.16; $t(31) = 6.00$, $p < .01$, $d = .42$), and bat walks (M = 3.83, SD = 1.02; $t(33) = 8.84$, $p < .01$, $d = 1.10$), as significantly higher on physical dominance compared to men (M = 2.97, SD = .86; M = 3.63, SD = .94; M = 3.55, SD = 1.14; and M = 3.25, SD = 1.03 respectively). All *t*-tests had either a large or medium effect size as discussed by Cohen (1988).

A similar result was found for likelihood of crossing the street, with women being significantly more likely to cross the street to avoid the man on the baseline walks (M = 2.62, SD = .75; $t(33) = 5.62$, $p < .01$, $d = .94$), unarmed walks (M = 4.10, SD = 1.11; $t(33) = 5.40$, $p < .01$, $d = .64$), umbrella walks (M = 4.05, SD = 1.20; $t(31) = 4.08$, $p < .01$, $d = .51$) and bat walks (M = 3.84, SD = 1.05; $t(33) = 4.34$, $p < .01$, $d = .65$) compared to men (M = 3.26, SD = .61; M = 3.43, SD = .97; M = 3.46, SD = 1.08; and M = 3.21, SD = .87 respectively).

Again, all *t*-tests had a large or medium effect size as discussed by Cohen (1988).

An independent samples *t*-test was conducted to investigate if there was a difference of ratings of physical dominance and likelihood of crossing the road for men who played contact sport and those who do not. Twenty-two of the men played contact sports, which involved football, rugby, martial arts, boxing, and basketball. For ratings of physical dominance, there was no significant difference between men who played contact sports, and those that do not, on any of the walks (baseline walk: M = 3.16 SD = .70 for those who play, M = 3.14, SD = .85 for those who do not, $t(32) = -.11$, $p = .92$. Unarmed: M = 3.85 SD = .92 for those who play, M = 3.84, SD = 1.05 for those who do not, $t(32) = -.02$, $p = .98$. Umbrella: M = 3.97 SD = 1.14 for those who play, M = 3.47, SD = 1.07 for those who do not, $t(30) = -1.21$, $p = .23$. Bat: M = 3.70 SD = .97 for those who play, M = 3.28, SD = 1.05 for those who do not, $t(27) = -1.09$, $p = .29$).

There was also no significant difference in likelihood of crossing the street between men who partook in contact sports and those who do not (baseline walk: M = 2.95 SD = .57 for those who play, M = 2.88, SD = .62 for those who do not, $t(32) = -.36$, $p = .72$. Unarmed: M = 3.66 SD = .97 for those who play, M = 3.96, SD = 1.01 for those who do not, $t(32) = .84$, $p = .40$. Umbrella: M = 3.73 SD = 1.12 for those who play, M = 3.82, SD = 1.01 for those who do not, $t(30) = .22$, $p = .82$. Bat: M = 3.60 SD = .98 for those who play, M = 3.47, SD = .83 for those who do not, $t(27) = -.38$, $p = .70$).

An independent samples *t*-test was conducted to investigate if there was a difference in ratings of physical dominance and likelihood of crossing the road for men who had engaged in a physical fight, where 18 of the men had been involved in a fight at some point in their life. For ratings of physical dominance, there was no significant difference between men who had been involved in a physical fight, and those that had not, on any of the walks (baseline walk: M = 3.18 SD = .74 for those who play, M = 3.12, SD = .73 for those who do not, $t(32) = -.24$, $p = .81$. Unarmed: M = 3.85 SD = .92 for those who play, M =

3.84, SD = 1.01 for those who do not, *t*(32) = -.04, *p* = .97. Umbrella: M = 3.92 SD = 1.16 for those who play, M = 3.61, SD = 1.09 for those who do not, *t*(30) = -.78, *p* = .44. Bat: M = 3.55 SD = .90 for those who play, M = 3.53, SD = 1.16 for those who do not, *t*(27) = -.06, *p* = .95).

There was also found to be no significant difference in likelihood of crossing the street between men had previously engaged in a physical fight and those who had not (baseline walk: M = 2.92 SD = .63 for those who play, M = 3.16, SD = .43 for those who do not, *t*(32) = 2.36, *p* = .06. Unarmed: M = 3.74 SD = 1.18 for those who play, M = 3.79, SD = .70 for those who do not, *t*(32) = .13, *p* = .90. Umbrella: M = 3.74 SD = 1.21 for those who play, M = 3.80, SD = .88 for those who do not, *t*(30) = .18, *p* = .86. Bat: M = 3.51 SD = 1.08 for those who play, M = 3.60, SD = .66 for those who do not, *t*(27) = -.28, *p* = .82).

Discussion

Summary of findings

The current study aimed to investigate perceptions of physical dominance and likelihood of crossing the street to avoid the man from viewing walking stimuli, where the man either had his natural gait or a threatening walk which involved him carrying an umbrella, a baseball bat, or being unarmed. There was found to be a significant, positive correlation between the baseline walk and girth, where physically larger participants were rated as higher in physical dominance. There was also a significant, positive correlation between self-rated dominance and ratings of physical dominance on the unarmed and umbrella walks, where men who rated themselves as higher on physical dominance were perceived to be higher in physical dominance by raters. A significant difference was seen between the baseline, unarmed, and bat walk, with participants rating the baseline walks as lower on physical dominance compared to the unarmed and bat walks. A similar discovery was found for ratings of crossing the street, where likelihood of crossing the street was significantly higher on the three threatening walks (unarmed, umbrella, and bat) compared to the baseline walk. Finally, a gender difference was found, with women rating the men’s walks as higher in physical dominance and being more likely to cross the street on all four walks compared to men, where all results showed a large or medium effect size.

Hypothesis one: There will be a significant, positive correlation between physically dominant traits and ratings of physical dominance.

Hypothesis one stated that there would be a significant, positive correlation between physically dominant traits and ratings of physical dominance. This hypothesis can only be partially supported as correlations were only apparent between two traits and the walks. There was found to be a significant, positive correlation between ratings of self-rated dominance and the unarmed and umbrella walk. This self-reported measure was used for the first time in this thesis, and suggests that onlookers perceptions of physical dominance align with the perceptions men have of themselves. These results are similar to those in of study one, despite using a different measure to gain self-reported physical dominance. The ability to measure self-dominance is beneficial, and likely evolved as miscalculating own physical dominance could result in engaging in a physical conflict that could not be won, or be extremely high in cost. The findings further suggest that men are able to portray their physical dominance in their movements, a finding that has not been investigated extensively in research but has been consistently found in this thesis.

A significant, positive correlation was also found between baseline walks and girth, with physically larger men being rated as higher in physical dominance. Whilst these findings are unsurprising based off the previous chapters, there was no correlation between girth and physically dominant ratings on any of the threatening walks. One explanation for this is that the baseline walk shows their natural gait, while the threatening walks are an unnatural situation as the participant may not have been fully angered by any of the scenarios. Furthermore, all participants were asked to approach the BOB, something which they may not do in a natural situation, even if angered. This could then lead to participants moving in an unnatural manner and therefore not displaying the traits, in this case girth, in their movements.

Hypothesis two: There will be a significant positive correlation between physically dominant traits and likelihood of crossing the street.

Hypothesis two stated that there would be a significant, positive correlation between physically dominant traits and likelihood of crossing the street. This hypothesis is not supported as there was found to be no significant correlation between likelihood of crossing the street and any of the physically dominant traits. One explanation of this could be that participants are picking up cues of other traits not measured in this study and basing their decision to avoid the man based on those cues. This study only looks at a small number of physically dominant traits (strength, girth, and self-rated dominance), and the findings of the current study suggest that it could be another trait that observers are wary of when deciding if the man should be avoided. As debated in the previous studies, people may be crossing the street to avoid verbal confrontation. From March 2021 to March 2022, 15% of men and 22% of women experienced being insulted or shouted at by a stranger in public (ONS, 2022). It is incidents such as these that lead to the report finding that 24% of men and 37% of women had stopped walking in quiet places (for example, parks and open spaces) after dark. In these situations, traits relating to physical dominance are not necessarily involved within the conflict, therefore reasons for crossing the street could be assessed on cues unrelated to physical dominance.

Hypothesis three: There will be a significant difference between ratings of the baseline walk and threatening walks, with threatening walks rated as higher in physical dominance

Hypothesis three stated that baseline walks would be rated significantly lower in physical dominance compared to the three threatening walks (unarmed, umbrella, and bat walks). This hypothesis can partially be supported, as there was found to be significant differences between the baseline walks and the unarmed and bat walks, with the baseline walk being rated significantly lower in physical dominance compared to these two threatening walks. While the umbrella walk did see an increase in ratings of physical dominance, it was not a significant difference. These findings further support study two’s results that men are altering their body movements to display threatening intent, and that onlookers of this are picking it up.

Although there was a significant difference between the baseline walk and two of the threatening walks, there was no significant difference in ratings of physical dominance between any of the threatening walks. These findings suggest that perceptions of physical dominance do not increase when a weapon is used compared to being unarmed. A possible explanation is that while possessing a weapon could increase damage inflicted, movement may not need to change to portray this increased level of dominance as the visual cue of a weapon is enough. In our study, the weapon was not concealed and was clearly on display during motion capture, thus the men may have relied on their potential opponent seeing the weapon. The men were not aware that the weapon would not be displayed to the raters, and this could explain why their movements were not perceived as more threatening than an unarmed threatening walk.

Furthermore, there was no significant difference between ratings of physical dominance on the bat walks compared to the umbrella walks. The aim of the umbrella was to act as a control, as while it was a similar size to the baseball bat, it is unlikely to inflict the same level of damage. However, the umbrella was still used as a weapon, with 12 participants (35.3%) using it when engaging in physical violence against the BOB. This could explain why participants were still rating those movements as high in physical dominance: while conventionally an umbrella is not used as a weapon, participants did use it with that intent, and it is that intent that raters are noticing.

Hypothesis four: There will be a significant difference between ratings of the baseline walk and threatening walks, with people being more likely to cross the street to avoid the person on threatening walks.

Hypothesis four stated that raters would be significantly less likely to cross the street when viewing baseline walks compared to the three threatening walks (unarmed, umbrella, and bat walks). This hypothesis is supported: raters were more likely to cross the street when a threatening walk was presented compared to a baseline. As with the ratings of physical dominance, these findings further support the notion that men alter their movements when aiming to threaten, and onlookers are picking this up.

Like study two, there was a significant difference between the baseline walks and all three threatening walks, with the participants rating the threatening walks as leaving them more likely to cross the street to avoid the man. However, there was no significant difference between the three threatening walks. This again suggests that visual cues of the weapon may be used to provide information regarding increased damage, without the man needing to adjust his body movement cues. As with ratings of physical dominance, there was no significant difference between the umbrella walks and the bat walks, further supporting the belief that this could be due to the participants using the umbrella as a weapon and participants detecting that intent.

Hypothesis five: There will be a gender difference between men and women and how they rate the stimuli on physical dominance.

The study showed that women were more likely to rate the men’s walking gait as higher in physical dominance compared to men and were also significantly more likely to cross the street to avoid them. This supports the previous literature that women are more likely to be fearful of crime compared to men (see gender differences in study two, Fisher, 1995; Hale, 1996; Jennings et al., 2007; ONS, 2021).

Evaluation and future research

The systematic review (chapter one) suggests that there is no research investigating our perceptions of men when carrying a weapon using motion capture. This study was an exploratory investigation, using weapons in a motion capture setting and provided key information regarding our perceptions of movement when holding a weapon. While a limitation of the study could be the use of a baseball bat as a weapon, the research team agreed that it would be the best weapon for the study in terms of practicality and ethical concern. Within England and Wales, the most common method of murder was a sharp instrument, such as a knife, with 40% of all homicides involving one, whereas only 5% involved a blunt object in the year 2020-2021 (ONS, 2021). Due to increased numbers of knife crimes compared to blunt objects, it would have been beneficial to use a knife as the weapon within the study, however ethically this presented problems for the safety of the participants and researcher.

Furthermore, another limitation of the current study was the inability to use characters for the motion capture. This resulted in the height being unstandardised, and while there was an attempt to control for this with the camera angle, it is still a limitation of the study, as raters may have been basing their ratings on height. To counteract this in the future, more markers could be placed on the participants hand’s to reduce the likelihood of problems occurring, allowing the characters to be standardised for height. A further issue of the study is the amount of walking conditions the participants took part in. Participants were required to walk in a threatening manner three times, which could result in fatigue by the final walk. In future, an Aggressive Provocation Questionnaire could be administered at the end of the study to better understand how participants were feeling after all four walking conditions.

Future research could expand upon the study to further our limited knowledge in this area. As there was no correlation between physically dominant traits and likelihood of crossing the street, this could be further investigated to better understand how people are making judgements on who could be a potential threat to them. One idea is a two-part study: a qualitative aspect asking participants why they have chosen the ratings may give a clearer insight into what is deemed threatening and at what point participants would avoid a situation. Furthermore, eye-tracking could reveal where participants are focusing on when making their judgements. This may give clues as to which movements are being assessed to determine physical dominance, and if this aligns with the biomechanical analysis within study one.

Additionally, future research could investigate perceptions when the walkers are actively trying to conceal a weapon. As previously discussed, the three walks were comparable on both physical dominance and likelihood of crossing the street. This could be due to the walkers not being aware that the weapon would be concealed to the participants who rated the walks. It may not be necessary to alter body movements further to display increased physical dominance when the weapon is clearly on display, as the weapon itself acts as a cue of dominance. Therefore, by asking the men who acted as walkers to conceal the weapon, it may give further insight into if movements are altered, and if onlookers perceive men as higher in physical dominance and are more likely to cross the street, when possessing a concealed weapon.

Conclusion

The study aimed to establish whether perceptions of physical dominance and likelihoods of street crossing were based on men’s baseline walks, and three threatening walks: one unarmed, one with an umbrella, and one with a baseball bat. There was a significant, positive correlation between self-rated dominance and the unarmed and umbrella walks, with men who rated themselves higher in physical dominance being perceived as such. There was also a significant, positive correlation between girth and the baseline walks, with physically larger men being rated as higher in physical dominance.

There was also a significant difference in perceptions of the walkers, with the threatening walks being rated as higher in physical dominance and having a higher likelihood of crossing the street compared to the baseline walks. These findings follow the previous studies discoveries and support the notion that men have evolved to display their physical dominance though their biological motion, and that onlookers are able to decipher between threatening and non-threatening movement.

Study four

Introduction

Changes in light moving across the cells in the back of our eyes allow us to vividly picture the world in front of us (Goldstein, 2008). While central (i.e., foveal) vision is the sharpest, this only represents a tiny proportion of our visual field, extending 5° from the centre, leaving our peripheral vision responsible for the majority of our visual field (Loschky et al., 2017). It is a combination of micro-saccades (tiny constant motions of the eye) and the visual input from two eyes that helps our brain to extrapolate and sharpen our visual field to appear vibrant and wide angled, despite having some ‘hardware’ limitations from the raw input. Whilst natural selection provides us with a clear incentive to detect threats, these threats are unlikely to be approaching us only within the limited field of the fovea. Within primates, it has been found that there is a specialised circuit located in the limbic cortex where peripheral vision is quickly processed (Yu et al., 2012).

Ikeda et al., (2005) investigated humans’ perceptions of biological motion and found that our peripheral vision is significantly poorer at detecting motion than our central vision. However, Gurnsey et al., (2008) found that removing task recognition impairments, such as the dot noise mask used in Ikeda et al., (2005), led to better performance identifying biological motion in peripheral vision. Smith and Rossit (2018) further illustrated that facial expressions presented to the visual periphery can be identified. This study presented stimuli at 30° from the fovea and found that some expressions are easily detected and recognised in the peripheral vision, specifically fear, happiness, and surprise. The detection of a fearful face is clearly beneficial when it comes to reacting to a potential threat, and so recognition, even in the less-than-ideal conditions of the visual periphery, would benefit survival (Smith & Rossit, 2018).

Darwin (1872) discussed how snakes have played an important role as a threat to both humans and non-human primates. The Snake Detection Theory (Greene, 1997) argues that the expansion of object recognition pathways in the brain arose from pre-attentional visual detection of fearful stimuli. This theory argued that environmental pressures on primates led to these systems developing quickly and accurately to detect a potential predator in a diverse set of visual conditions. This may be because a predator or threat may not always be presented in visually optimal conditions. As snakes use camouflaged-based hunting strategies which can involve concealing themselves until the optimum time to strike (Greene, 1997), this supports the concept of being able to detect threat in the peripheral vision.

This theory was further investigated by Soares et al., (2014) who conducted multiple studies assessing snake detection replicating conditions that would mimic survival-critical scenarios for individuals. The researchers suggested the existence of an evolutionary advantage in snake detection, and used three sets of stimuli to test this: brief exposure times, the snake using camouflage in a cluttered environment, or being present in the visual periphery. These last set of stimuli were presented in three different locations: foveal (<1.2°), parafoveal (3.4°), and peripheral (5.7°) locations. The findings of the study supported the notion of snake detection theory, as snake stimuli were detected with the same proficiency regardless of the location presented, whilst other fearful and neutral stimuli (i.e., spiders and mushrooms, respectively) lost accuracy when presented within the parafoveal and peripheral fields. This provides some evidence for the theory that snakes may have played a key part in the evolution of our peripheral vision, and the visual system has evolved to detect fearful stimuli, even in suboptimal visual conditions.

Snake Detection Theory (Soares et al., 2014) discusses the importance of detecting a threat within the peripheral vision, a topic under researched within humans. Our ability to detect physically dominant traits in the periphery would also be beneficial to avoid the costs that come with combat with a much stronger opponent. The research around Snake Detection Theory and our perceptions of biological motion within our peripheral vision supports the notion that we have likely evolved to detect a threat within this visual field, yet there has been minimal research conducted into it.

Aims

Based on the previous research suggesting peripheral vision may facilitate recognition of survival-relevant cues, the aim of the current study is to better understand our ability to detect threatening behaviour in our visual periphery. Like study three, five hypotheses were formulated:

1) There will be a significant, positive correlation between physically dominant traits and ratings of physical dominance.
2) There will be a significant, positive correlation between physically dominant traits and likelihood of crossing the street.
3) There will be a significant difference between ratings of the baseline walk and threatening walks, with threatening walks rated higher in physical dominance.
4) There will be a significant difference between ratings of the baseline walk and threatening walks, with people being more likely to cross the street to avoid the person on threatening walks.
5) There will be a gender difference between men and women and how they rate the stimuli on physical dominance.

Method

Stimuli

The men's gait stimuli collected in study three was used in this study. This totalled 128 videos; 34 baseline walks, 34 unarmed walks, 29 umbrella walks, and 31 bat walks, all between 2-4 seconds long.

Participants - Raters

An *a priori* power analysis showed that 34 participants were needed as raters for the study to detect a medium effect at 80% power for running a repeated measures ANOVA. Forty participants were recruited via opportunity sampling though social media, with the inclusion criteria being that they had to be over the age of 18 years old and corrected-to-normal vision. The sample had an age range of 22-57 years old (mean age = 28.45 years old, SD = 8.10 years old), with 22 women, 17 men, and one non-binary participant.

Due to the number of videos, two blocks were created, each with 64 videos. This was to ensure that the study fit within the optimum time for a study (Revilla & Höhne, 2020). This meant each video was viewed by 20 raters, block one had 20 participants: 12 women, 7 men, and one non-binary participant (aged between 22-57 years old, mean = 27.84 years old, SD = 3.69 years old), and block two had participants: 10 women and 10 men (aged between 22-53 years old, mean = 29 years old, SD = 8.43 years old).

Materials

Participants were asked their age and gender, and a question to assess their own physical dominance: "*if you were to engage in a physical fight win a member of the same sex who is of a similar size to you, how likely are you to win?"* on a 1 – 7 scale (1 being 'not very likely at all', 7 being 'extremely likely').

A computerised gaze-contingent experiment was written in Python 3.8.10 using the PsychoPy3 libraries (Peirce et al., 2019), to present the stimuli to participants. An EyeLink 1000 eye-tracker with a desktop mount (SR Research Ltd., Ottawa, ON, Canada) tracked participants' right eye and fed this input back to the Python code. This experiment was displayed on a monitor 80cm away from the participant, with a 144Hz refresh rate screen and a pixel resolution of 1920x1080 pixels.

Procedure

Participants completed their demographics and the physical dominance questionnaires and then were taken to the eye-tracking lab. Participants were randomly allocated one of the two blocks to view. If they had participated in the study as walkers, they were allocated to the block they were not in to avoid the recognition of a familiar gait, which has been found to be possible in previous research (Cutting & Kozlowski, 1977), therefore removing further chance of ratings being made on attributes other than their movement.

At the beginning of the study, four slides explaining the experiment were shown to the participant, as well as a definition of physical dominance before starting the experiment. The definition was the same used in the previous studies, which was that physical dominance was: '*Having the physical ability to win unarmed fights, with those who have higher physical dominance winning more fights'* (Archer, 1988).

Participants were instructed that at the beginning of every video, a drift check would happen to ensure the trackers accuracy (see Figure 15).

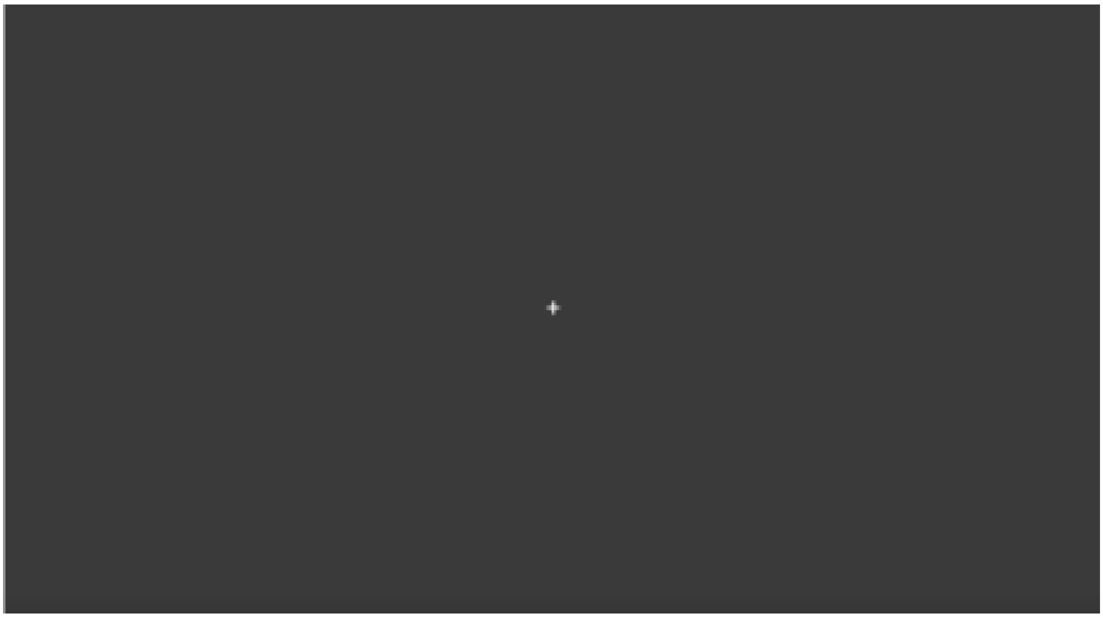

Figure 15: Drift check

Once the drift check was completed, they were prompted to look at the right-hand side of the screen. Doing so rotated a fixation cross (similar to a loading animation) to tell participants they were looking in the right place. If their gaze was not within the green box, the box would turn red, and the fixation cross would not move (see Figure 16).

