Universidade do Minho
Escola de Psicologia

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Beyond the Realms of Attractiveness: Investigating Time Perception and AI Evaluations

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Investigating Time Perception and AI Evaluations
Nuno Filipe Rocha Fernandes
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Nuno Filipe Rocha Fernandes

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e da
Professora Doutora Sandra Cristina de Oliveira Soares

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Statement of Integrity

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Além dos Domínios da Atratividade:

Investigando a Perceção Temporal e as Avaliações de IA

Resumo

Os julgamentos de atratividade moldam os nossos comportamentos diários, tendo um impacto nas nossas interacções sociais e ao nível reprodutivo. A investigação tem demonstrado que a sensação de "congelamento do tempo" que experienciamos ao vermos uma pessoa atraente resulta de um mecanismo evolutivo associado à prontidão para a ação, provocado por uma excitação fisiológica. No entanto, ainda não está claro como fatores como o ciclo menstrual e as expressões emocionais influenciam a relação entre a atratividade e a percepção temporal. Adicionalmente, com o avanço da Inteligência Artificial (IA), torna-se crucial perceber como os modelos de predição de atratividade facial tomam decisões. Assim, procuramos analisar se o dimorfismo sexual e a emocionalidade influenciam as avaliações destes modelos. Conduzimos quatro estudos: os dois primeiros exploraram a perceção temporal de estímulos atraentes; os últimos focaram-se em avaliações algorítmicas de atratividade. No Estudo 1, examinámos o efeito do ciclo menstrual nas perceções temporais de estímulos atraentes, enquanto o Estudo 2 explorou a interação entre a emocionalidade e atratividade facial na perceção temporal de participantes de ambos os géneros. Nos Estudos 3 e 4, avaliámos o impacto do dimorfismo sexual (Estudo 3) e expressões emocionais (Estudo 4) nas predições de atratividade feitas por um modelo de IA (VGG-19). De acordo com o esperado, as vozes masculinizadas foram reproduzidas durante mais tempo na fase fértil do ciclo menstrual. E ainda, corroboramos resultados de estudos anteriores acerca do efeito da visualização de faces atraentes na dilatação temporal. Contudo, não encontramos evidência a suportar uma influência quer do ciclo menstrual ou das expressões emocionais neste efeito. Em termos de IA, o modelo demonstrou uma preferência por rostos femininos e por expressões de felicidade ou neutras, alinhando-se com teorias sobre preferências evolutivas ligadas à qualidade reprodutiva e ao investimento parental. Esta tese investiga os fatores que contribuem para a sobrestimação de estímulos atraentes e avança a compreensão dos processos subjacentes envolvidos nas avaliações humanas e algorítmicas da atratividade.

Palavras-chave: atratividade, ciclo menstrual, dimorfismo sexual, expressões faciais, IA, perceção temporal

Beyond the Realms of Attractiveness:

Investigating Time Perception and AI Evaluations

Abstract

Judgments of attractiveness shape our daily behaviors, thus understanding the cognitive processes involved in this perception offers evolutionary advantages that impact reproduction and social interactions. Previous research suggests that the "time-freezing" sensation we experience when encountering an attractive person stems from an evolutionary mechanism linked to action readiness, triggered by a physiological arousal response. However, it remains unclear how factors such as the menstrual cycle and emotional expressions influence the relationship between attractiveness and time perception. Additionally, with the advancement of AI, it is crucial to understand how facial attractiveness prediction models make their decisions. In this work, we investigate whether variables such as sexual dimorphism and emotionality affect attractiveness evaluations of AI models. We conducted four studies: the first two explored the time perception of attractive stimuli; the last two focused on algorithmic evaluations of attractiveness. In Study 1, we examined the effect of the menstrual cycle on temporal perceptions of attractive stimuli, while Study 2 explored the interaction between emotionality and facial attractiveness on the time perception of participants of both genders. In Studies 3 and 4, we assessed the impact of variables such as sexual dimorphism (Study 3) and emotional expressions (Study 4) on attractiveness predictions made by an AI model (VGG-19). As expected, masculinized voices were reproduced for a longer duration during the fertile phase of the menstrual cycle. Additionally, we corroborate findings from previous studies regarding the effect of viewing attractive faces on temporal dilation. However, we found no evidence to support an influence of either the menstrual cycle or emotional expressions on this effect. In terms of AI, the model demonstrated a preference for feminine faces and for happy or neutral expressions, aligning with theories about evolutionary preferences related to reproductive quality and parental investment. This work investigates the factors that contribute to the overestimation of attractive stimuli and advances our understanding of the underlying processes involved in attractiveness evaluations, both human and algorithmic.