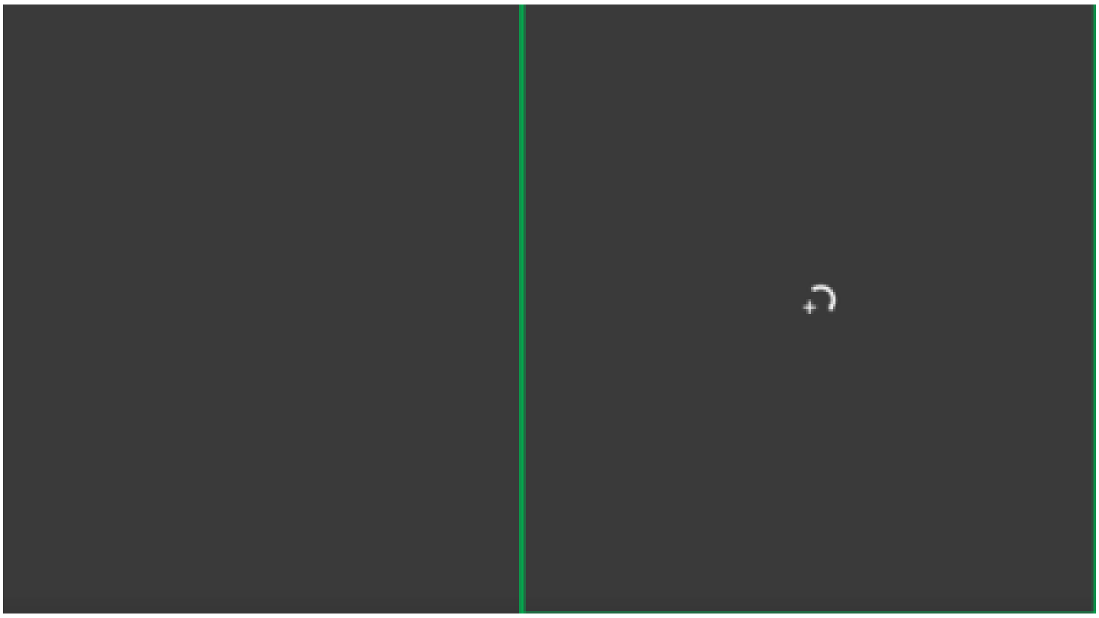

Figure 16: Prompt for participant to look towards the right-hand side of the screen

Participants were then told that on the left-hand side of the screen a man would walk towards them, but they could not look directly at him. On the right-hand side of the screen was a picture of a greyscale street (see Figure 17). The street was added for participants to have a detailed section of the screen to look at rather than a blank screen. This was done in an attempt to minimise visual fatigue (Patterson et al., 2006).

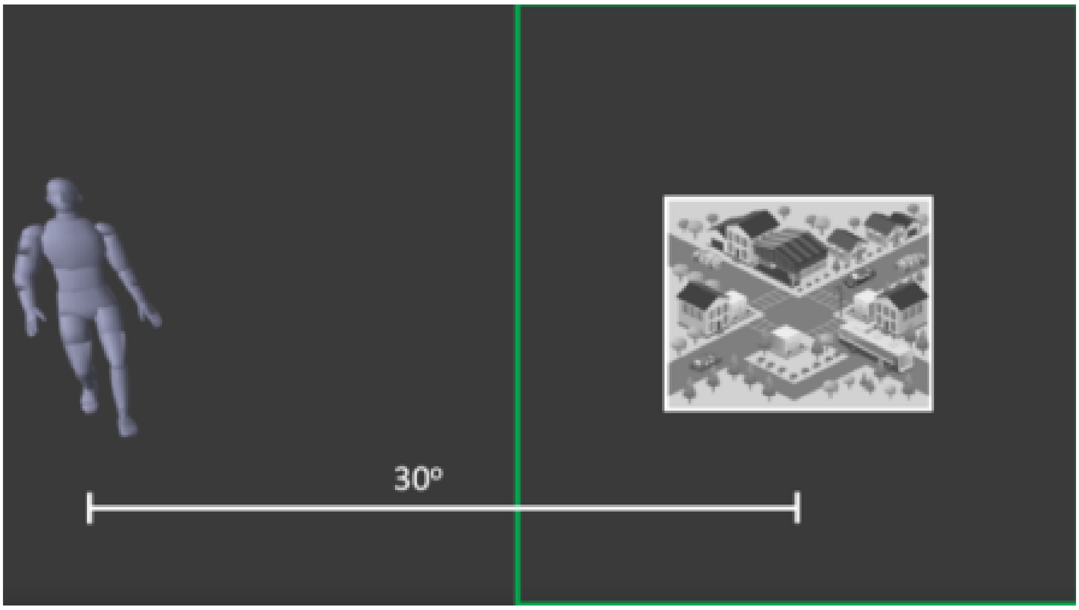

Figure 17: Participants view of the walker, 30º away from the focal point of the street

A clear line in the middle of the screen detailed where was "safe" to look. Participants were able to view anywhere on the right-hand side of the screen, however if the coordinates of their right eye gaze crossed the line, the line would turn red, and the video would disappear (the trial itself would be moved to the end of the experiment and would be viewed at the end of the block) (see Figure 18). This was implemented to guarantee that participants never looked directly at the walk, thus ensuring that the judgements were based on the visual peripheral alone. A threshold of 300ms was implemented to allow participants to blink during the trails without them immediately ending due to the lack of gaze. The stimuli were viewed 30º from foveal vison, as per Smith and Rossit, (2018), where it was found that emotion in the faces can be detected in the peripheral at 30º.

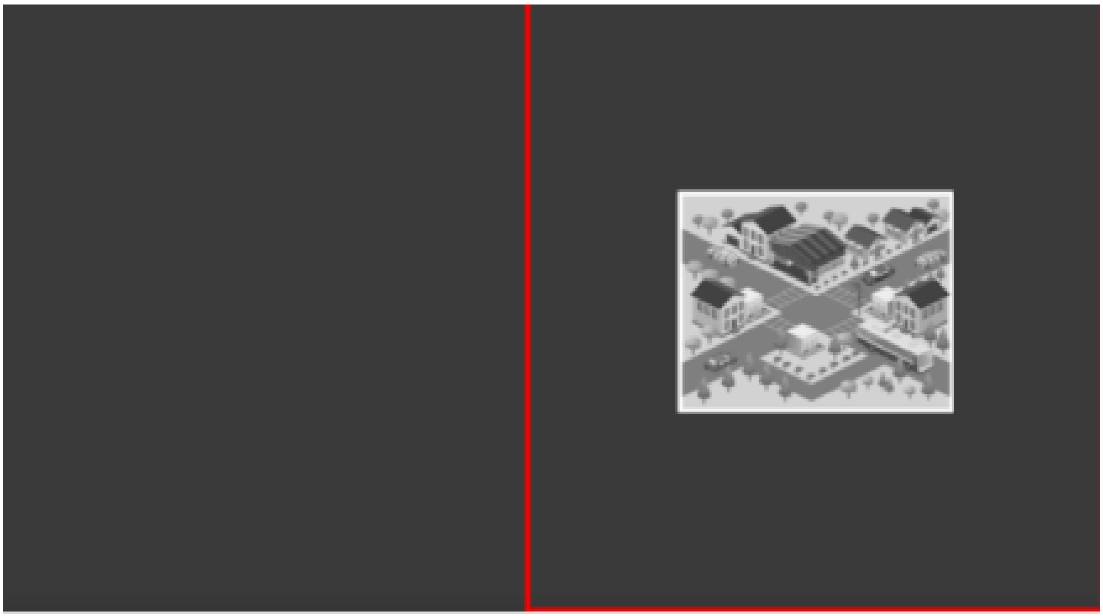

Figure 18: Visual when participants looked at the left-hand side of the screen

The videos were presented in a randomised order. After each video, three questions were presented on the screen, one at a time, with a seven point Likert scale: '*How physically dominant do you think this man is?*', ranging from 1 (not dominant at all), to 7 (extremely dominant); '*How likely are you to walk across the street to avoid this man?*', ranging from 1 ('I would not cross the street'), to 7 ('I would definitely cross the street'); and '*How creative do you think this man is?*', ranging from 1 ('not creative at all'), to 7 ('extremely creative'). To help reduce fatigue, there were three equally spaced breaks throughout the study, with the option to take more if needed. In total, the study lasted approximately 25 minutes.

Treatment of Data

All measurements for the stimuli (the men who took part in the motion capture portion of the study) were the same as study three, with the same traits being analysed in the current study (self-rated dominance, and the four traits within the Aggression Provocation Questionnaire, O'Connor et al., (2001), anger, frustration, irritation, and their reaction, see Table 21 for means and standard deviation for each trait).

The ratings of physical dominance, likelihood of crossing the street, and creativity were calculated by averaging the scores given by the 20 raters who had viewed the videos (baseline, unarmed, umbrella, and bat, see Table 22 for means and standard deviations). Girth was calculated by summing the participants chest, shoulder, and bicep circumference (mm) with their weight (kg) (in line with Hill et al., 2013, see Table 20 for the principle component analysis and loading factors), and strength was an average of their handgrip strength task (kg), as seen in study three.

Results

All statistics were calculated in SPSS version 26. The 19 men who participated in the motion capture had scores calculated on 12 variables (Table 18) where means and standard deviations were calculated for each trait (see Table 27).

Table 27: Means and standard deviations for the traits in study four

Measure		Mean (SD)
Strength		45.09kg (7.90kg) (range: 33.5kg – 76kg)
APQ	Anger	28.26 (8.13) (range: 10 – 42)
	Frustrated	30.03 (8.86) (range: 10 – 42)
	Irritated	31.79 (8.12) (range: 14 – 42)
	Reaction	36.88 (4.60) (range: 25 – 51)
Girth		2916.72 (258.32) (range: 2054 – 3601)
Self-rated physical dominance		4.56 (1.31)

		(range: 1-7)
Perceived Physical Dominance	Baseline	3.17 (.46) (range: 2.30 – 4.11)
	Unarmed	3.84 (.75) (range: 2.40 – 5.65)
	Umbrella	3.51 (.64) (range: 2.58 – 4.84)
	Bat	3.67 (.88) (range: 2.40 – 3.66)
Street Crossing	Baseline	2.42 (.41) (range: 1.47 – 3.10)
	Unarmed	3.16 (.78) (range: 2.05 – 5.65)
	Umbrella	2.97 (.75) (range: 1.75 – 4.32)
	Bat	3.15 (.40) (range: 1.65 – 5.65)
Creativity	Baseline	3.40 (.29) (range: 2.89 – 4.10)
	Unarmed	3.27 (.42) (range: 2.47 – 4.35)

Umbrella	3.45 (.38) (range: 2.68 – 4.55)
Bat	3.27 (.40) (range: 2.30 – 4.05)

Correlations

Pearson's correlations were conducted between strength, self-rated dominance, anger, frustration, irritation, reaction, strength, girth (see Table 29 and Table 30 for mean scores), and the physical dominance ratings and street crossing ratings on walks on all four of the participants walks (see Table 28 for mean scores). A correlation was also conducted between creativity ratings and physical dominance and street crossing, where no significant correlation was found (p >.05), supporting its use as a control question in the study.

Table 28: Means and standard deviations for ratings on the baseline, unarmed, umbrella, and bat walks for physical dominance and crossing the street

	Dominance Ratings Means (SD)	Street Crossing Likelihood Means (SD)
Baseline	3.11 (.46)	2.36 (.40)
Unarmed	3.75 (.68)	3.10 (.78)
Umbrella	3.48 (.62)	2.94 (.75)
Bat	3.52 (.80)	3.01 (.98)

Table 29: Correlation between traits and physical dominance ratings

							Dominance ratings per walk			
	Anger	Frustration	Irritated	Reaction	Girth	Strength	Baseline	Unarmed	Umbrella	Bat
Dominance	-.037	.004	.000	.243	**.555****	**.513****	.243	**.382***	.116	.388
Anger		**.882****	**.835****	**.483****	-.077	-.177	.219	.221	.174	.149
Frustration			**.923****	.510**	-.001	-.139	.247	.194	.257	.167
Irritated				**.615****	.064	-.085	.252	.212	.231	.128
Reaction					.166	.196	.246	.218	-.053	.146
Girth						**.678****	**.447****	.217	.130	.346
Strength							.314	.164	.161	.198

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

Table 30: Correlation between traits and crossing the street ratings

							Street crossing likelihood per walk			
	Anger	Frustration	Irritated	Reaction	Girth	Strength	Baseline	Unarmed	Umbrella	Bat
Dominance	-.037	.004	.000	.243	**.555****	**.513****	.036	.251	.157	.336
Anger		**.882****	**.835****	**.483****	-.077	-.177	.319	.196	.209	.231
Frustration			**.923****	**.510****	-.001	-.139	.308	.086	.269	.203
Irritated				**.615****	.064	-.085	.261	.083	.235	.159
Reaction					.166	.196	.073	.032	-.112	.075
Girth						**.678****	.371	.197	.290	.298
Strength							.212	.076	.125	.114

** Correlation is significant at the .01 level, * Correlation is significant at the .05 level

There was found to be a significant, positive correlation of medium strength according to Cohen (1988) between self-rated dominance of the walker and ratings of physical dominance on the unarmed walk (*r(*32) = .32, *p* = .03), where men who rated themselves as higher in physical dominance were perceived that way. There was also a significant, positive correlation of medium strength between girth and ratings of physical dominance on the baseline walks (*r*(32) = .45, *p* <.01), where physically larger men were rated as higher in physical dominance compared to physically smaller men.

There were no other significant correlations between the men's traits and perceptions of physical dominance or likelihood of crossing the street in any of the walks.

Regression

Due to the significant correlations found between girth and ratings of physical dominance on the baseline walks (see Table 29), an enter method regression was conducted. The initial regression contained the predictor variable of girth and ratings of physical dominance on the baseline walks as the outcome variable. The results of the regression suggest that girth explains 20.0% of the variance in ratings of physical dominance: $R^2 = .20$, $F(1,32) = 8.01$, $p = .01$, with girth being a significant predictor ($\beta = .45$; $t(32) = 2.83$, $p = .01$).

A second regression was conducted with the predictor variable of self-rated dominance and ratings of physical dominance on the unarmed walks as the outcome variable. The results of the regression suggest that self-rated dominance explains 14.6% of the variance in ratings of physical dominance, $R^2 = .15$, $F(1,32) = 5.45$, $p = .03$, with self-rated dominance ($\beta = .38$; $t(32) = 2.34$, $p = .03$) being a significant predictor.

ANOVA

To ensure the data was suitable for a repeated-measures ANOVA, three assumption checks were conducted. Independence of observations and normality of the DVs (by viewing Q-Q plots) were sufficient. Mauchly's test of Sphericity was non-significant for both physical dominance ($\chi^2(5) = 3.19$, $p = .67$) and street crossing ($\chi^2(5) = 5.72$, $p = .34$), showing that the data has met all assumptions and will be suitable for a repeated-measures ANOVA.

The first one-way repeated measures ANOVA revealed a significant effect of walk type on dominance ratings (F(3,81) = 7.30, p <. 01, η_p^2 = .21). Pairwise post-hoc comparisons revealed that only baseline (M = 3.11, SD = .46) and unarmed (M = 3.75, SD = .68) walks differed significantly (p <. 01, d = 1.12, a large effect size as discussed in Cohen, 1988) at the Bonferroni corrected alpha level of α = .008, with unarmed walks being rated as significantly more dominant than baseline walks.

The second one-way repeated measures ANOVA revealed a significant effect of walk type on street crossing ratings (F(3,81) = 10.87, p < .01, η_p^2 = .58). Pairwise post-hoc comparisons revealed three significant differences between the walking types, with baseline walks (M = 2.36, SD = .40) being rated as significantly less likely to be avoided compared to unarmed (M = 3.10, SD = .78; p < .01, d = 1.04), umbrella (M = 2.94, SD = .75; p < .01, d = .97), and bat walks (M = 3.01, SD = .98; p < .01, d = .88), again showing large effect sizes in line with Cohen (1988) at the Bonferroni corrected alpha level of α = .008.

t-tests

Paired samples *t*-tests were conducted to investigate a potential gender difference between the ratings of physical dominance and street crossing (see

Table 32 and

Table 32 for descriptive statistics).

Table 31: Means and standard deviation for men and women's score on all four walks for physical dominance

	Men	Women

	Mean (SD)	Mean (SD)
Baseline	2.88 (.47)	3.33 (.57)
Unarmed	3.61 (.88)	4.03 (.79)
Umbrella	3.23 (.66)	3.67 (.75)
Bat	3.43 (.97)	3.84 (.95)

Table 32: Means and standard deviation for men and women's score on all four walks for street crossing

	Men Mean (SD)	Women Mean (SD)
Baseline	1.76 (.36)	2.89 (.53)
Unarmed	2.44 (.82)	3.72 (.86)
Umbrella	2.27 (.69)	3.41 (.82)
Bat	2.47 (1.02)	3.72 (1.06)

There was found to be a significant difference between men and women on all walks. In regards to ratings of physical dominance, women rated the baseline walk (M = 3.33, SD = .57; $t(32) = -4.72$, $p < .01$, $d = .86$), unarmed walk (M = 4.03, SD = .79; $t(32) = -4.16$, $p < .01$, $d = .50$), umbrella walk (M = 3.67, SD = .75; $t(27) = -3.81$, $p < .01$, $d = .59$), and bat walk (M = 3.84, SD = .95; $t(30) = -4.24$, $p < .01$, $d = .43$) as higher in physical dominance compared to men (M = 2.88, SD = .47; M = 3.61, SD = .88; M = 3.23, SD = .66; and M = 3.43, SD = .97 respectively), with medium to large effect sizes (Cohen, 1988).

These results were replicated in likelihood of crossing the street, with women being significantly more likely to cross the street to avoid the man on the baseline walk (M = 2.89, SD = .53; $t(32) = -12.13$, $p < .01$, $d = 2.50$), unarmed walk (M = 3.72, SD = .86 $t(32) = -11.59$, $p < .01$, $d = 1.52$), umbrella walk (M = 3.41, SD = .82, $t(27) = -10.93$, $p < .01$, $d = 1.50$), and bat walk (M = 3.72, SD = 1.06; $t(30) = -14.37$, $p < .01$, $d = 1.20$) compared to men (M = 1.76, SD =

.36; M = 2.44, SD = .82; M = 2.27, SD = .69; and M = 2.47, SD = 1.02 respectively), all with large effect sizes (Cohen, 1988).

An independent sample *t*-test was conducted to investigate if there was a difference of ratings of physical dominance and likelihood of crossing the road for men who played contact sport and those who do not. Twenty-two of the men played in contact sports, which involved football, rugby, martial arts, boxing, and basketball. For ratings of physical dominance, there was no significant difference between men who played contact sports, and those that do not, on any of the walks (baseline walk: M = 3.16 SD = .44 for those who play, M = 3.17, SD = .51 for those who do not, $t(32) = .10$, $p = .92$. Unarmed: M = 3.86 SD = .79 for those who play, M = 3.80, SD = .70 for those who do not, $t(32) = -.24$, $p = .81$. Umbrella: M = 3.65 SD = .64 for those who play, M = 3.28, SD = .58 for those who do not, $t(30) = -1.57$, $p = .13$. Bat: M = 3.84, SD = .85 for those who play, M = 3.37, SD = .89 for those who do not, $t(27) = -1.50$, $p = .14$).

There was also found to be no significant difference in likelihood of crossing the street between men who play contact sports and those who do not (baseline walk: M = 2.41 SD = .35 for those who play, M = 2.42, SD = .52 for those who do not, $t(32) = .06$, $p = .96$. Unarmed: M = 3.01 SD = .71 for those who play, M = 3.27, SD = .91 for those who do not, $t(32) = .60$, $p = .55$. Umbrella: M = 3.00 SD = .73 for those who play, M = 2.90, SD = .82 for those who do not, $t(30) = -.34$, $p = .73$. Bat: M = 3.24, SD = 1.08 for those who play, M = 3.01, SD = .97 for those who do not, $t(27) = -.61$, $p = .55$).

An independent sample *t*-test was conducted to investigate if there was a difference of ratings of physical dominance and likelihood of crossing the road for men who had engaged in a physical fight, where 18 of the men had been involved in a fight at some point in their life. For ratings of physical dominance, there was no significant difference between men who had been involved in a physical fight, and those that had not, on any of the walks (baseline walk: M = 3.20 SD = .44 for those who had, M = 3.12, SD = .50 for those who had not, $t(32) = -.52$, $p = .61$. Unarmed: M = 3.88 SD = .72 for those who had, M = 3.80, SD = .81 for those who had not, *t*(32) = -.31, *p* = .67. Umbrella: M = 3.41 SD = .59 for those who had, M = 3.63, SD = .70 for those who do not, *t*(30) = .89, *p* = .38. Bat: M = 3.78, SD = .85 for those who had, M = 3.53, SD = .93 for those who had not, *t*(27) = .78, *p* = .44).

There was also found to be no significant difference in likelihood of crossing the street between men had previously engaged in a physical fight and those who had not (baseline walk: M = 2.42 SD = .36 for those who had, M = 2.41, SD = .36 for those who had not, *t*(32) = -.58, *p* = .95. Unarmed: M = 3.20 SD = .86 for those who had, M = 3.10, SD = .71 for those who had not, *t*(32) = -.37, *p* = .72. Umbrella: M = 3.00, SD = .80 for those who had, M = 2.94, SD = .72 for those who had not, *t*(30) = -.20, *p* = .84. Bat: M = 3.23, SD = 1.11 for those who had, M = 3.06, SD = .94 for those who do not, *t*(27) = -.46, *p* = .65).

Discussion

Hypothesis one: There will be a significant, positive correlation between physically dominant traits and ratings of physical dominance.

Hypothesis one stated that there would be a significant, positive correlation between ratings of physical dominance and the physically dominant traits of the men. The findings echo the results of study three, where a significant, positive correlation was found between the baseline walk and girth, in that physically larger men were rated as more physically dominant. Furthermore, there was a significant, positive correlation between self-rated dominance and perceived dominance on the unarmed walk, where men who rated themselves as higher in physical dominance were also perceived in such a manner. As these were the only significant correlations found, hypothesis one can only be partially supported.

These two correlations were also found in study three, with incredibly similar results (the correlation between girth and ratings of physical dominance were *r* = .445 and *r* = .447 for study three and four respectively, whereas the correlation between self-rated dominance and dominance were *r* = .372 and *r* = .382 for study three and four respectively). The similarity between the two sets of findings strengthens that there is a link between girth and self-rated physical dominance and perceived physical dominance, and that these are observable in both the central and peripheral vision, despite the limited view in the peripherals. However, as there were no significant correlations between the majority of the walks and physically dominant traits, it suggests that it may be another trait (not measured by the current study) that is being observed when rating physical dominance.

Hypothesis two: There will be a significant, positive correlation between physically dominant traits and likelihood of crossing the street.

Hypothesis two stated that there would be a significant correlation between likelihood of crossing the street and physically dominant traits. Replicating the findings from study three, there were no significant correlations between any of the physically dominant traits and crossing the street, therefore not supporting hypothesis two. This again supports the notion that when assessing a threat and if we should avoid it, other traits may be being assessed other than strength, girth, and self-rated physical dominance, as discussed in study three.

Hypothesis three: There will be a significant difference between ratings of the baseline walk and threatening walks, with threatening walks being rated higher in physical dominance.

Hypothesis three states that there will be a significant increase in ratings of physical dominance from the baseline walks to the threatening walks. The results showed that baseline walks were rated as significantly lower in physical dominance compared only to the unarmed walk, partially supporting hypothesis three as there was no significant difference between baseline walks and the umbrella and bat walks.

These findings support the notion that men alter their body movements when aiming to be threatening, but not the concept that carrying a weapon could increase perceptions of physical dominance. This may be that the differences in movements between carrying a weapon and not carrying a weapon is not picked up on within the peripheral or central vision. As discussed within study three, men may not be altering their movements when carrying a weapon in a similar manner as they would when unarmed, as the presence of a weapon may be enough to deter an opponent. Therefore, these movements may be less obvious when viewed outside of our central vision.

Hypothesis four: There will be a significant difference between ratings of the baseline walk and threatening walks, with people being more likely to cross the street to avoid the person on threatening walks.

Hypothesis four stated that there will a significant increase of ratings of crossing the street from the baseline walks to the threatening walks. The results showed that individuals were significantly more likely to cross the street when faced with the threatening walks than the baseline, supporting hypothesis four. Similar to studies two and three, there was a significant difference between the baseline walks and all three threatening walks, with the threatening walks resulting in participants being more likely to cross the street, however there was no significant difference between the three threatening walks themselves. This further suggests that visual cues of the weapon may be used to give information regarding increased damage, without the man needing to adjust his body movement.

Hypothesis five: There will be a gender difference between men and women and how they rate the stimuli on physical dominance. For ratings of physical dominance and likelihood of crossing the street, it was found that women were more likely to assign a higher value on both questions compared to men. These findings repeat what the previous research has found, and supports that women are more fearful of crime compared to men (see gender differences in study two; Fisher, 1995; Hale, 1996; Jennings et al., 2007; ONS, 2021).

Evaluation and future research

The current study gives new findings into our understanding of threatening body movements. Minimal research has been conducted into how we perceive threat within our peripheral vision. These unique findings give insight into our ability to detect threatening behaviour, with the results suggesting that threatening and non-threatening motions can be differentiated, even within our limited peripheral vision.

While the study produced insights into our peripheral vision and the ability to detect threatening motions, there are still limitations. As the avatars were unstandardised in height, this presents potential issues as participants may be basing the ratings on height. As discussed within study three, this could be controlled for in future stimuli collection by using more detailed hand markers to reduce the chances of recording problems on the arms.

Future research should investigate different peripheral angles to better understand our perceptions of threat. Previous research has utilised a wide range of angles, with Smith and Rossit (2018) using both 30 º and 15 º to detect facial expressions, and Soares et al., (2014) presented stimuli at <1.2°, 3.4°, and 5.7°. Using different angles may give us more knowledge into how we perceive the threatening cues and if there is a point in which our ability to detect a threat significantly decreases.

Conclusion

The study used motion data and measured ratings of physical dominance, alongside the likelihood of crossing the street, when viewing a man's baseline walk compared to three conditions: an unarmed threatening walk, a threatening walk while holding an umbrella, and a threatening walk while holding a baseball bat, within the peripheral vision. The results of the study showed that participants were able to differentiate between the baseline walk and the three threatening walks, with the baseline walks rated as significantly lower than the three threatening walks for likelihood of crossing the street. However, this was not apparent in ratings of physical dominance, where only the unarmed threatening walk was rated as significantly higher than the baseline walk, suggesting that carrying a weapon may not make any perceptual motion differences to observers. Furthermore, women were more likely to cross the street to avoid the all the men's walks and rated them higher in physical dominance compared to men. These findings echo study two and three's findings that men have evolved to display their physical dominance though their biological motion, and that onlookers are able to decipher between threatening and non-threatening movement. This chapter suggests that this is also possible within the peripheral vision, which further supports the notion that we have evolved to both portray and detect threat.

Study three and four: Comparison

Introduction

Central vision and peripheral vision provide different functions in processing visual stimuli, whereby central vision provides fine-grained, sharp information, compared to the lower spatial frequency and blurred information provided by peripheral vision (Wang & Cottrell, 2017). Research suggests that peripheral vision provides more information regarding the environmental scene (Larson & Loschky, 2009), whereas more fine-grained tasks such as facial recognition are hindered by the lack of spatial resolution (Harry et al., 2012) . However, research into detecting threat in both peripheral and central vision has been minimal in humans.

The stimuli in studies three and four were the same, and were presented to raters central or peripheral vision. Both sets of results suggest that participants rated more threatening walks as higher in physical dominance compared to baseline walks. The aim of the current chapter is to compare the findings from the previous two studies to give better insight into how we process threatening stimuli in our central and peripheral vision.

Results

All statistics were calculated in SPSS version 26.

Correlations

Pearson's correlations were initially conducted to investigate if there was a relationship between ratings in the central and peripheral vision for both physical dominance and street crossing (see Table 33 and Table 34 respectively).

Table 33: Pearson's Correlation between peripheral and central vision for ratings of physical dominance

		Central Vision			
		Baseline	Unarmed	Umbrella	Bat
Peripheral Vision	Baseline	**.696 ****	.221	.132	.147
	Unarmed	.201	**.754****	**.624****	**.592****
	Umbrella	**.558****	**.699****	**.594****	**.887****
	Bat	.329	**.632****	**.863****	**.556****

** Correlation is significant at the .01 level

When investigating the ratings between central and peripheral vision, there was a significant, positive correlation between the baseline walk ($r(32) = .70$, $p < .01$, see Figure 19), unarmed walk ($r(32) = .75$, $p < .01$), umbrella walk ($r(32) = .59$, $p < .01$), and bat walk ($r(32) = .56$, $p < .01$) for ratings of physical dominance, meaning that if a walker was rated as high in dominance when viewed in central vision, he was also rated that way in peripheral vision.

Numerous additional significant correlations were found for ratings of physical dominance between the central and peripheral vision (see Table 33).

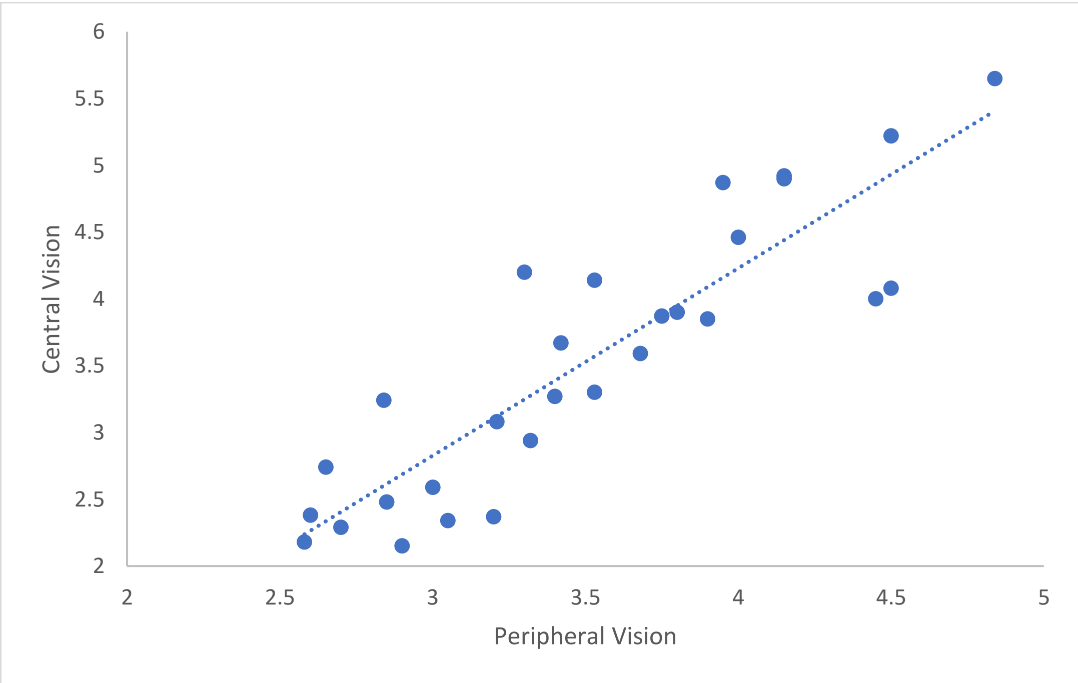

Figure 19: Ratings of physical dominance from central and peripheral vision on the baseline walk, r = .70

Table 34: Pearson's Correlation between peripheral and central vision for ratings of crossing the street

		Central Vision			
		Baseline	Unarmed	Umbrella	Bat
Peripheral Vision	Baseline	.299	**.406***	**.472****	**.499****
	Unarmed	-.154	**.805****	**.582****	.338
	Umbrella	.269	**.718****	**.628****	**.783****
	Bat	-.012	**.499****	**.787****	**.622****

* Correlation is significant at the .05 level, ** Correlation is significant at the .01 level

For likelihood of crossing the street to avoid the man, there was a significant positive correlation on the unarmed walk ($r(32) = .81$, $p < .01$), umbrella walk ($r(32) = .63$, $p < .01$) and bat walk ($r(32) = .62$, $p < .01$) when investigating the ratings between central and peripheral vision, meaning that if a walk made observers want to cross the road using their central vision, the same was found using peripheral vision.

Additional significant correlations were found for likelihood of crossing the street on walks between the central and peripheral vision (see Table 34). However when viewing the correlations between the umbrella and bat walks, an unusual pattern was found. There was a stronger correlation between ratings of the bat and umbrella walks ($r(32) = .79$, $p < .01$) when viewing the bat walk in the peripheral vision and umbrella walk in central vision ($r(32) = .70$, $p < .01$ for ratings between viewing the bat walk in the central vision and umbrella walk in peripheral vision), than the umbrella/umbrella walks ($r(32) = .63$, $p < .01$) and the bat/bat walks ($r(32) = .62$, $p < .01$). When viewing a scatterplot of the data, two outliers were found which could explain this anomaly. Therefore, Spearman's correlations were conducted (see Table 35). Whilst this did increase the strength of the correlation between the umbrella/umbrella ($r_s(32) = .74$, $p < .01$) and bat/bat ($r_s(32) = .76$, $p < .01$) walks, the correlation was still not as strong as the relationship between viewing the umbrella walk in the central vision and bat walk in the peripheral vision ($r_s(32) = .87$, $p < .01$) and viewing the umbrella walk in the peripheral vision and bat walk in the central vision ($r_s(32) = .88$, $p < .01$).

Table 35: Spearman's correlation for ratings of physical dominance on the umbrella and bat walks

		Central Vision	
		Umbrella	Bat
Peripheral Vision	Umbrella	**.739****	**.881****
	Bat	**.872****	**.760****

** Correlation is significant at the .01 level

t-tests

Ratings of both physical dominance and likelihood of crossing the street were higher when viewed in the central vision compared to peripheral vision (see Table 37 and Table 36).

Table 36: Means and standard deviations for physical dominance ratings on central and peripheral vision

	Central Vision Means (SD)	Peripheral Vision Means (SD)
Baseline	3.17 (.46)	3.11 (.46)
Unarmed	3.84 (.75)	3.75 (.68)
Umbrella	3.51 (.64)	3.48 (.62)
Bat	3.67 (.88)	3.52 (.80)

Table 37:Means and standard deviations for street crossing ratings on central and peripheral vision

	Central Vision Means (SD)	Peripheral Vision Means (SD)
Baseline	2.92 (.58)	2.36 (.40)
Unarmed	3.77 (.98)	3.10 (.78)
Umbrella	3.77 (1.06)	2.94 (.75)
Bat	3.56 (.91)	3.01 (.98)

When running paired samples *t*-tests, there was no significant difference between the physical dominance ratings from the central vision to peripheral vision. There was a significant difference for crossing the street between the baseline walks (central vision M = 2.92, SD = .58, peripheral vision M = 2.36, SD = .40, $t(33) = 4.90$, $p < .01$, $d = 1.12$), unarmed walks (central vision M = 3.77, SD = .98, peripheral vision M = 3.10, SD = .78, $t(33) = 6.14$, $p < .01$, $d = .76$), umbrella walks (central vision M = 3.77, SD = 1.06, peripheral vision M = 2.94, SD = .75, $t(33) = 4.45$, $p < .01$, $d = .87$), and bat walks (central vision M = 3.56, SD = .91, peripheral vision M = 3.01, SD = .98, $t(33) = 3.12$, $p = .01$, $d = .58$), with the likelihood of crossing the street to avoid the man being higher in ratings from the central vision compared to the peripheral vision, showing medium and large effect sizes according to Cohen (1988).

Discussion

The current chapter aimed to better understand how threat is detected in both the central and peripheral vision, and how comparable they are. However, while these findings do help us better understand our perceptions of threat within the central and peripheral fields, caution must be used for these results due to the unequal samples. The current chapter compares ratings within the central (where 50 participants viewed each video) to peripheral vision (where 20 participants viewed each video).

With regards to ratings of dominance, the results between the central and peripheral vison were comparable, with there being no significant difference between ratings of physical dominance on any of the four walks (baseline, unarmed, umbrella, and bat). These findings suggest that threat may be detected equally as well between central vision and peripheral vision. This would be beneficial due to the importance of detecting a threat at an early stage. If a threat appears within the peripheral visual field first, detecting this movement will be advantageous in order to orient vision toward the threat (i.e., moving it over to central vision) and preparing to fight or flee.

When comparing the results for likelihood of crossing the street, there was a significant difference between central and peripheral vision for all four walks, with walks viewed in the central vision being rated as higher in likelihood of crossing the street compared to viewing the same walk within the peripheral vision. As there was a significant difference between likelihood of crossing the street from the baseline walks to the threatening walks when viewed in the peripheral vision, it does suggest that threat can be detected within the peripheral vision, but the comparison suggests that crossing the street is less likely when viewed in this field compared to central vision. As more information is processed within the central vision (Wang & Cottrell, 2017), this seems like a logical finding. Furthermore, Mienaltowski et al., (2019) found that detecting threat (by using fearful and angry faces as stimuli) was most prominently perceived within central vision, and that detection declined as stimuli were presented further from the fovea. This could explain the results of the current study, where threatening intent was not deemed as threatening compared to viewing the stimuli within the central vision.

In summary, the results seem to suggest that detecting physical dominance in both the central and peripheral vision is comparable. While there was found to be a significant difference between the two for ratings of likelihood of crossing the road, this can be explained due to the more detailed information processed within the central vision. Due to the uneven group sizes, more data will be collected for the peripheral vision aspect to ensure the data is comparable and give strength to the results.

Discussion

Summary

This thesis has investigated how physical dominance information is encoded into the walking gait of men, how men's gait may change when approaching an opponent, and whether observers can accurately decode cues to physical dominance from body language alone. Study one used the walks of men at baseline as stimuli for measuring perceptions of physical dominance. A strong, significant, positive correlation was found between ratings of physical dominance, and the strength and girth of the man. A gender difference was also found, with women rating the walks higher in physical dominance compared to the men. When conducting biomechanical analysis on the data, a swing-like motion was strongly positively correlated with ratings of physical dominance.

Study two introduced an arousal state condition, where men were asked to approach an opponent after listening to an embellished provocation scenario. This walk was then deemed their threatening walk. Participants were asked to rate the baseline and threatening walks on physical dominance, and how likely they would be to cross the street to avoid the man. The question regarding crossing the street aimed to gain insight into how successful the altered body movements were in deterring a potential opponent from physical conflict, but also as a measure of the extent to which movements cues can influence decision making in such scenarios. There was a strong, significant, positive correlation between ratings of the baseline walk with strength and girth for ratings of physical dominance, where physically larger and stronger men were perceived to be higher in physical dominance, suggesting that build plays a key role in assessing physical dominance. There was no significant increase in judgments of physical dominance from the baseline to threatening walks. There was however an increased likelihood of crossing the street when viewing the threatening walks compared to the baseline walks. Again, there was found to be a gender difference, with women being more likely to cross the street compared to men.

Study three investigated perceptions of physical dominance when a weapon is being carried. Men had their baseline walks recorded, as well as three threatening walks: an unarmed but threatening walk, a threatening walk holding an umbrella, and a threatening walk holding a baseball bat. These were presented to participants to assess physical dominance and likelihood of crossing the street to avoid the man. A correlation showed no link between physically dominant traits and likelihood of crossing the street, but girth positively correlated with the baseline walks perceptions, and self-rated dominance correlated with the unarmed and umbrella walks for ratings of physical dominance. There was a significant increase in ratings of physical dominance and street crossing from the baseline walks to the threatening walks, but no significant difference between the three threatening walks for either question. Finally, a gender difference was found where women were more likely to rate the walk as higher in physical dominance and more likely to cross the street compared to men.

The final study used the same stimuli as study three but presented solely within the peripheral vision as opposed to central vision in the other studies. A correlation found no link between physically dominant traits and likelihood of crossing the street, but there was a significant, positive relationship between the baseline walks and girth, and the unarmed walks and self-rated dominance of the men and ratings of perceived physical dominance. As with the findings from study three, a significant difference in perceived dominance was found between baseline walks and threatening walks, where threatening walks were rated higher in physical dominance were more likely to elicit crossing the street in avoidance. No significant differences were found between the three threatening walks for either question. A gender difference was seen where women rated all the walks as higher in physical dominance and were more likely to cross the street compared to men.

When comparing the results of study three (stimuli presented within the central vision) with study four (stimuli presented within the peripheral vision), there was no significant difference in the ratings between visual areas for physical dominance, suggesting that physical dominance can be accurately assessed across the visual field. There was however a significant difference in the likelihood of street crossing between the two visual fields, where all four walks (baseline, unarmed, umbrella, and bat) viewed within the peripheral vision were rated as significantly lower compared to viewing the same stimuli within the central vision. Previous research has shown that threatening behaviour may be best assessed within central vision (e.g., Mienaltowski et al., 2019) and that central vision provides the most information (Wang & Cottrell, 2017), supporting the current findings.

General discussion of aims

The following explores the extent to which each of this thesis' aims were met.

Aim one: By using modern motion capture techniques, we will quantify men's movements in various states in a series of controlled experiments to investigate whether we accurately assess physical dominance as seen in previous research using static and vocal stimuli

In studies three and four, participants were able to accurately assess physical dominance by differentiating between a baseline and threatening walk. While study two also used baseline and threatening walks as stimuli, participants were unable to distinguish between the two. However, as discussed within study two, this may be due to there being less variance in natural physical dominance in the walkers, leading to the non-significant results. If the stimuli were not particularly dominant, it may be harder for raters to pick up on the changes in biological motion between baseline and threatening walks.

The results of studies thee and four found between baseline and threatening walks suggest that men alter their movements when aiming to threaten, and observers can accurately perceive these changes in motion. This suggests that men use similar cues as social animals do: altering their movements prior to physical aggression starting. As discussed in the introduction, certain species (such as chimpanzees (*Pan troglodytes*), and gorillas (*Gorillas*)) have been found to alter their movements to intimidate and show their physical dominance to a potential opponent (leMouton et al., 1999; Rosier & Langkilde, 2011; Tutin & Fernandez, 1991). While this was not found within study two, this may be due to the participants involved within the stimuli creation (as previously discussed). Furthermore, large effect sizes were repeatedly found across studies three and four when investigating the differences in perceptions from baseline to threatening walks, showing just how substantial the difference in perceived physical dominance was between the two walks.

Study four shows that it is possible to detect these physically dominant movements within the peripheral vision. Due to the high cost that can be involved with physical conflict, it would be beneficial to assess physical dominance in different fields of vision. This thesis supports this notion, as baseline walks were rated significantly less likely to have raters cross the street, and significantly less physically dominant compared to the threatening walks, when viewed in both central and peripheral vision. Our central vision has a very small degree of focus, and if we could only detect threats when they came towards us directly, this would leave us at risk. By being able to detect threats in our peripherals, this gives us extra time to prepare to either fight, or flee.

Across the four studies, it was repeatedly found that strength and girth influenced ratings of physical dominance and the likelihood of the observer to cross the street to avoid the man. This leads us to the conclusion that size information, which is critical to physical dominance, is encoded into walking gait and that observers can pick up on this. Moreover, strength often correlated with ratings of physical dominance or likelihood of crossing the street, predominately on the baseline walks. These findings suggest that physically larger and stronger men are being perceived as physically dominant and leading participants to avoid them when the men walk in their natural gait. Strength and size play key roles when inflicting damage, and therefore would be beneficial to be able to assess from motion.

While size and build did influence physical dominance judgements in natural baseline walks, this finding was less consistent when viewing walks where the man was approaching an opponent. One explanation of this could be due to the artificiality of the study. As discussed within studies two, three, and four, participants may not actually want to approach an opponent in a real-life situation but were forced to within these studies. This therefore may create unnatural movements, particularly if the participant has never had to approach an opponent before. This awkwardness in motion could therefore be disguising the cues we see in baseline walks. This could explain why build was seen to have a relationship with baseline walks, but not threatening walks. The thesis attempted to investigate how familiar the participants were with approaching an opponent by asking what sports they played (to determine if they played contact or non-contact sport) and if they had previously been involved in a physical fight (only asked in study two and three). However the lack of detail in the question may be a limitation of the study. Participants were simply asked if they had ever engaged in a physical fight, which could result in participants stating yes, even if the fight occurred years, if not decades earlier. Therefore, future studies should better understand the timeframe and frequency of physical conflict.

Bojanic et al., (2019) found personality differences between those who played contact and team sports. The study found that those who engaged in contact sport were lower in self-esteem than those who engaged in team sports, but were higher in conscientiousness. This difference could alter the ways in which they approach a situation where a physical conflict is possible, yet this was not found in the thesis. This could be due to not specifying the level of sport played, or how often. Furthermore, the majority of the men (over 50% in each study) played football, and while classed as a contact sport following Conley et al., (2014), it is not as contact-based as other sports (such as boxing or MMA) and could therefore influence the findings.

Additionally, we did not collect data on how well the APQ angered participants, and so we cannot be sure they were truly walking with the intent to threaten. While it can be assumed that the scenario did have an impact on the participants emotional state (as multiple participants engaged in physical aggression with the BOB), it might not have worked as intended on all participants. Furthermore, the participants may not have felt fully immersed in the scenario, due to the environment they were in.

To summarise, this thesis suggests that observers can differentiate between a threatening walk and a baseline walk. Furthermore, a man’s build, encoded into his walking gait, plays a key role in how physically dominant he is judged to be, and how likely observers are to avoid him.

Aim two: Which, if any, kinematic features correlate with perceptions of physical dominance?

Study one used some preliminary biomechanical analysis to investigate which, if any, kinematic features correlate with perceptions of physical dominance. Comparing the five highest walks for physical dominance to the five lowest rated walks, we found a pendulum-like motion of the upper-body. This swing, or swagger, in the motion of the mid-hip to T10 area of the body significantly correlated with ratings of physical dominance, in that men who had more swing in their walks were rated as more physically dominant than those with lower levels of swing. Due to the nature of the swing motion, this likely made the upper-body look larger than it is.

A man's upper-body muscle mass plays a key role within intrasexual selection, having on average 75% more arm muscle mass (Abe et al., 2003) and 90% more upper-body strength compared to women (Lassek & Gaulin, 2009; Mayhew & Salm, 1990). This additional strength is crucial for both attacking opponents and protecting oneself. By exaggerating their upper-body size, it may increase perceptions of upper-body muscle mass, thereby increasing perceptions of the damage that could be inflicted upon an opponent. This exaggeration of one's size has repeatedly been seen in the animal kingdom (see study one), yet no research to our knowledge had investigated the idea of an intimidation gait in humans. The biomechanical analysis of study one provides vital information into how men threaten a potential opponent, potentially through using this pendulum-like swing to increase perceptions of their physical dominance.

Due to impact of COVID-19 (as discussed within the COVID statement), data collection for the latter studies were still ongoing until the final few weeks of the thesis. Therefore, biomechanical analysis was not possible on the data from studies two, three, or four. This analysis will be carried out in the future to give a better understanding of the robustness of our preliminary findings. Furthermore, postural cues may also impact on raters' judgements of physical dominance. Upon viewing the walks rated highest in physical dominance from study three and four, we feel that position of the shoulders extending outwards and forwards from the body may also be a predictor of ratings of physical dominance, as these seem to be larger and more pronounced in the highest rated walks. These movements will be analysed by looking at the differences between the angles of the shoulder and upper-arm markers. These additional biomechanical analyses will further the limited understanding we currently have regarding kinematic features related to physical dominance.

Aim three: Are there any gender differences between men and women when judging someone's physical dominance using biological motion?

A gender difference was repeatedly found across this thesis, where women were more likely to rate the walks higher in physical dominance compared to men, and were also more likely to cross the street to avoid the man. These findings support a range of literature that suggests women are more fearful than men of crime, despite being less likely to be a victim of most violent crime, excluding sexual offences and domestic abuse (Fisher, 1995; Hale, 1996; Jennings et al., 2007; ONS, 2021).