Keywords: AI, attractiveness, facial expressions, menstrual cycle, sexual dimorphism, time perception

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Abbreviations

AI	Artificial Intelligence
p	p-value
r	Pearson's correlation
MHC	Major Histocompatibility Complex
FSH	Follicle-Stimulating Hormone
DF	Dominant Follicle
LH	Luteinizing Hormone
fMRI	Functional Magnetic Resonance Imaging
XAI	Explainable Artificial Intelligence
EU	European Union
CNN	Convolutional Neural Network
SET	Scalar Expectancy Theory
BeT	Behavioral Theory of Timing
LeT	Learning-To-Time
AGM	Attention-Gate Model
EEG	Electroencephalography
ms	Milliseconds
ERP	Event-Related Potential
preSMA	Pre-Supplementary Motor Area
PRNE	Perceived Resting Negative Emotion
F0	Fundamental Frequency
n	Number
M	Mean
SD	Standard Deviation
Hz	Hertz
cm	Centimetre
dB	Decibel
s	Second
ISI	Inter-Stimulus Interval
ITI	Inter-Trial Interval

LMM	Linear mixed-effects model
IQR	Interquartile Range
R^2	Coefficient of Determination
F	F-statistics
df	Degree of Freedom
t	t-statistics
SE	Standard Error
SCR	Skin Conductance Response
HR	Heart Rate
WHR	Waist-to-Hip-Ratio
IADS	International Affective Digital Sounds
IAPS	International Affective Pictures System
KDEF	Karolinska Directed Emotional Faces Database
FRL-London	Face Research Lab London Set
SAM	Self-Assessment Manikin
GLMM	Generalized Linear Mixed Model
X^2	Chi-Square
OR	Odds Ratio
ECG	Electrocardiogram
VGG	Visual Geometry Group
ResNet	Residual Networks
CFD	Chicago Face Database
RMSE	Root Mean Squared Error
MAE	Mean Absolute Error
Adam	Adaptative Moment Estimation
REML	Restricted Maximum Likelihood
d	Cohen's d
CI	Confidence Interval
DNN	Deep Neural Network
ADFES	Amsterdam Dynamic Facial Expressions Set
b	Beta
LDFAT	Dual-supervised Feature-Attribute-Task

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Overview

How does our sense of time seem to warp when encountering someone we find attractive? Is that person's smile truly aimed at us, or are we caught in a fleeting moment? Do women's time perceptions of attractiveness vary within the menstrual cycle, perhaps as an evolutionary mechanism linked to reproduction? How might AI beauty prediction algorithms alter our fundamental experience of attraction?

This doctoral thesis investigates these complex questions, focusing on the impact of attractiveness on time perception and the factors that influence the perception of attractiveness itself. The research conducted specifically examines the role of the menstrual cycle and facial expressions in how attractiveness affects time perception. Additionally, it explores facial beauty prediction, analyzing whether AI algorithms are influenced by sexual dimorphic traits and emotional expressions.

To offer a comprehensive overview of these processes, this doctoral thesis is structured into six distinct chapters: an introductory theoretical chapter (Chapter 1), followed by four chapters dedicated to the empirical studies conducted (Chapters 2-5), and concluding with a general discussion (Chapter 6), which presents the main findings and provides a reflection on the overall work.