A recent ONS (2021) report showed that one in every two women felt unsafe when walking alone after dark compared to only one in seven men. This could explain why woman participants in studies two, three, and four were more likely to cross the street to avoid the man compared to participants who were men. Killias (1990) discussed how inherent vulnerability may be responsible for this, specifically in relation to exposure to risk, seriousness of consequences, and loss of control, a concept that has good support in the literature (e.g., Hale, 1996; Maxfield, 1984). Specifically, women may feel this vulnerability due to the perception that they are often exposed to danger, or that they may not be able to defend themselves if a threatening situation is to appear (Smith & Torstensson, 1997). The result of this is that women may over-estimate the physical and psychological consequences of falling victim to a crime, essentially as a defence mechanism (Jackson, 2009). Another theory as to why women may be more likely to cross the street to avoid a man may be due to the fear of sexual assault. Women are far more likely to be the victim of sexual assault compared to men (Truman et al., 2016), and the fear of this specific crime may overshadow other types of crime. This could therefore result in an overall increased fear of all types of crime (Choi & Merlo, 2021). A final explanation of these gender differences could be due to the feelings of men. It has previously been argued that men are socialised to believe that they should not fear crime, a belief that if true, could further explain the consistent gender differences throughout the thesis (Day, 2001; Goodey, 1997; Rader & Haynes, 2011). This theory was supported by Choi and Merlo (2021), who found that masculinity has a significant negative relationship with fear of crime, where higher masculinity resulted in a lower fear of crime. Additionally, media reporting on crime can often skew towards reporting women as the victim and men as the perpetrators of crime, which may lead to a false sense of security in men, as discussed within the Exposure Model (Gerber, 1972).

Intent

One key question that must be asked is regarding the intent of the walkers. Whilst studies two, three, and four used scenarios to provoke the men into presenting a threating walk, it is not clear how effective this was at inducing agitation, nor what the walker's intentions were during their approach to the BOB. As studies three and four found that onlookers of these walks were able to differentiate between movements of a threatening and non-threatening walk, it does suggest that the movements are altered, but the intent of the walk is still unclear. These studies utilised weapons, and weapons can be used as an offensive weapon, but also as a defence. The intended use of the weapons, whether offensive or defensive, may alter body movements differently.

Previous research into intent suggests that some intentions can be revealed via body movements. Quintero et al., (2017) conducted a machine learning study investigating pedestrian's intentions to cross a street. Joint markers were viewed of 490 sequences from 302,470 pedestrian poses in 31 participants to understand the intent of the walker, i.e. walking, stopping, or standing. By viewing the 3D positions and displacements of 11 joint markers, a trained machine learning algorithm was able to categorise the intention of the pedestrian with 95.13% accuracy. These findings show that intent can alter body movements, which should be investigated to further understand threatening behaviour. In studies three and four, the stimuli used both an umbrella and a baseball bat as a weapon, but these could be used with different intents. For example, both could be used in a more defensive manner to try and deter an opponent, with the intent to avoid engaging in a physical conflict. Similarly, both could be used as an offensive weapon to attack a potential opponent. As the aforementioned research illustrates, intentions can alter body language to the extent that machine learning algorithms can accurately predict them. Movement could be subtly different depending on if the person is acting in an offensive or defensive way, therefore intention information is a critical piece of the puzzle in the processing of body language.

Understanding intent can both present a limitation for the current study, and a future research suggestion. To gain a better understanding of intent, we could discuss intentions with the participants after the motion capture session to provide context into their body movements. This, combined with precise biomechanical modelling may allow us to unpick subtle differences in movements that may predict their intentions and actions.

Limitations

While studies in this thesis used high-end motion capture technology, the ecological validity of the research is a clear limitation. The stimuli creation was obtained in a motion capture lab, where the men wore sportswear and had reflective markers placed on them before walking in front of the researcher. This is a very unrealistic setting for provoking genuine threatening walks.

Ecological validity must again be considered in the context of the threatening walks. While participants chose a scenario that they felt would lead to threatening behaviour, this cannot be guaranteed. Participants may have felt none of the scenarios would bother them in a real-life setting, or that while the scenario did bother them, it may not be enough to make them threaten a potential opponent. Whilst the lack of ecological validity of some visual stimuli-focused studies has been discussed (e.g., Coelho et al., 2019), the research conducted in this thesis is unlikely to be conducted in a natural environment for several reasons. For example, we could capture the motion of MMA fighters during a match, however the likelihood of obscured markers is high, and the fight would most likely result in markers falling off. Additionally, research into aggression can be ethically dubious in more natural situations. Observational studies could be conducted, utilising CCTV images of nightclubs or other areas likely to see fights, but then the ability to capture these movements is lost.

Furthermore, changes in emotional arousal were not measured, bringing into question if the Aggression Provocation Questionnaire (O'Connor et al., 2001) actually elicited agitation in walkers. Had a measurement been implemented before and after the threatening walk, it would give an indication of if the scenario was in fact successful at changing mood to provoke the motion changes we were looking for. Future research should expand upon this by using physiological measures, such as heartrate or skin conductance, to advance understanding of the emotional state of walkers during their threatening walks.

Another issue was the lack of link found between ratings of physical dominance and any of the traits on the Aggression Provocation Questionnaire (O'Connor et al., 2001). The questionnaire measures three traits: anger, frustration, and irritation, yet these do not indicate an individual's physical dominance. While a man may feel anger, frustrated, and irritated, this does not mean they will win a physical conflict. The final measure on the questionnaire is their reaction to a scenario and if they would engage in physical conflict. Overall, very few of the participants indicated they would engage in physical conflict, but even if they would, again this does not indicate their ability to win the physical conflict. Therefore, the lack of relationship between this questionnaire and ratings of physical dominance could be explained by the questionnaire not actually assessing an individual's ability to win a conflict.

Future Research

The main focus of our future research will be to continue analysing the kinematic data. Furthermore, as discussed within the COVID-19 statement, a qualitative study interviewing police officers was planned to understand how they detect threatening behaviour as this information may help target future biomechanical analysis. This study was originally planned to see if police officers are noticing the same motions that the biomechanical data pulled out, or if there are other motions they notice that need to be analysed. Future research should continue with this, as there has been no research into the kinematic features of threatening movements of men which means the biomechanical analyses here were data driven more than theory driven. Though the kinematic analysis did produce sensible findings related to the upper-body that makes sense in an intrasexual context, by understanding what features are being used by police officers who witness fights frequently, it could support the current findings, or suggest a new direction to investigate. This avenue could be further expanded with the use of gaze analysis in an eye-tracking study. By examining what participants are looking at prior to making judgements of physical dominance, we can see if the same movements are being picked up on by observers without frequent experience of seeing fights as police officers, as well as what comes out of the biomechanical analyses.

Another avenue for future research could be to investigate intentions. As discussed previously, intent can play a key role in the altering of body movements, therefore this is a factor that should be investigated. To implement this, participants could have their movements recorded whilst taking into account their ultimate action (e.g., striking an opponent, or using the weapon to merely threaten). The preceding movements could be analysed to look for differences leading up to the action taken. Observers could also be shown these animations to guess what the intention is to explore whether we have cognitive mechanisms to infer action solely from the approaching gait.

Implications

By understanding what movements are involved when displaying threatening intent, this could be used as a base for creating algorithms to assist in detecting physical dominance before it results in aggression. Smith (2004) found that CCTV operators within the UK worked long hours, with low pay and minimal praise, leading to Dunphy et al. (2015) arguing that due to issues such as these, a semi-automated service should be brought in to ensure that criminal activity can be minimised. By creating a program to assess if someone is behaving threateningly, this could reduce the burden put on CCTV operators. Instead of having to diligently monitor several screens at once, they would be alerted to a specific screen when key body movements were detected. It would then be the operator’s judgement as to whether action is needed, with the aim of potentially reducing the number of physical fights in public. This is of particular importance, as Police forces in England and Wales have suffered years of austerity-related budget cuts (an estimated 19% cut between 2010 and 2019), and recruitment freezes (15% reduction in officers, Mann et al., 2020; Caveney et al., 2020), leaving them understaffed and under resourced.

A training programme could also be created to assist police officers in detecting a threat before it happens. Physically dominant movements could be input into a virtual reality training environment to give officers more experience in seeing threatening movements, in a safer environment. Virtual reality training environments are already successfully used in many disciplines including medicine (Jiang et al., 2022), fire fighting (Cha et al., 2012), disaster management (Hsu et al., 2013), and the police (Munoz et al., 2020). This could assist in the de-escalation of situations before physical conflict occurs.

Conclusion

In conclusion, across four studies, this thesis demonstrated that physical dominance can be assessed from the body language of men and suggests that men's movements are altered when in a provoking situation where they need to approach a potential opponent. This was demonstrated by threatening walks being routinely rated as being higher in physical dominance compared to baseline walks. These movements are not just able to be decoded when in the central view, but also in the visual periphery. Judgments on what makes someone a potential threat may ultimately be based on their build, but this is encoded into their walking gait and observers can accurately assess this. Furthermore, men may attempt to exaggerate their physical dominance by adopting a swagger-like body movement and this leads observers to inflate their ratings of physical dominance. By and large, the results of this thesis provide a novel insight into the neurocognitive mechanisms that help us rapidly assess the formidability of an approaching opponent, even when he is approaching from our visual periphery. In processing this information, we are better able to navigate the ensuing altercation to ensure our survival.

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Appendix A

Authors	Paper	Stimuli	Method	Findings	Summary
Albert, Wells, Arnocky, Liu, and Hodges-Simeo (2021)	Observers use facial masculinity to make physical dominance assessments following 100-ms exposure.	40 morphed facial photographs (20 masculine and 20 feminine).	96 student men (aged 18-27, mean age = 20.16 years) rated the 40 facial photographs on physical dominance on a 1 to 7 scale.	Fixed effect of sexual dimorphism was a significant predictor of participants physical dominance ratings (β = 0.34, SE = 0.09, t = 3.54, p < .01).	Observers assigned higher dominance to masculinised faces - even after brief exposure.
Aung, Rosenfield and Puts (2021)	Male voice pitch mediates the relationship between objective and perceived formidability.	Study One: 231 men (aged 18-26) had vocal recordings of the Rainbow Passage done. This is a passage used frequently in speech research as the first four lines of the passage use all phonemes for American English.	Study One: 565 student men (no mean age stated) rated one of the 30 blocks (each containing approximately 25 vocal recordings) on dominance on a 1-7 scale.	Study One: Height (estimate = 0.06, SE = 0.03, p = .03) and vocal tract length (VTL) (estimate = 0.11, SE = 0.03, p < .01) significantly predicted physical dominance ratings. Adding fundamental frequency (F0) to the model (estimate = -0.13, SE = 0.02, p < .01) reduced the predictive power	The voice pitch of men mediated the relationship between objective and perceived formidability suggesting that men's voice pitch transmits information about formidability.

				of height on physical dominance ratings (estimate = 0.04, SE = 0.03, *p* = .22).	Height was and VTL was also found to predict physical dominance ratings.
		Study Two: Voice recordings of 74 men (aged 17-30) saying the English vowels (a/e/i/o/u).	Study Two: 125 students (78 females) rated the voices on perceived height and physical dominance using a 1-7 scale.	Study Two: Height (estimate = 0.28, SE = 0.02, *p* < .01) and VTL predicted male physical dominance ratings (estimate = 0.34, SE = 0.03, *p* < .01). When F0 (estimate = -0.65, SE = 0.03, *p* < .01) was added to the model, the predictive power of height on dominance rating was reduced (estimate = 0.14, SE = 0.02, *p* < .01). When testing if f0 mediates the relationship between measured height and perceived height, both measured height (estimate = 0.24, SE = 0.01, *p* < .01) and VTL predicted perceived height (estimate = 0.48, SE = 0.01, *p* < .01). When F0 (estimate = -0.69, SE = 0.01, *p* < .01) was added to the model, the predictive power of measured height on perceived height was reduced (estimate	

				= 0.09, SE = 0.01, *p* < .01). A mediation analysis was run, with F0 as a potential mediating variable and VTL as a covariate. The average mediation effect of F0 on the relationship between measured height and perceived height was 0.15 (*p* < .01), mediating 63.97% of the total proportion with 95% CI [0.60, 0.68]. The mediating effect of VTL, independent of F0 was also tested. In this model, the average mediation effect of VTL on height and perceived height was 0.08 (*p* < .01), mediating 48.21% of the total proportion with 95% CI [0.44, 0.53].	
Borráz-León, Cerda-Molina, Rantala, and Mayagoitia-Nova (2018)	Choosing fighting competitors among men: testosterone, personality, and motivations.	Study One: 6 photographs of men's bodies, 3 previously rated as high in dominance, 3 previously rated as low in dominance.	Study One: 120 heterosexual men (mean age 22.05) completed biographical questionnaires and measures assessing aggressiveness,	Study One: 48 (40.3%) participants chose high-dominant masculine men as competitors; 71 (59.7%) chose low dominant masculine men as competitors, with the probability of a high-dominance, masculine man as a rival increased with higher	Levels of aggressiveness and self-esteem can alter the choosing of a rival.

			intrasexual competition, self-esteem, dominance, and masculinity and a testosterone sample was taken pre and post questionnaires. Participants were then asked to choose an opponent for a wrestling contest.	scores of aggressiveness of participants (β = -.08, Wald = 4.25, *p* = .04).	
		Study 2: 6 photographs of women, 3 that were previously rated as high in attractiveness, 3 that were rated as low in attractiveness.	Study 2: The same participants from study 1 were asked to pick an opponent from the male photographs and were told they would have a date with the woman in the photograph if they won. The photographs were of a man with	Study Two: Analyses indicated post-T levels, self esteem, and aggressiveness were related to choice of possible rivals according to mate value of the women (post-test T: β = .94, Wald = 7.13, *p* = .08; self-esteem: β = .04, Wald = 8.37, *p* = < .01; aggressiveness: β = .04, Wald = 6.16, *p* = .01).	

			high-dominant masculinity followed by a photograph of a woman with high or low attractiveness and a photograph of a man with low-dominant masculinity followed by a photograph of a woman with high or low attractiveness.		
Butovskaya, Windhager, Karelin, Mezentseva, Schaefer and Fink (2018)	Associations of physical strength with facial shape in an African pastoralist society, the Maasai of Northern Tanzania.	Handgrip strength and facial photographs were collected from a sample of 120 men and 89 women of the Maasai of Northern Tanzania. Handgrip strength was split into two groups, young adults (aged 20-29, n = 95) and mid adults (aged 30-50, n = 114, no mean age stated).	Morphometric analysis was conducted on each of the facial photographs to identify facial shape patterns.	Facial shape and handgrip strength were significantly associated in all four groups (young men (r = .37, p = .01), mid-adult men (r = .26, p = .03), young women (r = .29, p =. 01), mid adult women (r =.35, p = .01)). Mid-adult men had a less consistent shape pattern to other groups. In younger men, and both groups of women, higher handgrip strength was	Those with higher handgrip strength tended to have wider faces with a lower and broader forehead, a wider distance between the medial canthi of the eyes, a wider nose, fuller lips, and a larger, squarer lower facial outline compared with

				associated with wider faces, lower and broader foreheads, wider noses and fuller lips. They also had larger and more square facial outline compared to weaker individuals in their age groups. Weaker individuals had longer and more slender faces, narrower noses, and more pointed chins. Stronger men had thicker eyebrows in both age groups, as well as fuller lips. Weaker men had broader jowls and chin areas.	weaker individuals of the same age-sex group, showing a physiological difference in the face between strong and weak individuals.
Carré, McCormick, and Mondloch (2009)	Facial structure is a reliable cue of aggressive behaviour.	Study 1: 24 facial photographs of men (mean age = 19.08 years) were taken as well as self-reported aggressive behaviour. Facial width to height ratio (fWHR) was calculated for the faces.	Study 1: 16 women and 15 men (mean age = 19.94 years). Participants were asked to rate the facial photographs on aggression, dominance, masculinity, trustworthiness,	Study 1: Single-sample t-test comparing individual correlations to null values showed estimated aggression was positively associated with the facial WHR of facial stimulus (men raters: $t(14) = 16.94$, $p < .01$, women raters: $t(15) = 9.23$, $p < .01$, combined: $t(30) = 16.41$, $p < .01$).	Findings suggest that fWHR is a reliable cue of aggression in men.

			and attractiveness on a 1-7 scale (1 = not at all, 7 = very) after viewing them for 2,000 ms.	It was also found that estimated aggression was positively associated with actual aggression of the stimulus faces (men: $t(14) = 6.95$, $p < .01$, women: $t(15) = 8.81$, $p < .01$, combined: $t(30) = 11.21$, $p < .01$). The mean estimated aggression for each face was associated with both the facial WHR ($r = .59$, $p < .01$, $r = .42$, $p = .04$ respectively) and actual aggression of the stimulus faces. Estimates of aggression were significantly correlated with ratings of dominance ($r = .92$), masculinity ($r = .86$), trustworthiness ($r = .90$), and attractiveness ($r = .57$). Estimates of aggression and of dominance were correlated significantly with the facial WHR ($r = .59$ and $r = .54$, respectively).	

		Study 2: The same stimuli from study 1 was used.	Study 2: 16 women, (mean age = 19.38 years) were asked to rate the photographs *"How aggressive would this person be if provoked?"* on a 1 – 7 scale (1 = not at all, 7 = very much so) after viewing them for 39ms.	Study 2: Estimates of aggression among these participants were highly correlated with estimates of aggression from participants in Study 1, who were given 2,000-ms exposure to the stimulus faces (r = .82, p < .01). Single-sample t-test comparing individual correlations to null values showed estimated aggression was positively associated with both the facial WHR (t(15) = 10.24, p < .01), and actual aggression of the stimulus faces (t(15) = 4.49, p < .01). The mean estimated aggression for each face across participants was associated with FWHR: r = .70, p < .01.	
Carré and McCormick (2008)	In your face: Facial metrics predict aggressive behaviour in the laboratory	Study 1: 88 facial photographs of undergraduate students (37 men and 51 women, mean age = 18.98 years). Height of upper face and bizygomatic width was calculated to give	Study 1: Participants completed a trait dominance questionnaire (Goldberg et al.,	Study 1: There was a main effect of gender: F (5,82) = 3.04, p = .01), where men had a greater facial ratio (t(86) = 2.33, p = .02, d = .50); scored higher on trait dominance (t	Findings suggest that a bigger facial ratio may be an honest cue of aggression in both

	and in varsity and professional hockey players.	facial wifth to height ratio (fWHR).	2006) and were photographed while in a seated position, maintaining a neutral facial expression. Participants then completed the Point Subtraction Aggression Paradigm, Cherek (1981) to assess aggression.	(86) = 2.15, *p* = .04, *d* =.46); and were more aggressive than women (*t* (86) = 2.18, *p* = .03, *d* = .47). Separate regression analyses for men and women were computed with trait dominance and fWHR s predictors of aggressive behaviour. For men, face ratio predicted 15% of unique variance in aggressive behaviour (R^2 = 0.18, *F* (2,34) = 3.60, *p* = .04; *t* (36) = 2.50, *p* = .02). For women, face ratio and trait dominance did not predict aggressive behaviour, nor did the interaction.	a lab and real life setting.
		Study 2: 21 undergraduate men (mean age = 22.81 years) varsity hockey players facial photographs were taken from the university website. Height of upper face and bizygomatic width was calculated.	Study 2 and 3: The penalty minutes that each player accrued per number of games played during the 2007–2008 season	Study 2: Individual differences in face ratio in male hockey players explained 29.2% of the variance in penalty minutes per game played (*r* = .54, *p* = .01), with a bigger face ratio resulting in more penalty minutes per game.	

		Study 3: Facial photographs were obtained for every player who played on the Canadian teams of the NHL during the 2007–2008 season whose pictures were available on the Entertainment and Sports Programming Network (ESPN) website. After exclusion, a total of 112 facial photographs were used. Height of upper face and bizygomatic width was calculated.	(obtained from the Ontario University Athletics website for study 2 and from ESPN's website for study 3) were used as the measure of aggression. Penalties included behaviours such as slashing, cross-checking, high-sticking, boarding, elbowing, checking from behind, fighting and so on.	Study 3: Individual differences in the face width-to-height explained a significant proportion (no statement of proportion was given in the paper) of the variance in aggressive behaviour in NHL hockey (r =0.30, p = < .01), where those with larger facial ratios showed more aggressive behaviour.	
Cartei, Bond, and Reby (2014).	What makes a voice masculine: Physiological and acoustical correlates of women's ratings of	37 men (aged 20 - 25, mean = 20.6 years) had their height measured and saliva samples taken for testosterone. Three types of vocal recordings were taken; a list of single-syllable words (isolated word stimuli), the sentence "*people look, but*	20 student women (aged 20 - 25, mean = 21.8 year) listened to all stimuli and rated them on masculinity on a 1-7 scale (1 = not	Men with lower F0 were perceived as more masculine (ρ = −.53, p < .01). Men with narrower format spacing were also perceived as more masculine, though path coefficients revealed that format spacing had a weaker	Men who were taller and had higher levels of testosterone have lower F0 and format spacing and were rated as more masculine.

	men's vocal masculinity,	*no-one ever finds it*" extracted from the Rainbow passage (sentence stimuli), and the statement "*the object I have in front of me is a kettle*" (connected speech stimuli), giving a total of 111 vocal stimuli. Fundamental frequency (F0) values and the frequency of the first four formants (F1–F4) were obtained from these stimuli.	at all masculine, 7 = very masculine).	correlation with perceived masculinity than F0 (ρ = −.33, $p < .01$). Women rated taller men with high T levels as being more masculine. The link between height and masculinity was stronger (ρ = .30, $p < .01$) than the link between T levels and masculinity (ρ = .23, $p < .01$). The relationship between T and masculinity was indirectly mediated by F0 (ρ = −.25, $p < .01$) and the direct path was not significant. The direct path between height and masculinity was significant (ρ = .13, $p < .01$).	
Dixson, Sherlock, Cornwell, and Kasumovic (2018).	Contest competition and men's facial hair: beards may not provide advantages in combat.	Facial photographs of 395 UFC fighters who had partaken in 600 fights were used.	Facial hair was rated on a 0-9 scale (0 = clean-shaven, 1 = stubble, 2 = moustache, 3 = goatee (without moustache), 4 = Goatee (with	When investigating if previous contest outcomes, facial hair, height, stance, and reach predicted contest outcome, the only significant predictor was reach, with those with a longer reach winning more fights (z = 2.60, $p < .01$).	Facial hair was not associated with fewer losses or greater fighting ability, however fighters with longer reaches won more fighters

			moustache), 5 = Sideburns, 6 = Sideburns and moustache, 7 = moustache and soul patch, 8 = Full beard (trimmed), 9 = Full beard). Fight outcomes were taken from online sources on a 1-7 scale (1 = knock out, 2 = technical knockout, 3 = doctor or corner stoppage, 4 = submission, 5 = unanimous decision, 6 = split decision, 7 = no contest).	Bearded males won 49.3% of the time. When grouping the contest outcome (group 1 - knock out and technical knockout, group 2 - stoppage due to injury, submission, judge decisions and some disqualification or no contest judgements), facial hair was not a significant predictor of outcome.	than those with a shorter reach.
Dixson, Lee, Sherlock, and Talamas (2017).	Beneath the beard: do facial morphometrics influence the strength of judgments of	Study 1: Facial photographs of 37 men (mean age = 27.86 years) when clean shaven and with a full beard were taken. fWHR and jaw size were measured.	Study 1: 751 participants (mean age - 35.86 years, 398 men, 89.5% heterosexual) rated the faces on	Study 1: There was a significant correlation between jaw size and ratings of masculinity (r = .36, p = .03), with larger jaws being rated as more masculine but neither of these correlated with fWHR.	Men with beards were rated as more dominant than those without.