The introductory chapter covers both experimental and theoretical research on attractiveness and time perception and is divided into six main sections. Sections 1-4 focus on the perception of attractiveness, beginning with a brief introduction, followed by a review of key characteristics of physical attractiveness, its moderators, and the state-of-the-art in facial beauty prediction. In sections 5-6, we provide an overview of prominent theories in the field of time perception and examine the current understanding of how attractiveness and emotionality influence time perception. The chapter concludes by outlining the motivation behind this dissertation and summarizing the studies conducted.

In the central section of this dissertation, we present four chapters (Chapters 2-5), each detailing the experimental studies conducted. In Chapters 2 and 3, we describe two empirical experiments that explore the influence of the menstrual cycle and facial expressions on the effect of attractiveness on time perception, respectively. Following this, Chapters 4 and 5 focus on AI evaluations of attractiveness, specifically examining sexual dimorphism and facial expressions. Each empirical study is comprehensive, featuring its own literature review, methodology, results, and discussion.

The final chapter (Chapter 6) offers a general discussion that integrates findings across studies, addresses limitations, and offers suggestions for future research. It concludes with a reflection on the overall implications of these findings. At the end of the dissertation, we include a chapter with supplementary materials related to the empirical studies conducted.

CHAPTER 1

General Introduction

1. The Study of Physical Attractiveness

1.1. Physical attractiveness: A brief introduction

Beauty is said to be in the eye of the beholder. Evolutionary theories, however, have been challenging this notion by providing evidence that attraction to good-looking individuals is merely a by-product of natural selection, with high-quality genetic mates being perceived as more attractive (Buss, 1989; Cunningham et al., 1995; Jones & Hill, 1993; Symons, 1995). Research on the topic suggests that, although there is room for cultural differences in attractiveness judgments (Swami et al., 2006; Tovee et al., 2006), there is also a remarkable cross-cultural consistency in what physical traits individuals find appealing (Buss, 1989; Langlois et al., 2000; Shackelford et al., 2005). Significant correlations ($p <$ .05) of cross-ethnic ($r = .88$) and cross-cultural ($r = .94$) ratings of attractiveness were found (Langlois et al., 2000). For instance, studies have shown that certain physical features are generally perceived as attractive. These include symmetrical and average facial features, as well as indicators of sex and sexual maturity (i.e., sexual dimorphism;Carrito et al., 2016; Grammer & Thornhill, 1994; Penton-Voak et al., 2001; Rhodes et al., 1999). Other factors that may contribute to perceived attractiveness include, for example, a healthy skin condition, age, and weight (Little, Jones, et al., 2011; Rhodes, 2006).

Interestingly, this genetic advantage of having attractive physical features seems to come along with several social advantages, a phenomenon known as the halo effect (Dion et al., 1972). The halo effect is a cognitive bias where individuals' overall perceptions of a person tend to influence their evaluations of specific traits or characteristics linked to that individual, even when there's enough information available to form independent judgments (Nisbett & Wilson, 1977). The attractiveness halo impacts people's social judgments (Little, 2021) since humans often rely on facial cues to make inferences about others' personalities (Sutherland et al., 2015; Todorov et al., 2015). Indeed, a positive correlation has been found between facial attractiveness and trustworthiness judgments (Oosterhof & Todorov, 2008; Xu et al., 2012). Impressively, attractiveness assessments can be made at a glance, preceding trustworthiness judgments (Calvo et al., 2018; Gutiérrez-García et al., 2019), and accurately performed even when beholders claim not to be able to perceive the faces accurately (Olson & Marshuetz, 2005). However, the impact of attractiveness on social perceptions extends to other domains beyond trustworthiness. Attractive individuals are often perceived as possessing other socially desirable traits such as intelligence, happiness, warmth, professional and marital competence, and future occupational success (Dion et al., 1972; Feingold, 1992; Langlois et al., 2000; van Leeuwen & Macrae, 2004).