	men's beardedness?		either attractiveness, dominance, or masculinity on a 0-100 scale (0 = low in the trait, 100 = high in the trait).	Facial hair had a main effect on physical dominance, with full bearded men being rated as more dominant than clean shaven men. Objective facial masculinity had a significant main effect on dominance, with objectively masculine men rated as more dominant than less masculine men. However, there were no significant main effects or interactions for fWHR or jaw size models.	
		Study 2: The same faces from study 1 were used to create facial composites of both the clean-shaven and bearded photos, to create large and small jawed composite men.	Study 2: 626 participants (315 men, mean age = 37.26 years) rated the faces on either attractiveness, dominance, or masculinity (0 = low in the trait, 100 = high in the trait).	Study 2: There was significant main effects of degree of facial hair and jaw size on masculinity ratings in that masculinity ratings were significantly higher for the bearded composites than the clean-shaven composites: $t(206) = 20.73$, $p < .01$), and for larger jawed composites than smaller jawed composites ($t(206) = 12.44$, $p < .01$). A significant interaction	

				between facial hair and jaw size was reported, with composites with full beards and larger jaws rated as more masculine than bearded faces with small jaws, and both sets of clean-shaved composites: $F(1,205) = 46.92$, $p < .01$, $\eta_p^2 = 0.19$. For dominance ratings, there were significant main effects of degree of facial hair and jaw size on dominance ratings, in that bearded compisites were rated as significantly more dominant than clean shaven composites: $t(208) = 15.90$, $p < .01$, and for larger jawed composites than smaller jaws: $t(208) = 5.12$, $p < .01$. There was also a significant interaction effect between beard degree and jaw size and dominance ratings: $F(1, 207) = 122.42$, $p < .01$, $\eta_p^2 = 0.37$. There was no significant difference in dominance between faces with full beards and smaller vs. larger jaws:	

				t(208) = 1.38, *p* = .17, however bearded faces of both jaw sizes were rated as more dominant than clean-shaven faces of both jaw sizes, while clean shaven larger jawed images were rated as more dominant than clean shaven smaller jawed images.	
Doll, Hill, Rotella, Cárdenas, Welling, Wheatley and Puts (2014).	How well do men's faces and voices index mate quality and dominance?	63 male participants had their voices recorded speaking the first six sentences of a passage. Facial photographs were taken with a neutral expression, and were asked '*what percentage of men your age could beat you in a physical fight?"*	35 male psychology students rated the faces and voices on fighting ability and leadership. Some were acquaintances of the stimuli participants and some were strangers. The rating tasks used an 11-point Likert scale (0–10) except for the question "What percentage of men your age	Ratings of fighting ability significantly predicted independent ratings of leadership ability for both facial photos ($r(59) = 0.48$, $p < .01$) and voice recordings ($r(52) = 0.35$, $p = .01$), and ratings by acquaintances predicted leadership ability ($r(58) = 0.50$, $p < .01$). A multiple regression model predicting ratings of fighting ability ($R^2 = 0.13$, $F(2,48) = 3.54$, $p = 0.04$) showed that face ratings ($\beta = 0.56$, $p = .03$), but not voice ratings, made by independent raters significantly predicted ratings	Facial photos were more predictive of both self and acquaintance reports of leadership ability and fighting ability. Voice ratings were not predictive.

			could you beat in a physical fight?" which was from 0 to 100% in increments of 10%	by acquaintances. The interaction between face and voice ratings was not significant. Ratings of leadership was not significant. Correlations investigating voice and face ratings separately found that only photos had predictive ability: fighting ability (*r*(58) = 0.37, *p* < .01) and leadership ability (*r*(58) = 0.27, *p* = .04) significantly predicted. Male participants' self-ratings of fighting ability (*r(*58) = .31, *p* = .02), but not leadership (*r*(58) = .03, *p* = .86), significantly predicted equivalent ratings made by male acquaintances.	
Evans, Neave, and Wakelin (2006).	Relationships between vocal characteristics and body size and shape in human males:	50 (aged 18 - 68, M = 29.08 years) heterosexual male participants had vocal recordings of them speaking the English vowels.	50 heterosexual males between 18-68 (M = 29.08 years) had their voices recorded and analysed (mean	A significant negative correlation between mean fundamental frequency and weight was found: *r* = -.34, *p* = .02, with heavier participants having a lower frequency. Similarly, shoulder	There was found to be a significant negative correlation between fundame ntal frequency and measures of body

	An evolutionary explanation for a deep male voice.		fundamental frequency and formant dispersion). Physical measurements were taken from the skull, neck, shoulders, chest, and waist circumferences, as well as height, weight, shoulder-hip ratio, shoulder-waist ratio, waist-hip ratio, BMI, and lung capacity.	circumference was significantly negatively correlated with mean fundamental frequency ($r = -.29$, $p = .04$) and chest circumference was significantly negatively correlated with mean fundamental frequency ($r = .28$, $p = .04$). Shoulder–hip ratio was also significantly negatively correlated with mean fundamental frequency ($r = -.49$, $p < .01$). These results suggest the larger the specified body size, the lower the fundamental frequency. Weight and height were significantly negatively correlated with formant dispersion ($r = -.43$, $p < .01$; $r = -.32$, $p = .02$), with heavier and taller individuals having smaller formant dispersion. Similarly, neck, shoulder, chest, waist and shoulder-hip ratio all significantly negatively correlated with format dispersion ($r = -.50$, $p < .01$, $r = -.56$, $p < .01$, $r = -.45$, $p <$	shape and weight and between formant dispersion and measures of body size as well as body shape, showing that vocal cues can indicate body size, shape, and weight.

				.01, *r* = -.39, *p* = .005, *r* = -.39, *p* < .01), all suggesting that the larger the specified body size, the smaller the formant dispersion.	
Fink, Butovskaya, and Shackelford (2019).	Assessment of physical strength from gait: data from the Maasai of Tanzania.	80 males from the UK (aged 18-42, no mean age stated) had their walks recorded using motion capture and strength taken via a hand dynamometer.	The walks of the 10 physically strongest walkers and 10 physically weakest walkers were viewed by 100 participants from the Maasai of Tanzania (51 men, 49 women, ages 18-39, mean = 25.6 years) and rated on a 1-3 scale on strength with 1 being weak and 3 being strong.	The gait of strong men was judged lower on strength ($z = -5.50$, $p < .01$) compared with weak men. A similar result was found when performing the tests separately for male and female judges ($z = -3.45$, $p < .01$, $z = -4.32$, $p < .01$) and age (younger - $z = -4.95$, $p < .01$, older - $z = -2.52$, $p < .05$).	Ratings of strong walkers were judged weaker in strength compared to weak walkers, suggesting that perceptions of physical strength from gait may not be universal.
Fink, André, Mines, Weege, Shackelford, and	Sex difference in attractiveness perceptions of strong and	80 males (aged 18-42, no mean age stated) had their walks recorded using motion capture and strength taken via a hand dynamometer.	The walks of the 10 physically strongest walkers and 10 physically weakest walkers	There was a main effect of walker strength on perceptions of dominance ($F(1,99) = 29.99$, $p < .01$, partial $\eta 2 = .23$), and	Both men and women judged stronger male walkers higher on dominance and

Butovskaya (2016).	weak male walkers.		were viewed by 51 men and 50 women (aged 18-54, mean - 24) from a university in Germany and rated on strength and dominance on a 1-7 scale e (1 = low on attribute, 7 = high on attribute).	perceptions of strength ($F(1,99) = 106.61$, $p < .01$, partial $\eta 2 = .52$), with strong walkers scoring higher on both attributes. Observer sex had a main effect on dominance ($F(1,99) = 3.96$, $p < .05$, partial $\eta 2 = .04$), with women giving higher judgments than men, but there was no significant main effect for strength.	strength compared to weak walkers.
Fink, Wübker, Ostner, Butovskaya, Mezentseva, Muñoz-Reyes, Sela, and Shackelford (2017).	Cross-cultural investigation of male gait perception in relation to physical strength and speed.	80 males (aged 18-42, M) had their walks recorded using motion capture and strength taken via a hand dynamometer. Walks were also manipulated to have a 'slow', 'fast' and 'normal' speed walk.	The walks of the 10 physically strongest walkers and 10 physically weakest walkers were viewed by 188 men and 199 women (aged 16-50 years old) from universities in Germany, Chile, and Russia and rated on a 1-7 scale on strength where 1 = low in strength and 7 = high in strength.	For judgements on the 'normal' speed, strong walkers were rated as stronger compared to weak walkers (F $(1,207) = 203.98$, $p < .01$), this was seen in both sexes of the raters. There was no interaction effect of location of rater on perceptions of strength.	Stronger walkers were judged to be stronger compared to weaker walkers, suggesting that we are able to assess strength from gait.

Fink, Täschner, Neave, Hugill, and Dane (2010).	Male faces and bodies: Evidence of a condition-dependent ornament of quality.	Facial and body photographs were taken of 43 Caucasian men. Participants were between 18-30 years old (M = 23.8 years). Participants had 3 photos taken: face, body with head blocked out, and back of body.	The three photographs were rated by 78 Caucasian heterosexual women aged 18-34 (M = 23.1 years). The photographs were presented independently so that a total of 26 different women rated each set. Participants were asked to rate the photographs on a 1-7 scale on masculinity and dominance (1 = low on attribute, 7 = high on attribute).	There was a positive significant correlation between both attributes and the facial and body photographs. For dominance ratings: face and front body, $r = .53$, $p < .01$, face and back body, $r = .42$, $p < .01$, and front and back body, $r = .80$, $p < .01$. For masculinity ratings: face and front body, $r = .52$, $p < .01$, face and back body, $r = .35$, $p < .05$, and front and back body, $r = .73$, $p < .01$).	Ratings of male faces significantly correlated with ratings of the same attributes (dominance and masculinity) as their bodies, therefore males who have perceived dominant and masculine faces also have dominance and masculine bodies.
Fink, Neave, and Seydel (2007).	Male facial appearance signals physical	32 white Caucasian men aged 18-32 (M = 23.5 years). Facial photographs were taken and strength measured via a hand	79 female raters (aged 19-32, M = 23.3 years) rated each face on a 1-7 scale on	When controlling for age and weight, a significant partial correlation was found between mean hand-grip strength and perceived masculinity ($r = .37$,	There was a significant positive correlation between strength and masculinity

	strength to women.	dynamometer along with height and weight.	dominance and masculinity (1 = low on attribute, 7 = high on attribute).	*p* = .02), and mean hand-grip strength and perceived dominance (*r* = .37, *p* = .02).	and dominance, suggesting that a male's physical strength is displayed in his facial characteristics.
Han, Kandrik, Hahn, Fisher, Feinberg, Holzleitner, DeBruine, and Jones (2017)	Interrelationships among men's threat potential, facial dominance, and vocal dominance.	44 men had 5 weekly sessions where a facial photograph was taken and a voice recording was taken saying a phrase, with the word 'hi' being used in the rating study and strength was taken using a dynamometer.	The 220 facial photographs and voice recordings were rated on dominance, strength, and weight on a 1-7 scale (1 = low on attribute, 7 = high in attribute) by 79 participants (32 men, 47 women, M= 23.3 years). Raters were randomly allocated to rate between two and four blocks of trials (mean number of raters per block of trials = 31.83)	A PCA was ran to produce three overall components, '*perceived vocal threat potential*', '*perceived facial threat potentia*l' which combined facial strength, dominance, and weight, and '*actual threat potential*' which combined handgrip strength from both hands, weight, and height. Scores on the perceived facial threat potential were positively correlated with scores on both the perceived vocal threat potential (*r*(44) = .37, *p* = .01) and the actual threat potential (*r*(44) = .32, *p* = .03). Scores on the perceived vocal threat potential and the actual threat	Mens actual threat potential was significantly correlated with perceived facial threat, but not vocal threat potential suggesting that men's faces may be a more valid cue of threat compared to vocal cues.

				potential component were not significantly correlated.	
Hodges-Simeon, Gaulin, and Puts (2010)	Different Vocal Parameters Predict Perceptions of Dominance and Attractiveness.	111 men (aged 18-24, M = 18.9 years) read a passage (the Rainbow Passage) and were asked to verbally address a male competitor in another room and describe why they might be respected or admired by other males. The males then rated their own and their competitors physical dominance.	86 men "audio raters" (ages 18–28, M = 20 years), 142 women "audio raters" (aged 18–30, M = 19.1 years), 67 men "content raters" (aged 18–26, M = 19.2 years), and 35 women "content raters" (aged 18–37, M = 19.5 years). Raters listened to a set of 30 or 31 of the vocal recordings which included raised, lowered, and unmanipulated voices and read the transcribed competitor discussion and rated them on	The change in fundamental frequency (F0) was significantly correlated with the change in fundamental frequency variation (F0-SD) for the speech to the competitor ($r = .43$, $p < .01$). Intensity (loudness) was positively correlated with mean F0 for the speech to the competitor ($r = .31$, $p < .01$). Vocal physical dominance was negatively correlated with F0-SD, ($r = -.29$, $p < .01$) and positively correlated with content physical dominance ($r = .65$, $p < .01$). F0-SD significantly predicted judgments of physical dominance, with lower F0 meaning higher judgements of physical dominance ($\beta = -.16$, $p < .05$), but mean F0 was not	Ratings of physical dominance was predicted by low F0 variation and physically dominant word content.

			perceived social and physical dominance on a Likert scale.	a significant predictor (β= −0.14, *p* = .08). Dominant content ratings were a strong positive predictor of physical dominance ratings (β = .62, *p* < .01). Stepwise multiple regressions were ran and found F0-SD and physically dominant content were significant predictor variables (β = −.18, *p* = .01 and β = .62, *p* < .01, respectively) for perceptions of physical dominance. The interaction between format dispersion (Df) and content (β = −.16, *p* = .02) also significantly predicted physical dominance.	
Holzleitner, Hunter, Tiddeman, Seck, Re, and Perrett (2014)	Men's facial masculinity: When (body) size matters.	Facial photographs of 40 men (M = 20.3 years). Height and BMI were measured. Facial masculinity score were calculated as the distance along the morphological masculinity axis from the component scores for a	20 female students (M = 21.4 years) rated the faces on masculinity on a 1-7 scale (1 = not very masculine at	Morphological masculinity significantly predicted perceived masculinity (R^2 = .11, $F(1,38) = 4.57$, $p = .04$). All three morphological scores were found to be significant predictors of perceived	Facial masculinity, height and BMI were all significant predictors of rated masculinity, with taller and heavier people being rated

		subject's face to the point on the morphological masculinity axis closest to the male average component scores,	all, 7 = very masculine). 17 participants (2 males, M = 21.6 years) rated body weight from the facial photograph on a 1-7 scale (1 = very underweight, 7 = very overweight). 39 participants (12 males, M = 26.8 years) rated the facial photographs on perceived physical height on a 1-7 scale (1 = very short, 7 = very tall).	masculinity, with morphological masculinity being the strongest predictor ($\beta = .46$, $p < .01$), followed by morphological scores of height ($\beta = .42$, $p = .01$) and BMI ($\beta = .35$, $p = .01$).	as higher in masculinity.
Johnson and Wilson (2019)	Racial bias in perceptions of size and strength: The impact of stereotypes	Study 1: 1660 students were photographed (M = 19.7 years). Males were photographed without shirts, women with black t-shirts. Strength was obtained via a	Study 1: 1088 students (M = 19.8 years) rated 40 photographs (20 men and 20 women) on	Study 1: Men with more upper body strength ($\beta = 0.16$, CI = [0.115, 0.199], $p < .01$) and larger biceps ($\beta = 0.28$, CI = [0.234, 0.318], $p < .01$) were rated as stronger. Black men	While race did impact ratings of size and strength, the targets physical features were more

	and group differences.	dynamometer, and height and bicep circumference were measured.	strength, toughness and their likelihood of beating an opponent on a 1-7 scale (no scale points give).	were rated as stronger than White men ($\beta = 0.50$, CI = [0.354, 0.636], $p < .01$), and Asian men were rated as weaker than White men ($\beta = -0.31$, CI = [–0.473, −0.150], $p < .01$). Physical features explained three to five times more variance than race.	tracked. This suggests that while individuals rely on physical information (such as strength, bicep size and height), racial stereotypes are still utilised.
		Study 2: The same facial photographs from study one were used but just the sample of 92 Asian and 133 Black targets	Study 2: 303 students (M = 19.6 years) rated 100 photographs (50 men and 50 women) on strength and height on a 1-7 scale (no scale points give).	Study 2: Men with more upper body strength ($\beta = 0.16$, CI = [0.20, 0.38], CI = [0.08, 0.25], $p < .01$) and larger biceps ($\beta = 0.29$, CI = [0.20, 0.38], $p < .01$) were rated as stronger. Taller men were not rated as stronger when analyses controlled for these physical measures ($\beta = -0.08$, CI = [−0.16, 0.01], $p = .08$). Race also impacted strength judgments when analyses controlled for objective strength. Black men were rated as stronger than White men ($\beta = 0.35$, CI = [0.15, 0.55], $p < .01$). Asian men were also rated as weaker	

				than White men (β = −0.42, CI = [−0.64, −0.19], $p < .01$). Taller men were rated as taller (β = 0.38, 95% CI = [0.32, 0.45], $p < .01$). Asian men were rated as shorter than White men (β = −0.31, CI = [−0.48, −0.14] $p < .01$).	
Kordsmeyer, Hunt, Puts, Ostner, and Penke (2018).	The relative importance of intra-and intersexual selection on human male sexually dimorphic traits.	157 German heterosexual males (age range: 18-34, M = 24.2 years). 3-D body and face scans were taken along with handgrip and upper body strength, height, and weight measurements. T-levels were taken at several intervals. Participants were video recorded talking about their personal strengths for one minute. Participants self-reported personality traits and sexual history was reported.	Videos were rated for dominance levels by 80 men (M = 24.1 years, SD = 6.1 years) by asking raters "*how likely is it this man would win a physical fight with another man?"* on scales of +5 (extremely likely) to -5 (extremely unlikely). 44 participants (21 women, M = 22.9 years, SD = 5.7 years) were	Male-male competition exerted a linear directional force favouring increased upper body strength (β = .09) and body size (β = .10). There was a negative correlational selection between physical strength and body height (γ = -.08), and positive correlational selection between physical strength and F0 (γ = .07). Canonical regression analysis of γ revealed two eigenvectors with significant nonlinear sexual selection.	These data may be interpreted as male-male competition having a stronger role on men's traits than female selection, particularly with regard to physical strength and size, but not height.

			recruited to rate the 3D body scans on perceived dominance levels assessed as above. 60 non-German speaking participants (30 women, M = 19.7 years, SD = 4.0 years) were recruited to rate the dominance of the voice recording as assessed above. 23 participants (11 men, M = 27.3 years, SD = 8.8 years) rated the dominance of the facial images as assessed above.	The first eigenvector was heavily positively weighted by height (.85) and heavily negatively weighted by physical strength (M =-.51). Given the negative non-linearity of selection (Θi = -.08* / λi = .17*), this shows strong preference for lower height and higher strength. The second eigenvector of nonlinear selection was heavily negatively weighted by body size (M = -.82). again, given the negative non-linearity (Θi = -.02 / λi = -.19*), shows preference for high body size. Finally, there was a third, positive linear selection eigenvector (Θi = .10* / λi = -.05), that selected for increased body size (M = .49), physical strength (M = .50), and decreased baseline T (M = -.48).	

				Together, the authors suggest a male-male competition can be visualised as a multivariate ‘saddle’ shaped plane on account of the combination of both positive and negative eigenvectors.	
Kordsmeyer, Freund, Vugt, and Penke (2019).	Honest signals of status: Facial and bodily dominance are related to success in physical but not nonphysical competition.	125 straight men (M = 24.1 years, SD = 3.3. years) with no hormonal disorders had two photos taken of their faces with neutral expression, along with 3-D body scans. The men then recorded a video answering the following question: “*What do you think, right now, is great about yourself?*” for one minute. Participants self-reported personality scales related to dominance and competitiveness. T-samples and cortisol measures were taken before and after a competition which included table football, a snatching game, arm	11 male raters (M = 29.6 years, SD = 10.2 years) rated the target photos for dominance as described above. 20 male raters (M = 23.1 years, SD = 3.1 years) rated the body scans for dominance as described above. Videos were rated by 400 women (M = 23.7 years, SD = 4.8 years) for dominance and competitiveness	A number of measures correlated significantly with winning the arm wrestling competition: observer rated facial dominance (r = .23, p < .05), observer related bodily physical dominance (r = .24, p < .05), physical strength (r = .32, p < .01), upper body strength (r = .32, p < .01), hand-grip (r = .22, p < .05), and self-reported trait dominance (r = .20, p < .05). There were no significant correlations with winning the overall competition. Physical strength significantly mediated both facial (β = .32, p < .01) and bodily rated dominance (β = .32, p < .01)	Mens perceived facial and bodily dominance predicts winning an arm wrestling content, but not non-physical competitions, and this is mediated by physical strength. These result support the role of face/body dominance as signals for behavioural dominance and fighting ability.

		wrestling, and a verbal fluency task.	on a scale of 1-5 where 1 is not at all and 5 is completely. Up to two informants completed the same personality scales for each participant (either friend or family member).	with winning the arm wrestling competition. There was no mediation effect of T reactivity, self/observer rated state dominance or competitiveness.	
Kordsmeyer, Stern and Penke (2019).	3D anthropometric assessment and perception of male body morphology in relation to physical strength.	165 German heterosexual men had the following measurements taken: mid-neck girth, waist girth, bust-chest girth, hip girth, upper-arm girth, forearm girth, thigh girth, ankle girth, calf girth, inside-leg-ankle girth, and shoulder width. Waist-to-hip ratio, shoulder-to-hip ratio, waist-to-chest ratio, chest-to-hip ratio, and leg length-to-height ratios were calculated. An aggregate indicator of upper body size was calculated by averaging *z*-	121 raters (61 male, M = 25.1 years, SD = 6.1 years) viewed the morphological models on either a 24" monitor or true-to-size projection on a white wall for 1 second each to familiarise raters, and then presented randomly. Raters were asked "*how*	A linear regression model predicting perceived strength was significant ($F(5, 146) = 56.61$, $p < .001$, $R^2_{adj} = .65$), with height ($\beta = -.22$, $t = -4.17$, $p < .01$) and waist-to-hip ratio ($\beta = -.51$, $t = -9.15$, $p < .01$) having a negative effect on perceived strength, and chest-to-hip ratio ($\beta = .50$, $t = 8.83$, $p < .01$), upper arm girth ($\beta = .47$, $t = 8.55$, $p < .01$), and body density ($\beta = .23$, $t = 4.40$, $p < .01$) all having significant positive effects on perceived strength.	Men's physical strength can be assessed when viewing 3D models, and certain body measurements predict both perceived and objective strength

		standardised shoulder width, bust-chest girth, and upper-arm girth. Total body volume and density were calculated. Physical strength was calculated using handgrip and upper body strength. Height and weight were also measured and used to calculate BMI. Body scans were used to create morphological models of each participant, free from skin texture and colour.	*physically strong is this man?*", on a scale from -5 (very weak) to +5 (very strong).	A linear regression predicting objective strength was significant ($F(5, 146) = 9.05$, $p < .01$, $R^2_{adj} = .21$), with no significant negative effects, and height (β = .19, $t = 2.44$, $p = .02$), upper arm girth (β = .30, $t = 3.63$, $p < .01$), and body density (β = .20, $t = 2.58$, $p = .01$) all having significant positive effects on objective strength. Mediation analyses on the association between perceived and objective strength found height (indirect effect = - .10, $p = .04$) and ankle girth (indirect effect = -.10, $p = .04$) to have significant negative indirect effects on the relationship, while upper arm girth (indirect effect = .25, $p < .01$), forearm girth (indirect effect = .25, $p < .01$), CHR (indirect effect = .13, $p = .02$), upper body size (indirect effect = .14, $p = .03$), and body density (indirect effect = .15, $p < .01$) all had	

				significant positive effects on the relationship between perceived and objective strength.	
Lefevre and Lewis (2014).	Perceiving aggression from facial structure: further evidence for a positive association with facial width–to–height ratio and masculinity, but not for moderation by self–reported dominance.	Study 1: 12 individual composite faces were created by combining three images of Caucasian men. These were then transformed in shape to be ±25%, ±37.5% and ±50% of the shape difference between low and high fWHR prototypes seen in a previous study, creating 72 composites (12 (composite starting face) x 3 (transform level) x 2 (prototype set). Each of the 12 composite faces were also transformed for sexual dimorphism, using the average shape difference between a male and female face.	Study 1: 102 participants (34 men, M = 25.91 years) were randomly allocated to one of the three transform level conditions and presented 24 fWHR image pairs and 12 sexual dimorphism pairs. Participants were asked '*If you were engaged in a physical fight with a same-sex peer, you would probably win!*' and rated the statement on a 1-10 scale on agree/disagree	Study 1: Participants chose the higher fWHR face as more aggressive in 58.3% of the trials and this was significantly above chance ($t(101) = 4.06$, $p < .01$). Similarly, for sexual dimorphism, participants chose the masculine face as more aggressive ($t(101) = 6.27$, $p < .01$). Results indicated that in both the 25% and 50% transform level conditions, the wider face was chosen as more aggressive significantly above chance (25%: $t(34) = 3.30$, $p = .02$; 50%: $t(28) = 3.00$, $p = .06$), however there was no significant difference in the 37.5% condition. Self-reported physical dominance was not associated with choosing the	Both male and female faces with increased fWHR and facial masculinity are perceived as more aggressive

			and gave self-rated dominance.	higher fWHR as more aggressive, however it did correlate with choosing the masculine face as most aggressive (r_s = -.36, p = .04), suggesting that more physically dominant men were less likely to use facial masculinity as a cue of aggressiveness.	
		Study 2: Stimuli were created in identical fashion to Study 1. The same 12 men were used, at two transform levels: 37.5% and 50% in both the fWHR and the sexual dimorphism transform. 15 women composite faces were created by combining three women identities each, which were transformed along the sexual dimorphism as well as the fWHR axis. For the fWHR axis, high and low fWHR prototypes were created.	Study 2: 258 participants (190 women, M = 24.1 years) were presented 12 male and 15 female fWHR image pairs as well as 12 male and 15 female sexual dimorphism image pairs and were asked to '*choose the person you think would react more aggressively if provoked*' and	Study 2: For each of the four stimuli types (male fWHR, male sexual dimorphism, female fWHR and female sexual dimorphism), the mean level of perceiving the high fWHR or highly masculine face as more aggressive increased in the 50% compared with the 37.5% condition. This increase was significant for male fWHR and female masculinity (t(258) = 2.12, p = .04, t(258) = 3.41, p = .01 respectively). In all four conditions and across both transform levels, participants chose the high fWHR or high masculinity face more often as	

			gave self-rated dominance.	the more aggressive face than would be expected by chance (all *p* < .01). In men, sexual dimorphism was more readily used in aggression detection (*t*(259) = 1.99, *p* = .05), whereas in women, fWHR was a significantly better cue (*t*(259) = 4.91, *p* < .01). When investigating the frequencies of choosing the high level face in each condition, results differed between sexes: high fWHR was chosen significantly more frequently in female than in male faces (*t*(259) = 4.67, *p* < .01), whereas high masculinity was chosen significantly more frequently in the male face (*t*(259) = 2.74, *p* = .01).	
Little, Třebický, Havlíček, Roberts, and Kleisner (2015).	Human perception of fighting ability: facial cues predict winners and losers in	228 MMA fighters' facial photographs were split into pairs of fighter and opponent. 3 groupings were created based on weight: lightweight,	Independent groups viewed sets of the facial photographs and were asked out of the photographs	MMA fighters perceived as being more likely to win a fight, did actually win more fights, (Z = 2.35, *p* = .02). Ratings of masculinity also predicted winning a match (Z	Individuals performed at rates above chance in correctly selecting the winner of MMA fights as more

	mixed martial arts fights.	middleweight, and heavyweight,	presented, who would win in a physical fight (N = 69, men = 32, M = 29.7 years), who is more masculine (N = 33, men = 11, M = 25.6 years), who is stronger (N = 30, men = 10, , M = 30.3 years), and who is more aggressive (N = 30, men = 12, M = 27.4 years)	= 2.00, p = .04), as did strength (Z = 2.00, $p < .05$) and aggressiveness (Z = 2.57, $p = .01$), with higher ratings resulting in more wins. One-sample t-tests indicated that winners were chosen significantly more often than losers by participants when asked who they thought would win in a fight ($t(113) = 2.36$, $p = .02$, $d = .44$), when asked who was more masculine ($t(113) = 2.17$, $p = .03$, $d = 0.4$), and when asked who was more aggressive ($t(113) = 2.74$, $p < .01$, $d = .52$).	likely to win the fight than the loser. It was also found that winners were seen to be more masculine, stronger, and more aggressive than losers.
Mannes (2013).	Shorn scalps and perceptions of male dominance.	Study 1: 25 men from a US university had facial photographs taken, 10 with shaved heads, 15 with hair.	Study 1: 59 students (24 men, M = 20.4 years) viewed the facial photographs and rated them on "*How powerful, influential and authoritative does this man look?*" on a 1-7 scale (1	Study 1: Men with no hair were rated as significantly more dominant than those with: $t(21) = 2.30$, $p = .03$.	Men were consistently rated as higher on dominance, confidence, masculinity, strength and norm violation when they had a shaved head compared to men with hair.

			= not at all, 7 = very)		There was a direct effect of shaving on dominance, mediated by masculinity and confidence in study two, but this was not found in study three.
		Study 2: Photographs of 4 men rated in study 1 were chosen for study 2. They were all white with medium length hair. These 4 photographs were altered to remove their hair, resulting in a total of 8 photos, 4 with hair and 4 without.	Study 2: 344 participants (167 females, M = 38.7 years) rated one of the eight facial photographs on dominance, confidence, norm violation, masculinity, age, height, and strength on a 1-9 scale (no scale points given).	Study 2: Hair manipulation significantly affected the ratings: *F*(9, 339) = 10.08, *p* < .01.Ratings of dominance (*t*(343) = 3.78, *p* < .01, *d* = 0.41) , confidence (*t*(343) = 2.02, *p* = .04, *d* = 0.22), masculinity (*t*(343) = 3.34, *p* < .01, *d* = 0.36), age (*t*(343) = 5.33, *p* < .01, *d* = 0.58), height (*t*(343) = 4.09, *p* < . 01, *d* = 0.44), and strength (*t*(343) = 4.24, *p* < .01, *d* = 0.46) were all significantly higher for men with digitally shaved head than with hair. A mediation analysis suggested that the unstandardised effect of the shaving manipulation on perceptions of dominance was significant and positive: *c* = 0.67, *SE* = 0.17, 95% CI [0.34, 0.99]. 42% of this effect is down to the indirect effect of	

				hair on perceptions of masculinity: a_1b_1 = 0.28, *SE* = 0.08, 95% CI [0.14, 0.48]. Shaving increased perceived masculinity: a_1 = 0.68, *SE* = 0.14, 95% CI [0.40, 0.96], which then increased perceived dominance: b_1 = 0.42, *SE* = 0.06, 95% CI [0.29, 0.54]. The direct effect of the shaving manipulation on perceived dominance was positive and significant: c^1 = 0.32, *SE* = 0.15, 95% CI [0.02, 0.61].	
		Study 3: A scenario used to describe a male was used, (all descriptions were the same except the mans hairstyle).This was: "John is a white, non-Hispanic male, 35 years of age. He works in the health care sector and has a basic college education. He lives in the mid-west United States. He is 5' 9"	Study 3: 552 participants (279 female, M = 44.1 years). They were presented with a description of a man. They were then asked to rate him on dominance, confidence, norm violation, and strength on a 9 point scale (no	Study 3: The man in the scenario was viewed least favourably on all attributes except for norm violation when described with thinning hair. Furthermore, he was rated the highest in dominance, masculinity, norm violation, and strength when described with a shaved head. There were significant differences in the ratings of John when described with a shaved head versus thinning hair: *F*(5, 549)	

		tall, weighs 180 pounds, and has [a shaved head/thinning brown hair/thick brown hair]".	scale points given).	= 4.42, $p < .01$). Specifically for dominance ($p = .02$), masculinity ($p < .01$), leadership ($p = .03$), and strength ($p < .01$ (), The unstandardised effect of the man having a shaved head compared to thick hair on dominance was positive and significant: $c = 0.26$, $SE = 0.14$, 95% CI [0.01, 0.54]. Only the indirect effect of masculinity was significant: $a_1b_1 = 0.04$, $SE = 0.03$, 95% CI [0.00, 0.12]. He was perceived as more masculine with a shaved head $a_1 = 0.23$, $SE = 0.12$, 95% CI [0.00, 0.47], which then lead to an increase in perceived dominance: $b_1 = 0.19$, $SE = 0.07$, 95% CI [0.06, 0.32]. As the other mediatiors were not significant, the remaining direct effect of hairstyle on dominance was not significant: $c^1 = 0.15$, $SE = 0.14$, 95% CI [-0.11, 0.43].	

McCarty, Hönekopp, Neave, Caplan, and Fink (2013).	Male body movements as possible cues to physical strength: a biomechanical analysis.	30 men (aged 19–37 years, M = 23.6 years) had their motion recorded during dance movements for 30 seconds. Upper-body strength and fitness levels were measured.	27 women (aged 17–18 years) and 21 men (aged 20–33 years) rated the motion on dance quality on a 1-7 scale (from 1 = extremely bad dancer to 7 = extremely good dancer).	There were significant positive correlations between male and female perceptions of dance quality and the dancer's handgrip strength ($r = 0.47$, $p < .01$, $r = 0.38$, $p < .05$ respectively).	Stronger men were perceived as being better dancers, suggesting that cues of strength can be observed from body movements.
Pisanski, Fraccaro, Tigue, O'Connor, and Feinberg (2014).	Return to Oz: Voice pitch facilitates assessments of men's body size	Study 1: 30 men (M = 19 years) had their voices recorded and height measured. Vocal recordings were of the English vowels in a normal and whispered tone.	Study 1: On each trial, 77 women listeners (M_{age} = 18.8 years) were presented with two men's voices of the same speech type: modal, whispered, modal SWS (sine-wave speech, i.e. synthesised, abiological speech devoid of pitch) or	Study 1: Participants preformed above chance in assessments of size from the voiced ($t(76) = 7.69$, $p < .01$) whispered speech, ($t(76) = 2.66$, $p < .01$), voiced SWS, ($t(76) = 2.05$, $p = .044$; and whispered SWS, ($t(76) = 3.24$, $p = .02$). Accuracy was higher for natural voices compared to SWS voices ($F(1,73) = 6.38$, $p = .01$) and for voiced than for whispered speech among natural but not among	Individuals are able to accurately assess physical size from vocal cues and artificially altering pitch does not affect accuracy

			whispered SWS and were asked to select which of the two voices belonged to the taller man.	synthesised voices, (*F*(1,73) = 6.63, *p* = .01). Listeners' accuracy was significantly better for voiced than all other types of voices: whispered (*t*(76) = 2.89, *p* < .01), modal SWS (*t*(76) = 3.7, *p* = .01) and whispered SWS: (*t*(76) = 3.07, *p* < .01).	
		Study 2: 5 modal and 5 whispered from the same 5 men were randomly drawn from the pool of speech stimuli used in Study 1 for Study 2. The formant component of men's modal and whispered speech was raised or lowered by 10% from baseline. They paired raised formant with lowered-formant speech stimuli within vocalizers and within each speech type resulting in a total of 10 voice pairs (5 modal-modal and 5 whispered-whispered). This resulted in both voice stimuli within a pair having originated from the same man, where the only difference between the	Study 2: 40 women (M = 19.38 years) and 18 men (M = 21.17 years) were presented with a single pair of voices (raised-formant vs. lowered-formant) and selected which of the two voices belonged to the taller man.	Study 2: For both modal and whispered speech, listeners associated relatively lower formants with larger body size on approximately three quarters of all trials, and significantly above chance (one-sample binomial tests vs. 0.5, *n* =58, *p* < .01).	

		stimuli was in their formants (raised vs. lowered).			
		Study 3: The 60 modal speech stimulus pairs used in study 3 were identical to those used in study 1, except the F0 was manipulated in a different manner. The voice F0 of all speech stimuli was either raised or lowered by adding or subtracting 0.5 equivalent rectangular bandwidth of the baseline F0 for speech stimuli used in the raised-pitch and lowered-pitch conditions, respectively.	Study 3: 120 women were randomly assigned to a raised-pitch (n = 60, M = 20 years) or lowered-pitch condition (n = 60, M = 19 years) listened to all 60 pairs of stimuli and asked to select which of the two voices on each trial belonged to the taller man.	Study 3: Listeners performed significantly better in the lowered-pitch condition where harmonics were denser than in the raised-pitch condition where harmonics were sparser ($F(1,118) = 4.89$, $p = .03$, $d = .41$).	
Pisanski, Oleszkiewicz, and Sorokowska (2016)	Can blind persons accurately assess body size from the voice?	30 men had their voices recorded speaking the English vowels twice. Height was also recorded.	91 adults (50 men) which included 28 congenitally or early blind (aged 24–65, M = 38.2 years), 40 late blind adults (aged	Mean accuracy of body size assessments significantly exceeded chance for sighted ($p = .01$), late blind ($p < .01$) and congenitally or early blind participants ($p = .04$).	Early blind, late blind, and sighted participants were all better than chance at accurately assessing who was a larger man.

			23–65, M = 48.7 years), and 23 sighted adults (aged 20–65, M = 39.2 years) rated one of four groups of voice stimuli. They were presented with two voices and asked to select which was the larger man.		This suggests that physical size can be portrayed via vocal displays and listeners of these can use them as reliable cues.
Pisanski, Isenstein, Montano, O'Connor, and Feinberg (2017).	Low is large: spatial location and pitch interact in voice-based body size estimation.	Study 1: 10 participants (5 males, M = 18 years) had their voices recorded speaking the English vowels. The pitch was then altered to high and low pitch, giving each participants two vocal recordings each.	Study 1: 46 women (M = 19.5 years) were asked "*how large is this person?*" on a 1-7 scale (1 = very small, 7 = very large). Recordings were played from different speakers in the room, once from low and high speakers and once from left and right speakers.	Study 1: lowered-pitch voices were judged as larger than raised-pitch voices ($F(1, 45) = 414.9$, $p < .01$), and men's voices were judged as physically larger than women's voices ($F(1, 45) = 76.5$, $p < .01$). Voices projected from different speakers around the room. Voices projected from the low and right sound speakers were judged as larger than voices projected from the high and left sound speakers ($F(1, 45) = 9.8$, $p < .01$).	Individuals with lower pitched voices were perceived as physically larger than those with higher pitches and men's voices are seen as larger than women's. Perceptions of size can alter depending on where the sound is coming from and if the listener

		Study 2: The same stimuli in study 1 was used.	Study 2: 48 females (M = 18.6 years) and 18 males (M = 18.7 years) listened to the stimuli in either a seated or standing position and asked "*how large is this person?*" on a 1-7 scale (1 = very small, 7 = very large).	Study 2: Voices lowered in pitch were rated as larger than voices raised in pitch ($F(1, 52) = 178.49$, $p < .001$), and men's voices were rated as physically larger than women's voices ($F(1, 52) = 145.38$, $p < .01$). Voices were generally rated as larger when participants were standing than when they were sitting ($F(1, 52) = 4.9$, $p = .03$).	is sitting or standing, as voices from low and right sound speakers were judged as larger and voices were rated as larger when the listener was standing opposed to sitting.
Pisanski, K., Mishra, S., & Rendall, D. (2012)	The evolved psychology of voice: evaluating interrelationships in listeners' assessments of the size, masculinity, and attractiveness of unseen speakers.	20 speakers (10 men and 10 women) were used from a previous study. Fundamental frequency (F0 or pitch) and the frequency of the first four formants (F1–F4) were obtained. Vocal recordings were manipulated four times, where F0 and FN were modified.	68 students (36 men, no mean age given) rated the vocal recordings on body size and masculinity on a 1-6 scale. Each participant rated 10 different speakers of the opposite sex for all five of the	There was a significant association between size and masculinity: male voices were rated by women as sounding larger and being more masculine (natural voice stimuli: $r^2 = 0.08$; manipulated voice stimuli: $r^2 = 0.50$). A PCA showed that women's ratings of the body size and masculinity of men were both weighted heavily and in the same direction on a	Males whose voices are perceived as masculine are also perceived to be physically larger.

			manipulated recordings.	component with an Eigenvalue of 1.80 (factor loadings of −0.87 and −0.89, respectively) that encompassed nearly 80% of the variation in both dimensions.	
Pisanski and Rendall (2011).	The prioritization of voice fundamental frequency or formants in listeners' assessments of speaker size, masculinity, and attractiveness.	Study 1: Using a Canadian database of the vocal recordings of 57 males and 57 females saying single syllable words, four voices (two male, two female) were chosen whose natural voice F0 and Fn values were either relatively low or relatively high for their sex. Alongside this, a further four voices (two male, two female) whose voices were all around the mean F0 and Fn in the sample were chosen to be digitally manipulated either by raising or lowering F0 by 20% while holding Fn constant, and either raising or lowering all formants by 10% while holding F0 constant. This resulted in	Study 1: 61 participants (30 men) listened to five vocal stimuli from eight different speakers and three different biosocial dimensions, totalling 120 trials, and were asked to rate the voices on either size, masculinity, or attractiveness on a six point scale (where 1 represents small/feminine/unattractive, and 6 represents	Study 1: Both men and women speakers with naturally low voices were rated as larger (men: $F(1, 59) = 39.56$, $p < .01$; women: $F(1, 59) = 72.89$, $p < .01$), and more masculine (men: $F(1, 59) = 130.19$, $p < .01$; women: $F(1, 59) = 267.88$, $p < .01$) than speakers with naturally high voices. The speakers whose F0 were manipulated to be lower were also rated as being larger (men: $F(1, 59) = 53.48$, $p < .01$; women: $F(1, 59) = 18.86$, $p < .01$), and more masculine: men: $F(1, 59) = 233.8$, $p < .01$; women: $F(1, 59) = 246.38$, $p < .01$) compared to speakers	Participants consistently rated lower voices as belonging to larger and more masculine, whether the voice was natural or manipulated.

		five voice stimuli for each of the eight speakers. Raters: 31 female and 30 male heterosexual undergraduates. Their task was to rate each voice on one of the three dimensions (either size or masculinity/femininity or attractiveness) using a six-point scale.	large/masculine/attractive).	whose *F*0 had been manipulated to be higher. Lowering speakers *F*n were also rated as larger (men: $F(1, 59) = 158.92$, $p < .01$; women: $F(1, 59) = 193.75$, $p < .01$), and more masculine (men: $F(1, 59) = 180.43$, $p < .01$; women: $F(1, 59) = 120.14$, $p < .01$) than speakers with *F*n manipulated to be higher.	
		Study 2: In this study, experimental voice stimuli were created to mimic natural speakers whose F0 and Fn features provided conflicting cues to size, masculinity, and attractiveness because they combined relatively low F0 with relatively high Fn (or vice versa).	Study 2: participants were assigned randomly to one of four testing groups that involved making frequency discriminations in either F0 or in Fn and in the voices of one or the	Study 2: There were no results in this study relevant to intra sexual selection, however briefly, using a series of ANOVAs, the authors outline that there was no differences between raters on their ability to discriminate. Also, discrimination of frequency-differences in F0 and Fn improved steadily as the magnitude of the	

		However, the level of agreement between the two voice features must not be biased in favour of one or the other as might occur if the differences in one feature were simply more easily discriminated than the other. Therefore, a preliminary step was to establish discrimination thresholds for frequency-differences in F0 and Fn. From the original database (see above), From this database, eight new speakers (four males, four females) were selected and an identical set of four words was used for each one. Experimental stimuli involved a pairing of two sets of the same four bVt words (boat, beat, book, and bait) spoken by the same individual. Each stimulus contained the original, unmanipulated recording (baseline condition) of the four-word set by a given	other of two sets of four speakers (each containing two male and two female speakers). Participants were presented pairs of voices and simply asked if they were the same or different.	frequency-difference between the baseline and test voice stimulus increased from 1% to 10%.	

		speaker followed by a repetition of the same word set by the same speaker but with either F0 or Fn increased by 1%–10% relative to that speaker's mean baseline values. Thirty seven female and 25 male undergraduates were recruited as raters in this 2 alternative forced choice paradigm (2AFC).			
		Study 3: The aim of this study was to establish what weight listeners put on F0 and Fn when making judgements on size, masculinity and attractiveness. This was done by creating experimental stimuli that put the two voice features in direct conflict with one another by amounts that were equally perceptually discriminable as per study 2's 2AFC.	Study 3: 68 participants (36 men) rated voices for masculinity, size, and attractiveness. The voices contained natural voices speaking four words, then four manipulations of the same four words, increasing or decreasing *F*0 and *F*n.	Study 3: For female listeners rating male speakers, there were significant main effects of experimental frequency condition ($F(4,120) = 160.6$, $p < .001$) and rating dimension ($F(2,60) = 90.17$, $p < .001$) as well as a significant interaction between the two ($F(8,240) = 85.76$, $p < .001$). Post-hoc analyses showed that females' ratings of all three dimensions were significantly greater for the voice conditions where Fn was	

		Thirty-two female and 36 male undergraduates took part as listeners.		lowered while F0 was raised by two or three JND's compared to the corresponding voice conditions where F0 was lowered and Fn was raised. For male listeners rating female speakers, there were significant main effects of experimental frequency condition (F(4,136) = 46.72, p < .001), rating dimension (F(2,68) = 6.72, p = .002), and a significant interaction between the two (F(8,272) = 112.72, < .001). Post-hoc analyses showed that males' ratings of size and masculinity were significantly greater for the voice conditions where Fn was lowered while F0 was raised either by two or three JND's compared to the corresponding voice conditions where F0 was lowered and Fn was raised.	

Puts, Apicella, and Cárdenas(2012).	Masculine voices signal men's threat potential in forager and industrial societies.	Study 1: US sample 176 men (M = 20.1 years) and 268 women (M = 20.4 years) had their voice recorded reading the rainbow passage. Bicep circumferences, height, and weight were measured, and hand grip strength was taken. Saliva was collected for testosterone levels. The Buss and Perry Aggression Questionnaire was used to measure aggression.	Study 1: US sample Vocal recordings were analysed and F0, F0-sd (fundamental frequency SD) and F1-F4.	Study 1: All acoustic parameters were strongly sexually dimorphic with Cohen's *d* ranging from 2.7 to 5.7 for all measures. In the regression model for mean F0 (*F*(7,167) = 15.99, *p* < .01), testosterone (*t(329)* = -2.87, β = -0.17, *p* = .05), height (f = -2.46, β = -0.16, *p* = .02) and F0 – s.d. (*t* = 9.51, β = 0.60, *p* < .01) were significant predictors. In zero-order correlations, mean F0 was significantly negatively related to height (*r*(175) = -0.17, *p* = .03) and testosterone (*r*(175) = - 0.15, *p* = .04), although these correlations were not significant after Bonferroni corrections. Physical aggression (*t(329)* = -3.40, β = -0.20, *p* < .01) and mean F0 (*t(329)* = 9.67, β = 0.58, *p* < .01) significantly predicted F0 - s.d. in the regression model for this parameter (F(2,173) =	All acoustic parameters measured in the study were related to at least one measure of male threat potential, suggesting that individuals can display their threat potential in vocal cues.

				53.90, *p* < .01). In zero- order correlations, F0 - s.d. was significantly negatively correlated with physical aggression (*r*(175) = -0.23, *p* = .03). Height (*t* = - 2.11, β = - 0.17, *p* = .04) significantly predicted Pf in the final model: *F*(7,167) = 4.22, *p* < .01). In zero-order correlations, Pf was significantly negatively correlated with height (*r*(175) = -0.24, *p* < .01), weight (*r*(175) = - 0.23, *p* = .02), physical aggressiveness (*r*(175) = -0.19, *p* < .01), and arm strength (*r*(175) = -0.26, *p* < .01).	
		Study 2: Hadza sample 32 Hadza men (aged 19-40, M = 29.6 years) and 43 Hadza women (aged 18-39, M = 28.9 years) had vocal recordings taken of them saying 'hujambo' (which loosely translates to 'hello' in English) and had height,	Study 2: Hadza sample Vocal recordings were analysed in the same manner as study 1.	Study 2: Hadza sample All acoustic parameters were strongly sexually dimorphic with Cohen's *d* ranging from 1.5 to 4.4 for all measures. Measures of threat potential (height, weight and arm strength), along with acoustic parameters as control	

		handgrip strength, and physical measurements taken		variables, were entered simultaneously into separate multiple regressions. In the regression model for mean F0 (F(5,25) = 8.38, p = .01), height (t = -2.39, β = 20.66, p = .03), weight (t = 2.53, β = 0.94, p = .02), arm strength (t = -2.16, β = 20.47, p = .04) and F0 - s.d. (t = 5.09, β = 0.64, p < .01) were significant predictors.	
Puts, Gaulin, and Verdolini (2006).	Dominance and the evolution of sexual dimorphism in human voice pitch.	111 heterosexual male participants (M = 18.9 years) had voice recordings of the Rainbow Passage taken. They were then told that he would be competing with a man for a lunch date with a woman. A recording of his response explaining why he might be respected or admired by the other man was collected (a competitive recording). They were asked to rate their own physical dominance on a 6 point scale. They also rated their competitors physical dominance.	Eighty-six heterosexual male participants (M = 20 years) rated the vocal recordings on physical dominance on a 0-100 line scale. Participants listened to 30 recordings of 30 or 31 competitive recordings.	There was no significant correlation between vocal pitch and dominance on the unmodified competitive recordings. A multifactor repeated-measures ANOVA revealed a significant main effect of pitch manipulation on dominance ratings (F(1,110) = 128.53, p < .01). Lowered pitch recordings received significantly higher physical scores than the same recordings raised in pitch (t(110) = 12.40, p < .01).	Masculine, low pitched voices increase ratings of physical dominance, and men who believed that they are more physically dominant than a potential opponent lower their vocal pitch when addressing them, whereas those who believe that they were lower in physical

		Average F0 was measured for each baseline and competitive vocal recording. These were then altered in pitch (one semitone lower, one semitone higher), giving each participant three vocal recordings.		The competition condition produced no significant overall change in voice pitch from baseline to competitive. However, individual F0 changes varied significantly with participants' perceptions of their relative physical dominance ($r_s(111) = -.27$, $p < .01$). Participants who rated themselves as more physically dominant than their competitor lowered their F0 when speaking to him (mean change = 2.08 Hz), whereas participants who rated themselves as less physically dominant on average raised their F0 when speaking to their competitor (mean change = + 1.94Hz). This difference was statistically significant ($t(77) = 2.55$, p =.01).	dominance raise their vocal tone
Puts, Hodges, Cá rdenas and Gaulin(2007) .	Men's voices as dominance signals: vocal fundamental and formant	Only study 3 is relevant here as the other 2 describe experiments that help develop stimuli for it.	Forty-two male participants rated 30 vocal recordings on how likely they	Three factors, each with two levels, were analysed: manipulation (raised vs. lowered), acoustic measure	Lowered voices were perceived as being produced by more physically dominance men.

	frequencies influence dominance attributions among men.	The authors manipulated 30 voice recordings from a previous dating game study where men spoke to a male competitor. Both F0 and Df were raised and lowered independently by 1.5 JND. Five versions were produced for each voice: unmanipulated, raised F0, lowered F0, raised Df, and lowered Df. The recordings were grouped into sets so that no participant heard two versions of the same voice forty-two men rated 30 voices on whether each speaker was likely to be able to win physical fights and whether he was likely to be a respected leader using a 10-point scale with strongly agree/disagree anchor points. For physical dominance, the question posed was "if this	would be to win a fight on a 1-10 scale (1= strongly disagree, 10 = strongly agree). Social dominance was also measured.	(F0 vs. Df), and dominance type (physical vs. social). In a Manipulation×Dominance Type repeated measures ANOVA, both F0 and Df negatively affected dominance ratings (F0: $F(1, 29) = 6.06$, $p = .02$; Df: $F(1, 29) = 37.40$, $p <.01$). The effect of Df manipulation was greater than the effect of F0 manipulation: Manipulation×Acoustic Measure interaction ($F(1, 29) = 4.32$, $p > .05$). Df negatively affected physical dominance ($F(1,29) = 45.82$, $\eta_p^2 = .61$, $p < .01$) and affected physical dominance ratings more than it affected social dominance ratings ($F(1, 29) = 7.92$, $p = .01$). F0 manipulation tended to affect physical dominance ratings ($F(1, 29) = 7.66$, $p = .01$) more than it affected social dominance ratings ($F(1, 29) = 1.89$, p = .18), but this interaction was not statistically significant ($F(1, 29) = 0.92$, $p = .35$).	

		man got in a fistfight with an average male undergraduate student, this man would probably win". For social dominance, a definition was given: "a dominant person tells other people what to do, is respected, influential, and often a leader; whereas submissive people are not influential or assertive and are usually directed by others."			
Raine, Pisanski, Bond, Simner, and Reby (2019).	Human roars communicate upper-body strength more effectively than do screams or aggressive and distressed speech	Study 1: 61 participants (30 men, M = 22.79 years) had vocal recordings taken. In the aggressive context, they were instructed to imagine themselves in a battle or war scenario and were instructed to say: '*That's enough, I'm coming for you!*', and then a nonverbal vocalisation expressing the same motivation. In the distress context, participants were asked to imagine that they were now in a position of weakness, with an attacker charging at them, and say:	Study 1: Multiple acoustic analysis were ran on the vocal recordings.	Study1: All four vocal conditions (roars, screams, aggressive speech, distress speech) were acoustically distinct from each other. Dominant formant frequency was negatively associated with strength for female vocalizers in aggressive speech (-.47), aggressive roars (-.47) and distressed speech (-.32).	Participants accurately judged differences in strength and did so most effectively from aggressive voice stimuli (roars and aggressive speech). Furthermore, listeners more accurately judged strength from roars than from aggressive speech. However, listeners'

		‘*Please, show mercy, don’t hurt me!*’, and an analogous nonverbal vocalisation. Height and strength were measured.			judgments of height were most accurate for speech stimuli.
		Study 2: vocal recordings from study 1 were used.	Study 2: 90 participants (42 men, M = 33.82 years) rated all 244 voice stimuli acquired in study 1 on perceived strength on a 101 point scale (0 = extremely weak, 100 = extremely strong).	Study 2 and 3: Aggressive speakers were rated as being stronger than distressed speakers ($p < .01$). This difference was significantly larger when listeners rated nonverbal vocalisations than when they rated speech sentences. Men were rated as stronger than women by men listeners judging aggressive roars ($p = .03$) however for all other conditions, females were rated as comparably strong to men, despite the men being physically bigger and stronger than the women. Listeners rated men as taller than women on all stimulus types and contexts ($p < .01$). This sex difference in height	
		Study 3: vocal recordings from study 1 were used.	Study 3: 60 participants (30 men, M = 33.80 years) rated all 244 voice stimuli acquired in study 1 on perceived height on a 101 point scale (0 = extremely short,		

			100 = extremely tall).	ratings was larger for aggressive than distress stimuli ($p < .01$), and for nonverbal vocalizations than for speech sentences ($p = .01$). Women rated aggressive roars produced by women vocalisers as stronger than did male listeners ($p = .03$). Women listeners judged vocalisers as taller than male listeners ($p = .01$), mainly when listening to aggressive roars ($p = .05$). For men, actual strength predicted perceived strength only when listeners rated aggressive stimuli ($p < .01$). For women, listeners could estimate strength from aggressive roars, aggressive speech, and distressed speech, ($p < .01$). For both men and women, the reliability of strength estimation was higher for aggressive roars than for aggressive speech or female distressed speech.	

				For men, actual height predicted rated height when listeners rated distress stimuli but not aggressive stimuli ($p <$ .01). For women, actual height predicted attributed height when listeners rated speech stimuli but not nonverbal vocalisations ($p = .01$).	
Re, Lefevre, DeBruine, Jones, and Perrett (2014).	Impressions of dominance are made relative to others in the visual environment.	Facial photographs of 47 Caucasian men (M = 25.25 years, SD = 4.64 years) and 83 Caucasian women (M = 23.04 years, SD = 3.81 years) were obtained from a commercially available database. Ten men and 10 women face composites were created from these photographs. An average woman's face was created from the 83 faces, and an average man's face was created from the 47 faces. Masculinised and feminised versions of the composites were created.	43 participants (22 women, 21 men; M = 31.00 years) were presented with two faces next to each other, an unmanipulated composite (target) and a masculinized or feminised version of one of the faces (non-target). Participants were always asked to rate the	A 2x2x2x2 ANOVA revealed a main effect of the sex of target face with men being rated as more dominant than women ($F(1,41) = 13.71$, $p < .01$, $\eta_p^2 = 0.25$). A main effect of the sex of non-target face was found, with dominance ratings of the target face being lower when the non-target face was male than female ($F(1,41) = 11.07$, $p < .01$, $\eta_p^2 = 0.21$). There was a main effect of the masculinity of non-target face, with lower dominance ratings	Ratings of physical dominance can be altered when other faces are on display. Masculinised non-target faces decreased the perceived physical dominance of a target face relative to when the non-target face feminine, and displaying a man’s non-target face decreased

			unmanipulated face on physical dominance on a 1-7 scale (1 = extremely submissive, 7 = extremely dominant).	of the target face when the non-target face was masculinized than when it was feminised ($F(1,41) = 18.73$, $p < .01$, $\eta_p^2 = 0.31$). There was a significant three-way interaction between sex of target face, sex of non-target face, and masculinity of non-target face, ($F(1,41) = 8.39$, $p < .01$, $\eta_p^2 = 0.17$). Separate 2x2 ANOVAs (sex of non-target x masculinity of non-target face) for men and women target faces. Both sex of non-target face ($F(1,41) = 10.57$, $p < .01$, $\eta_p^2 = 0.21$) and masculinity of non-target face ($F(1,41) = 6.01$, $p = .02$, $\eta_p^2 = 0.13$) had significant effects on dominance ratings when the target face was female, with target faces being rated as less dominant with male non-target faces and with masculinized versions of non-target faces. Sex of non-target face ($F(1,41) = 9.74$, $p < .01$, $\eta_p^2 =$	perceived dominance of a target face more so than a woman's non-target face. Perceived dominance of a man's target face was affected more by masculinization of a man's non-target faces than a woman's non-target faces.

				0.19) and masculinity of non-target face ($F[1,41] = 18.81$, $p < .01$, $\eta_p^2 = 0.31$) both had significant effects when the target face was male, with target faces being rated as less dominant when paired with male non-target faces and with masculinized versions of non-target faces. There was also a significant interaction between sex of non-target face and masculinity of non-target face when the target face was male, ($F(1,41) = 10.03$, $p < .01$, $\eta_p^2 = 0.20$), with the difference in dominance ratings between masculinised and feminised versions of the non-target face being greater when the non-target face was male than female, ($t(42) = 3.22$, $p < .01$, $d = 0.68$).	
Richardson, Waddington, and Gilman (2021).	Young, formidable men show greater	Study 1: 20 facial photographs of men (aged 18–33, M = 24.24 years) were used from a	Study 1: 81 men (aged 17-72, M = 34.81 years) were	Study 1: Participants correctly selected the masculinised face as appearing more dominant	On average, younger, taller, and stronger men showed greater

	sensitivity to facial cues of dominance.	previous study. These photographs were then modified to make masculine and feminine versions of them.	recruited. Height and bicep circumference were taken from the raters. Participants were shown the pairs of faces (one masculine and one feminine) and asked which one was more physically dominant.	86% of the time on average. There was found to be a main effect of participant age where for each decade of age the odds of selecting the masculinised face as more physically dominant decreased by a factor of 0.75 (95% CIs [0.59–0.96], *p* = .03).	sensitivity to facial cues of dominance. Participants were also more likely to associate younger than older masculinised faces with physical dominance.
		Study 2: Facial photographs of 32 men (aged 20–62, M = 33.53 years) were taken from a different sample to study 1 were used. Photos were manipulated in the same way as in study 1.	Study 2: 93 men between the ages of 18 and 85 (M = 40.93 years) had their grip strength taken using a dynamometer. Participants self-reported their own social dominance and were asked to rate which face was more	Study 2: Participants correctly selected the masculinised face as appearing more dominant 68% of the time on average. The best model contained the participant age and stimulus age with no interaction. The effect of participant age on dominance perceptions was negative (OR = 0.90 per decade of age, 95% CIs [0.82–0.99], *p* = .04), similar to the effect of stimulus age (OR	

			physically dominant when presented with the 32 pairs of photographs from study 1.	= 0.81 per decade of age, 95% CIs [0.74–0.88], *p* < .01). The second-best model (ΔAIC = 0.7) contained participant age and stimulus age, as well as grip strength.	
		Study 3: A randomly selected 30 of the 32 facial photos from study 2 were utilised. Facial photographs were again manipulated on masculinity, however for this study, two sets were created, one transformed from a composite of young men/women and one transformed from a composite of older men/women.	Study 3: 98 men (aged 18-85, M = 39.85 years) had their weight, grip strength, and upper arm circumference taken as well as their social dominance. Participant rated each of the 30 stimulus faces twice: one set younger, one set older.	Study 3: Participant correctly selected the masculinised face as appearing more dominant 61% of the time. The best model included all 3 main effects but no interaction effects. Participant age had a significant negative effect on dominance perception (OR = 0.93 per decade, 95% CIs [0.88–0.99], *p* = .03). The model including participant age and height showed a significant negative effect of age (OR = 0.93 per decade, 95% CIs [0.88–0.99], *p* = .05) on dominance perception.	
Saxton, Mackey,	A lover or a fighter?	6 men aged 19-21 participated in the study 4 times: once	40 participants (20 men, aged	Ratings of dominance were affected by both voice pitch	Lower pitched voices and higher

McCarty and Neave (2016).	Opposing sexual selection pressures on men's vocal pitch and facial hair.	when clean shaven, 5 days after last shave (light stubble), 9-10 days after last shave (heavy stubble), and 4-6 weeks after last shave (beard). Participants were video recorded saying, "*hello, how are you?*" each visit, as well as a final visit where the line was recorded and digitally manipulated (Two men were not available for the final recording session, therefore a recording from one of their original video sessions was manipulated). They were manipulated by raising and lowering the F0 by 25 and 50 Hz, giving each male 4 vocal recordings.	19-53 years) rated the videos on a 1-7 scale on dominance (1 = extremely submissive, 7 = extremely dominant).	($F(1.5, 55.2) = 70.35$, $p < .01$) and facial hair ($F(1.4, 54.0) = 11.98$, $p < .01$), with lower pitches and higher levels of beardedness being rated as more dominant. A repeated measures analysis was conducted with the 4 levels of facial hair and voice pitch as the within-subjects factors, voice pitch ($F(3,15) = 106.34$, $p < .01$), and facial hair ($F(3,15) = 9.94$, $p = .001$) both had a significant effect (lower pitch and higher beardedness) on dominance ratings, with no significant interaction ($F(9,45) = 1.22$, $p = .31$).	levels of beardedness increased ratings of dominance.
Šebesta, Třebický, Fialová, and Havlíček (2019).	Roar of a champion: loudness and voice pitch predict perceived fighting ability but not	40 men, all amateur MMA fighters (aged 19-33, M = 24 years) were categorised into three weight categories (lightweight, middleweight and heavyweight). Height, body weight, handgrip strength, age, and fighting record was recorded and lung capacity for	63 participants (31 men, aged 20-36, M = 27.1 years and 32 women, aged 18-33, M = 24.4 years) were asked to rate all participants' roars	Perceived formidability of utterances was highly correlated between men and women ($r(40) = 0.93$, 95% CI [0.871, 0.963], $p < 0.001$). A paired sample t-test showed a statistically significant sex difference in formidability ratings with men giving higher	Height, weight, and physical fitness did not predict perceived formidability from speech or from the roars. There was also no significant association

	success in MMA fighters.	34 of the participants was gathered. Participants had their voice recorded as they counted from 1-10 and then performed three intimidating roars (only the second roar was used for ratings). Roars were manipulated and analysed.	and utterances on formidability on a 1-7 scale over two sessions (1 = not successful, 7 = very successful when asked if they would win in a fight).	ratings than women ($t(39) = 9.165$, $p < .01$, $d = 1.449$, mean difference = 0.37 No significant relationship was found between formidability perceptions and fighting success. Linear mixed model analyses were run to predict perceived formidability from utterances and roars with F0, F3, HNR (dB), intensity, and duration entered as independent predictors. For utterances, the overall model explained 44.1% of variance, while fixed factors explained 9.6% of variance. F0 and intensity are significant predictors of perceived formidability. In the case of roars, the overall model explained 57% of variance and fixed factors explained 37.5% of variance. Perceived formidability was predicted by the F0, HNR, intensity, and duration	between formidability of the roars and utterances and actual fighting success. Perceived formidability was predicted mainly by roars' and utterances' intensity and roars' harmonics-to-noise ratio and duration. F0 predicted formidability ratings in both roars and utterances in that low F0 utterances but high F0 roars were rated as more formidable.

Sell, Bryant, Cosmides, Tooby, Sznycer, Von Rueden, Krauss, and Gurven (2010).	Adaptations in humans for assessing physical strength from the voice.	Sample 1: 63 males from the University of California (range 18-22 years old, M = 18.7 years) had a strength assessment (handgrip strength, flexed bicep circumference, and a photo rating that was done by 50 participants (18 men) who rated the photographs on a 1-7 scale on strength). Participants were also asked how many physical fights they had engaged in during the previous 4 years and completed the physical aggression subscale of the Buss-Perry Aggression Questionnaire. A vocal recording was taken saying "*this is an experiment, over and out*". Sample 2: 49 male Tsimane Indians (aged 19-68, M = 35.8 years) had vocal recordings taken in their native language stating, "*'Nobi cojiro tsun quin dyem' venchuban aca'yaty anic fer no'bacni tsun*", which	Sample 1: Fifty-three undergraduates (22 women, M = 20.7 years) rated the 63 US male voices on '*how tough he would be in a physical fight'*, physical strength, height, and weight on a 1-7 scale (1 = low on attribute, 7 = high on attribute. Sample 2. Thirty-one undergraduates (10 female, M = 19.7 years) rated the 49 male Tsimane voices on physical strength, height, and weight on a 7-point scale (1 = low on attribute, 7	Average individual estimates of strength from the voice were accurate and highly significant across all six male samples ranging from γ = 0.18 to 31 and this was similar across both familiar and unfamiliar languages. The accuracy was similar in estimates of strength from static facial cues, but lower than estimates from body images. While strength was accurately estimated from women's voices in US and Romanian sample, the effect was only about half as large for men's voices. Within sample 1, perceptions of fighting ability were very strongly correlated to the perceptions of physical strength (*r* = 0.98). Furthermore, the average perceived fighting ability scores were significantly positively correlated with their	Raters were able to gain information about physical strength from the voice, that was not supplied from visual cues. These assessments were accurate with both familiar and unfamiliar languages. Furthermore, the ability to estimate strength in men, is not a by-product of height and weight assessment.

		translates as, "*We will cross the river and then arrive home; it was a tough crossing for us*". Chest, shoulder, and handgrip strength was taken along with bicep circumference. Sample 3: 20 men (aged 15-71, M = 34.8 years) from the villages of Gobernador Sola and Ingeniero Maury in the province of Salta, Argentina had vocal recordings taken saying "*Cuando llueve se inundan las chacras, y la gente junta el maiz y prende fuego*", which translates to, *"When it rains the ranches get flooded, and the people gather the maize and light fires"*. Height, weight, chest strength, and bicep circumference were taken. Sample 4 and 6: 50 men (sample 4: aged 18-31, M = 20.2 years) and 50 women (sample 6: aged 18-22, M = 18.8 years) from the	= high on attribute). Sample 3. Thirty undergraduates (17 female, M = 18.8 years) rated the 20 Andean voices on physical strength, height, and weight on a 7-point scale (1 = low on attribute, 7 = high on attribute). Sample 4. Fifty-four undergraduates (42 female, M = 20.5 years) rated the 50 US male voices on physical strength, height, and weight on a 7-point scale (1 = low on attribute, 7 = high on attribute).	fighting history (r = 0.36, p < .01), and their physical aggression score, (r = 0.49, p < .01). In samples 1 and 4, the strength measurement was recomputed without the photograph rating component. This was conducted in a simultaneous regression analysis using both the average voice rating of strength and the average photograph ratings of strength. The results of the model showed independent contributions from both the photo ratings (sample 1: β = 0.52, p < .01; sample 4: β = 0.50, p < .01) and voice ratings (sample 1: β = 0.25, p = .02; sample 4: β = 0.27, p = .03) on actual strength. In samples 1, 3, 4 and 5, the stimuli participants rated their physical strength relative to other males. Self-reported	

		University of California had vocal recordings of the first sentence of the Rainbow Passage taken. Chest strength, bicep circumference, and photo ratings (24 participants, 12 female, rated body photos as done in first sample of participants) Sample 5 and 7: 44 men (sample 5: aged 20-38, M = 21.7 years,) and 30 women (sample 7: aged 20-29, M = 21.1 years,) students from the University of Timisoara in Romania had their chest and handgrip strength taken, as well as bicep circumference and a vocal recording of them saying "*Iesi si taci*", meaning "*Get out and be quiet*". Sample 8: 54 men (aged 18-23, M = 19.9 years) from the University of California, Santa Barbara had their chest strength taken and bicep measured. Vocal recordings	Sample 5. Twenty undergraduates (12 female, M = 19.1 years) rated the 44 Romanian male voices on physical strength on a 7-point scale (1 = low on attribute, 7 = high on attribute). Sample 6. Forty-seven undergraduates (30 female, M = 20.2 years) rated the 50 US female voices on physical strength, height, and weight on a 7-point scale (1 = low on attribute, 7 = high on attribute). Sample 7. Twenty-one undergraduates	strength did not account for any significant variance in voice ratings when actual strength was in the model (sample 1, actual strength β = 0.47, p = .02, self-reported strength β = 20.083, p = .57. Sample 3, actual strength β = 0.47, p = .05, self-reported strength β = 20.05, p = .82. Sample 4, actual strength β = 0.51, p < .01, self-reported strength β = 0.01, p = .98. Sample 5, actual strength β = 0.53, p < .01, self-reported strength β = 20.17, p = .22). Formant dispersion (Df) was measured from sample 8. Df did not correlate with physical strength (*r* = 0.08, *p* = .58) or weight (*r* = 0.04, *p* = .77), but did show a significant negative relationship with height (r = -0.36, p = .01). Df did show significant negative relationships with voice ratings (strength: *r* = -0.45, *p* < .01; height: *r* = -0.51, *p* < .01; weight: *r* = -0.37, *p* = .01).	

		were taken of them saying the English vowels.	(14 female, M = 19.0 years) rated the 30 Romanian female voices on physical strength on a 7-point scale. (1 = low on attribute, 7 = high on attribute) . Sample 8. Thirty-six undergraduates (25 female, M = 19.4 years) rated the recordings of vowel sounds from the 54 US males on physical strength, height, and weight on a 7-point scale (1 = low on attribute, 7 = high on attribute).		
Sell, Cosmides, Tooby, Sznycer,	Human adaptations for the visual assessment of	Study 1: 59 men (aged 18-32, M = 21.1 years) from the University of California, Santa Barbara had physical	Study 1: 142 University of California, Santa Barbara	Study 1: There was a significant correlation between the average perceived strength score for a target	Participants were able to accurately estimate the physical strength

Von Rueden, and Gurven (2009).	strength and fighting ability from the body and face.	measurements and strength taken as well as a facial and body photograph.	undergraduates rated the three sets of 59 photographs. Each subject rated only one set (full person, n = 35, 19 female; body only n = 34, 18 female; face only, n = 36, 22 female) on how physically strong they thought the man was compared to other men of his age on a 1-7 scale (1 = very weak, 7 = very strong). An additional 37 subjects (25 female) rated the full-person photos on aggressive formidability on a 1-7 scale (1 = not tough, 7 = very tough).	male and his actual upper body strength from photographs of the full person, body alone photographs, and facial photographs (r =0.71, $p < .01$, r = 0.66, $p < .01$, and r = 0.45, $p < .01$, respectively). Perceptions of the fighting ability strongly significantly correlated with perceptions of their physical strength: r = 0.96, $p < .01$). Perceptions of strength were both predicted by upper-body strength and fighting ability (r = 0.69, r = 0.71, both $p < .01$) respectively). A significant relationship was found between average toughness scores and the actual fighting behaviour (r = 0.30, p = .02).	of male targets from photos of their bodies and faces, largely independent of height, weight and age.

		Study 2: 109 men and 146 women (mean age: 19.4 years) had facial and body photos taken as well as chest and arm strength measured	Study Two: 132 students (76 women) rated the photographs on strength.	Study 2: Perceived strength assessed from body photographs and facial photographs of men significantly correlated with measured strength, (r = 0.57, p < .01, r = 0.39, p < .01)	
		Study 3: 53 adult Tsimane men (aged 19–77, M = 37 years) had facial photographs taken and chest, shoulder, and handgrip strength measured, along with flexed biceps circumference taken.	Study 3: Thirty-two students (17 female) rated the photographs on strength.	Study 3: Physical strength ratings were significantly correlated with actual strength (r = 0.52, p > .01)	
		Study 4: 28 men from the villages of Gobernador Sola´ and Ingeniero Maury in the province of Salta, Argentina (aged 15–71, M = 34.3 years) had photographs and biceps circumference taken. Height and weight were also obtained for 20 of the 28 subjects.	Study 4:28 students (19 females) rated the photographs on strength.	Study 4: Physical strength ratings were significantly correlated with actual strength (r =0.47, p = .01)	

Sell, Cosmides and Tooby (2014).	The human anger face evolved to enhance cues of strength.	Study 1: A facial photograph of the average European 20 year old male face was created. This was then modified in seven ways to display cues of anger, and in the opposite direction to create two faces: an anger-modified face and a control face for a total of 14 photographs. Each photograph was only modified in one of the following ways: lowered brow ridge, raise infraorbital triangle, widen nose, raise mouth, enlarge chin and chin bun, lips pushed forward, and lips thinned.	Study 1: 35 participants (25 female, M = 18.9 years) from the University of California, and 106 participants (80 female, M = 24.9 years) from Griffith University, Australia, were presented with each pair of faces side by side and asked to judge which appeared physically stronger.	Study 1: For all 7 sets of photographs, the aggressive face was more likely to be picked as stronger than the non-aggressive face (all $p < .01$).	Raters were more likely to rate faces that had been digitally altered to appear aggressive as stronger.
		Study 2: The same facial photographs from study 1 were used.	Study 2: Thirty-one students (M = 19 years) rated the pairs of facial photograph on which appeared the older of the two.	Study 2: Four of the seven anger faces were significantly more likely to be picked as older (all $p < .05$). Three of the seven there was no significant increase in the likelihood of the aggressive face as being picked as older.	

		Study 3: Photographs for study 3 were manipulated in the same way as study 1 and 2, but with the starting point of an older male (60 years old).	Study 3: 132 students (88 female, M = 21.09 years) were presented with the pairs of faces and asked who was the stronger and who was the older of the pair.	Study 3: Six of the seven anger faces were significantly more likely to be picked as stronger (all $p < .01$). For three of the seven there was no significant increase in likelihood of the aggressive face as being picked as older. Three of the seven anger faces were significantly more likely to be picked as younger (all $p < .05$), while two of the seven anger faces were significantly more likely to be picked as older (all $p < .01$) Eye size had no effect on the perceived strength of the face, however large eyes reliably made the face look younger (young faces: 77%, $\chi^2 = 9.32$, $p > .01$; old faces: 62%, $\chi^2 = 3.88$, $p = .05$).	
Třebický, Fialová, Stella, Coufalová,	Predictors of fighting ability inferences	Photographs of 44 MMA athletes from the Czech Republic (aged 18-38, M = 26.7 years) were taken.	46 men (aged 19-29, M = 21.96 years) and 48 women (aged 18-	A multiple linear regression analysis was run to predict perceived fighting ability with age, weight, isometric	There was found to be no significant links between the actual and the

Pavelka, Kleisner, and Havlíček (2019).	based on faces.	Physical, maximal isometric strength, lung capacity, and anaerobic capacity measurements were taken, and fighting ability calculated (the amount of wins compared to the amount of fights). Beardedness was also calculated by the research team rating each photograph.	38, M = 22.29 years) viewed each photograph in 360 degrees and rated the man on fighting ability (1 = very unsuccessful, 7 = very successful).	strength, lung capacity, and anaerobic capacity components were all treated as independent predictors. The overall model was significant (F(5, 38) = 2.79, p = .03, R^2 = 0.27), but none of the individual predictors significantly predicted the perception of fighting ability. There was a significant positive correlation between the fighter's perceived fighting ability and actual age (r = 0.35, p = .02), weight (r = 0.34, p = .02). A linear regression model significantly predicted perceived fighting ability (F(3, 40) = 3.58, p = .02, R^2 = 0.21). Among the predictors, body weight significantly predicted perceived fighting ability (β = 0.31, t = 2.03, p = 0.05). Beardedness was found to have no effect on fighting ability.	perceived fighting ability. However, heavier fighters were perceived as having a higher fighting ability and their was a significant positive relationship between the fighter's perceived fighting ability and actual age.

Třebický, Havlíček, Roberts, Little, and Kleisner (2013).	Perceived aggressiveness predicts fighting performance in mixed-martial-arts fighters.	146 photographs of MMA fighters were taken from the official web site of MMA division Ultimate Fighting Championship. For each fighter, data on his age, weight class, number of fights in the UFC, and number of wins in the UFC were obtained.	618 participants from the Czech Republic (216 men, M = 26.98 years, and 402 women, M = 26.18 years) rated a random subset 50 of the photographs on perceived aggressiveness on a 1-7 scale (1 = not aggressive at all, 7 = very aggressive). A further 278 participants (98 men, M = 28.31 years, and 180 women, M = 27.1 years, SD = 7.52) rated 50 of the photographs on perceived fighting ability on a 1-7 scale (1 = not at all, 7 = excellent).	There was a significant positive correlation between age and perceived fighting ability (r = .36, p < .01). There was also a significant positive correlation between the ratings of aggressiveness and perceived fighting ability (r = .48, p < .01), and aggressiveness and fighting success (r = .20, p = .01). Perceived aggressiveness (r = .31, p < .01) and perceived fighting ability (r = .30, p < .01) were positively correlated with weight. In a linear regression model, perceived aggressiveness was independently predicted by both fighting success (F(1, 14) = 4.91, p = .030, R^2 = .03), and weight (F(1, 143) = 13.68, p < .01, R^2 = .09). After weight was added as a covariate, perceived fighting ability was predicted by weight (F(1, 143) = 13.29, p < .01, R^2 = .09), but	Perceived aggressiveness was positively associated with actual fighting ability. Perceived fighting ability was positively associated with actual fighting ability but only in heavyweights. There was also found to be a significant relationship between perceived aggressiveness and facial shape.

				not by fighting success, (*F*(1, 143) = 0.24, p = .62, R^2 = .01). Heavyweight fighters were perceived to be better fighters than lightweights (*F*(2, 143) = 5.97, p < .01, R^2 = .08) but there was no other perceived differences between groups. Facial damage on the fighter showed a significant positive correlation with perceived fighting ability (n = 146, τ = .196, p < .01) A multivariate regression on perceived aggressiveness showed a significant relationship between perceived aggressiveness and facial shape: *F*(1, 144) = 2.42, p = .02, R^2 = .02. Controlling for the effect of the weight, it was found that the effect of face shape was not significant, however weight was significantly related to facial shape, *F*(1, 143) = 2.74, p = .02, R^2 = .02.	

				A model with both the main effect and the interaction of weight and aggressiveness was ran. The interaction was significant (*F*(1, 142) = 2.48, *p* = .03, R^2 = .02). Furthermore, a significant effect of perceived aggressiveness in heavyweights was found (*F*(1, 31) = 2.13, *p* = .04, R^2 = .06), but the same effect was not significant for lightweights. The regression of shape data on fighting success was not significant, but weight had a significant effect on facial morphospace (*F*(1, 144) = 2.72, *p* = .01, R^2 = .019) and had a significant effect on fighting success in heavyweights: *F*(1, 31) = 2.18, *p* = .03, R^2 = .07. No similar effect was found in lightweights. When analysing the faces, aggressive-looking faces were generally wider, and had a broader chin and larger nose,	

				as well as deep-set eyes beneath prominent eyebrows. Those with higher fighting success in heavyweights included a narrower chin, wider bizygomatic range, and a more horizontally depressed grid around the eyes. The morphology of fighting success was also characterised by a bigger nose and mouth with a distinct philtrum, compared with a typical losing fighter's face.	
Veto, Einhäuser, and Troje (2017).	Biological motion distorts size perception.	Study 1: Upright and inverted point light walks (PLW) were depicted from a frontal view, based on data of male actions from a previous study.	Study 1: 16 students (15 women, M = 20.1 years) viewed the point light walks and then estimated the size of the man when the image was no longer on the screen.	Study 1: Upright walkers were perceived to be larger than inverted (upside down) walkers ($t(14) = 6.12$, $p < .01$).	Upright PLWs are consistently judged as larger than inverted PLWs, while static point light figures do not elicit the same effect
		Study 2: The same point light walks from study 1 were used	Study 2: 24 students (19	Study 2: upright walkers were perceived to be larger than	

		as stimuli, as well as static images (taken from a snapshot of the point light walks).	women, M = 21.9 years) rated the point light walks and static stimuli in the same manner as study 1.	inverted walkers (*t*(23) = 2.37, *p* = .03). However, static images did not show a significant size-distortion effect (*t*(23) = 1.20, *p* = .24).	
		Study 3: This study used an indirect paradigm to judge the perceived size of upright and inverted PLWs. As upright PLWs are perceived as larger in studies 1 and 2, the authors predicted that a subsequent target presented after an inverted PLW (a circle) to appear as smaller and vice versa. Participants were told to ignore the PLWs and focus on the circles. This study describes placement and measurement of stimuli in degrees of visual angle. A typical trial involved participants fixating on a small cross in the centre of the screen where a PLW was	Study 3: 16 students (eleven females, mean age= 22.1) participated in the study.	Study 3: A point of subjective equality (PSE) psychometric function was fitted to each participant's data. This was achieved by plotting the percent of responses indicating that the target preceded by an upright walker was larger, against the difference between target (circles) sizes. A positive shift in PSEs towards larger targets at the inverted PLW location was found and this was significantly different from zero (t(15) = 3.51, p = .003).	

		presented both above and below this fixation for 250ms. On each trial, both an inverted and upright orientation PLW were presented, and their positions counterbalanced on a trial by trial basis. Following this presentation, a randomly littered inter stimulus interval (ISI) was presented followed by an untimed size judgement task involving two circles that replaced the PLWs. Participants were asked which circle was bigger.			
Wolff and Puts (2010).	Vocal masculinity is a robust dominance signal in men.	Study 1: 111 men (aged 18-24, M = 18.9 years) were informed that they would be competing against a man in another room for a lunch date with a woman, however the competitor and potential date were not there and previously recorded "stooge" vocals were used. Participants had several vocal recordings taken, including	Study 1: 87 men (aged 18–28, mean age 18.9 years) rated a random subset of approximately 30 vocal recordings on physical dominance on a 1-100 scale (1 = defiantly lose, 100	Study 1: When age was controlled for, self-rated physical dominance predicted mean physical dominance ratings of other men ($\beta = -0.24$, $t(86) = -2.29$, $p = 0.02$). Men who rated themselves higher in fighting ability rated other men lower in fighting ability, on average.	Men who rated themselves high on physical dominance rated the voices of other men lower on dominance. Men with intermediate testosterone concentrations rated the voices of other men lower

		while they informed their competitor why other men might respect or admire them. Participants gave self-rated dominance, dominance of competitor and number of sex partners in the past year. Voices were altered to finally produce 111 raised, 111 unmodified, and 110 lowered vocal stimuli recordings.	= defiantly win). Participants also gave number of sexual partners in the past year, and self-rated dominance.		on dominance compared to those with high or low testosterone levels.
		Study 2: Six men produced recordings of the Rainbow Passage during two sessions, one in the morning, one in the evening. Recordings were then raised or lowered in both fundamental frequency (F0) and formant dispersion (Df), therefore creating a total of 24 vocal stimuli recordings. Physical measurements were taken, such as height, bicep circumference, hand strength, and weight. A saliva sample for testosterone levels was also collected.	Study 2: 178 student men (aged 18-26, M = 20.14 years) listened to the 24 male voice stimuli and were instructed to indicate their agreement with the statement: "*If this man got into a fistfight with an average male undergraduate student, this man would probably win*" on a 1-10	Study 2: A mixed-model repeated measures ANOVA was conducted with four factors: session (session 1-morning, or session 2-evening), speaker (six individual speakers), acoustic parameter (F0 or Df), and manipulation (raised or lowered). Increasing vocal masculinity significantly increased dominance ratings relative to decreasing vocal masculinity ($F(153, 1) = 360$, $p > .01$). There was a significant difference in the effects of F0 and Df on dominance ratings (acoustic	

			scale (1 = strongly disagree, 10 = strongly agree). Participants also completed the Buss and Perry Aggression Questionnaire.	parameter×manipulation interaction: *F*(153, 1) = 72.4, *p* > .01). Post hoc tests showed that F0 influenced perceptions of physical dominance (*F*(1, 155) = 359.2, *p* > .01) to a greater degree than did Df (*F(*1,153) = 159.3, *p* > .01). It was found that men with either high or low levels of testosterone rated other men as more dominant than themselves(?), whereas men with average levels rated them lower in dominance than themselves(?) (*F*(153, 2) = 4.4, *p* = .01).	
Zhang, Hodges-Simeon, Gaulin, and Reid (2021).	Pitch lowering enhances men's perceived aggressive intent, not fighting ability.	Study 1a: A 28-year-old Caucasian man, "Nick", was recorded speaking 20 neutral phrases as well as "*you just hit my car*". This phrase was then edited to be 20 Hz higher or lower than the baseline recording	Study 1a: 66 student men (M = 19.7 years) were randomly assigned to one of the three between-subjects pitch-modulation conditions: pitch-lowered (n = 22), pitch maintained	Study 1a: Men with lowered pitch were perceived as more likely to have aggressive intent (*t*(63) = 4.98, *p* < .01) The main effect of the speaker's perceived chance of winning was significant (*F*(1, 62) = 29.3, *p* < .01), suggesting that on average, the speaker was perceived as	Male speakers with lower pitch are perceived as more likely to attack. However the experiments found no evidence that pitch lowering enhanced the speakers' perceived fighting

			(n = 21), and pitch raised (n = 23). Participants were asked to indicate how well the adjectives dominant, assertive, forceful, and aggressive described themselves on a 1-7 scale (1 = not well at all, 7 = very well). These were then averaged to give the participants a trait dominance score. After listening to the vocal recordings, participants rated them on perceived strength on a 1-7 (1= not strong at all, 7 = very strong) scale. They then read a	more likely to attack when he was perceived as more likely to win the physical fight. When investigating if pitch modulation influences perceptions of fighting ability, perceived physical strength was significant, ($F(1, 60) = 11.2$, $p = .01$). The main effect of the speaker's perceived aggressive intent was also found to be significant, ($F(1, 60) = 23.5$, $p < .01$).	ability after controlling for their perceived aggressive intent. Moreover, it was found that the speakers' perceived physical strength interacted with pitch modulation to influence their perceived aggressive intent

			scenario where 'Nick' was in a parked car and another driver hit his car door with his door. The raters then heard Nick say "*You just hit my car*" and rated his aggressive intent on how likely Nick was to hit, insult, push, and say the "F-word" to the offender if the offender did not apologise, as well as his fighting ability on a 1-7 scale (1 = not likely at all to win a fight, 7 = very likely). Finally, participants were asked to judge from memory whether Nick's voice sounded		

			deeper, higher, or the same in the hit-car recording compared to his voice in the baseline recording.		
		Study 1b: A different man was recorded counting from 1 to 10 and saying "*You just hit my car*" in a quiet room. These were again manipulated to have a pitch lowered, maintained, and raised condition.	Study 1b: 247 men (aged 21 - 70 years, median = 32 years) were randomly assigned to one of the three pitch-modulation conditions: pitch-lowered (n = 79), maintained (n = 90), and raised (n = 78). The method was the same as study 1a, however the sound of a car door was added to the vocal clip of *"you just hit my car*"	Study 1b: Participants in the pitch-lowered condition reported significantly stronger aggressive-intent perceptions than participants in the pitch-raised condition ($t(244) = 4.60$, $p < .01$, $d = 0.72$).	

		Study 2: Facial photos and voice recordings of two men who were physically strong or weak by objective standards were taken. The men recorded the same lines as study 2.	Study 2: 152 men (M = 20.1 years) were randomly assigned to the conditions of a 2 (speaker strength: strong/ weak) × 2 (pitch modulation: lowered/raised). Participants viewed the facial photo of either the strong or the weak speaker (both named "Nick") while listening to his baseline recording. After that, participants were asked to indicate how physically strong Nick was compared to an average male undergraduate student on a 9 point scale (−4 less so by a lot, 0	Study 2: one sample t-tests found that participants perceived the strong speaker to be physically stronger than their classmates: $t(71) = 6.83$, $p < .01$, $d = 1.62$, and the weak speaker to be physically weaker than their classmates: $t(79) = -3.45$, $p < .01$, $d = 0.78$. To test if participants would perceive the speaker to be more aggressive when he lowered his pitch a GLM was conducted. There was a main effect of pitch modulation: $F(1, 148) = 30.4$, $p < .001$, $\eta_p^2 = 0.17$, with participants in the lowered condition reporting stronger aggressive intent than in the pitch raised condition. There was no effect of speaker strength or interaction between speaker strength and modulation.	

			the same, 4 more so by a lot). Participants then listened to the recording of "*You just hit my car*" as if it was directed to them and gave ratings on aggressive intent, and if the voice sounded higher or lower than the baseline stimuli. They also self-reported their own dominance levels.		
Zilioli, Sell, Stirrat, Jagore, Vickerman, and Watson (2015).	Face of a fighter: Bizygomatic width as a cue of formidability.	Study 1: 241 UFC fighters facial photographs were collected, and fWHR was measured	Study 1: The facial photographs were analysed in relation to previous wins	Study 1: Fighters who lasted longer in the UFC had wider faces (r = .16, p = .01). Fighters who won more fights also had wider faces (r = .20, p > .01); however, the percentage of wins did not significantly correlate with fWHR (r = .10, p = .13). When controlling for the fact that the measures of fighting ability artificially lower the estimates	fWHR is predictive of actual fighting ability among professional combatants. fWHR correlated with assessments of formidability, in with natural faces, and computer-generated images

				for fighting abilities of heavy fighters (who fight only large fighters) and inflate the estimates for fighting ability of lighter fighters (who fight only smaller opponents), the results did not change. When controlling for both BMI and number of fights, the correlation between fWHR and win percentage was significant, (*r* = .12, *p* > .05). A significant correlation between fWHR and number of wins was found among lightweight (*r* = .18, *p* > .05) and heavyweight (*r* = .29, *p* = .04). Among Caucasian fighters, fWHR correlated with the percentage of wins (*r* = .20, *p* = .02). Among non-Caucasian fighters, fWHR correlated with the total number of fights (*r* = .28, *p* > .01) and the total number of wins (*r* = .28, *p* > .01). When controlling for number of fights, there was a significant correlation between fWHR and percentage of win which was significant for Caucasian fighters (*r* = .23, *p*	of strong and weak faces.

				> .01) but not for non-Caucasian fighters ($r = .02$, $p = .81$).	
		Study 2: Two pairs of composite faces were generated. The first pair was a composite of the most experienced fighters (those with the highest number of fights) matched with a composite of the less experienced fighters (those with the least number of fights). The second pair was a composite of the widest faced fighters with a composite of the thinnest faced fighters.	Study 2a: 36 participants (16 men, M = 21.7 years, 20 women, M = 21.8 years) were asked how tough each male would be in a physical fight on a 1-7 scale and who would win in a physical fight between 1-8 (1 = "*Left image is much tougher*" to 8 = "*Right image is much tougher*"). After testing, there was a concern over if the wide/narrow faces might differ in perceived ethnicity, thus potentially	Study 2a: An independent samples t-test showed that the composite of experienced fighters was rated as more formidable than the inexperienced composite ($t(35) = 4.69$, $p < .01$). The widest faces were rated as more formidable than the narrow faces ($t(35) = 2.37$, $p = .02$). When subjects were forced to pick which composite face appeared tougher, they chose the experienced face over the inexperienced face significantly more often: $t(35) = 5.54$, $p = .02$). An independent samples t-test indicated that combatants with the most fights had wider faces than people with only 10 fights ($t(23) = 2.447$, $p = .022$). The fighters with the widest faces had more wins than	

			changing the results. Therefore, the 12 widest and 12 narrowest “apparent non-African or non-Asian origin” faces were combined. 40 participants (20 men, M = 20 years, and 20 women, M = 20.3 years) were asked to identify which would be more likely to win in a physical fight, using the same scale.	fighters with the narrowest faces (*t*(18.90) = 1.998, *p* = .060). Similarly, Caucasian fighters with the widest faces had more wins than Caucasian fighters with the narrowest faces (*t*(28) = 1.873, *p* = .072), but this was not a significant difference.	
			Study 2b: 32 participants (16 men, M = 21.5 years, 16 women, M = 21 years). Participants were asked to rate individual fighters’	Study 2b: Ratings of formidability were positively correlated with both total number of fights (*r* =.46, *p* > .01) and total number of wins (*r* = .45, *p* > .01), predicting respectively 21% and 20% of their unique variance. fWHR	

			faces on a 1-7 scale on "*how tough each would be in a physical fight—how likely he would be to beat his opponent.*"	positively correlated with perceived formidability (*r* = .46, *p* > .01).	
		Study 3: fWHR of individual facial images was artificially varied to create 12 image pairs, with each pair of images made from a base composite face transformed to make a wider fWHR image and a narrower fWHR image.	Study 3: 124 participants (66 men, mean age = 21.3, 58 women, mean age = 21.3). The 12 image pairs were rated on a scale of 1–8 with 1 = "*Left image is much stronger*" to 8 = "*Right image is much stronger*"	Study 3: One-sample t-tests comparing perceived formidability to what would be expected by chance showed that the wider faces were rated as significantly stronger than narrower faces (*t*(123) = 3.57, *p* > .01).	

Appendix B

Body Segment	Marker
Head	LFHD (left front head)
	LBHD (left back head)
	RFHD (right front head)
	RBHD (right back head)
Upper-Body	CLAV (clavicle)
	STRN (sternum)
	RBAK (upper right back)
	C7 (upper back)
	T10 (lower back)
Arms	LSHO (left shoulder)
	RSHO (right shoulder)
	LUPA (left upper arm
	RUPA (right upper arm)
	LELB (left elbow)

	RELB (right elbow)
	LFRM (left forearm)
	RFRM (right forearm)
Hands	LWRA (left inside wrist)
	RWRA (right inside wrist)
	LWRB (left outside wrist)
	RWRB (right outside wrist)
	LFIN (left finger)
	RFIN (right finger)
Waist	LASI (left front hip)
	RASI (right front hip)
	LPSI (left back hip)
	RPSI (right back hip)
Legs	LTHI (left thigh)
	RTHI (right thigh)
	LKNE (left knee)
	RKNE (right knee)

	LTIB (left tibia)
	RTIB (right tibia)
Feet	LHEE (left heel)
	RHEE (right heel)
	LANK (left ankle)
	RANK (right ankle)
	LTOE (left toe)
	RTOE (right toe)