Furthermore, this positive bias towards attractive people can also shape social attitudes and interactions, by modulating empathy for pain elicitation (Balconi et al., 2020; Meng et al., 2020), biasing vote intentions (Franklin & Zebrowitz, 2016; Jäckle & Metz, 2017; Little, Burriss et al., 2007) and hiring processes (Baert & Decuypere, 2014; Goulão et al., 2024; Henderson et al., 2009), and leading to more lenient sentences in criminal contexts (Ahola et al., 2009; Beaver et al., 2019; Stewart, 1980; Swanner, 2022). It is therefore clear that physical attractiveness has a powerful impact on social cognition, highlighting the critical need to precisely identify the traits that contribute to facial attractiveness.

Additionally, the present thesis aims to explore key research areas on attractiveness within human mating behavior and romantic relationships. Romantic relationships have been said to significantly and positively impact mental and physical health, longevity, and general well-being (Apostolou et al., 2019, 2023; Apostolou & Kagialis, 2020; Costello et al., 2022; Sommerlad et al., 2018; Van De Velde et al., 2010; Waite & Lehrer, 2003; Wong et al., 2018). Since physical attractiveness is a significant predictor of success in attracting romantic partners (Jokela, 2009; Rhodes et al., 2005; Riggio & Woll, 1984), it becomes relevant to study what traits may contribute to higher overall attractiveness perception. More specifically, our investigation will focus on factors such as sexual dimorphism, symmetry, emotional expression, and sexual hormones (for a review, see Thornhill & Gangestad, 2006), and their influence on human cognitive processes.

1.2. Compounds of Physical Attractiveness

1.2.1. Sexual Dimorphism

Sexual dimorphism is a biological phenomenon frequently observed in human and non-human animals and refers to observable differences in traits between males and females of a particular species (e.g., seize, bone structure, or plumage color; Darwin, 1871; Frayer & Wolpoff, 1985). In humans, it is also intimately related to the masculinization or feminization of secondary sexual characteristics that take place during puberty, conveying information about the genetic quality of an individual in terms of heritable benefits (Little, Jones, et al., 2011). More specifically, the development of more extreme sexual dimorphic phenotypes (more feminine phenotypes for women, more masculine for men) is thought to be appealing because they imply the possession of genes beneficial to the offspring's survival or reproduction (Little, Jones, et al., 2011, 2013; Puts, 2010). Therefore, both males and females have evolved to display distinct sexual characteristics (Darwin, 1871) and simultaneously feel attracted to these sexually dimorphic traits in opposite-sex peers (Barber, 1995; Symons, 1995). Together, these findings support the role of cues signaling good health to human attraction. Among these traits are wide shoulders, beards, low-pitch

voices, and masculine facial features in men, and wide hips, breasts, and feminine facial traits in women (Wilson et al., 2017).

The sexual dimorphism hypothesis in facial attractiveness refers to the preference for sexual distinctive facial characteristics. For instance, men benefit from displaying more masculine features (Johnston et al., 2001; Penton-Voak et al., 2001), such as an enlarged brow ridge, thicker jawline, and wider face (Scott et al., 2013), whereas more feminine traits are particularly appealing in women (Fraccaro et al., 2010, Perrett et al., 1998), which could be identified by a smaller jawline and a narrower face (Little, Jones, et al., 2011). Masculine facial traits in men are indicative of higher basal levels of testosterone (Penton-Voak & Chen, 2004), an immunosuppressive hormone, compromising the body's defense against infections (Foo, Nakagawa, et al., 2017). Consequently, only men with good genetic quality and robust immune systems can afford to invest in secondary sexual traits (Folstad & Karter, 1992; Hamilton & Zuk, 1982). Hence, men displaying more masculine traits tend to appeal to potential mates, as they are perceived as healthier (Penton-Voak & Chen, 2004; Thornhill & Gangestad, 2006) and more dominant (Neave et al., 2003; Thornhill & Gangestad, 2006). Evolutionary theories propose that preferences for sexually dimorphic traits are linked to distinct mating functions. For instance, men may exhibit facial characteristics to signal strength and dominance, as dominant individuals often attain higher social status, enhancing their ability to provide essential resources for reproduction (Geary et al., 2004). On the other hand, women may convey signals of youth and fertility (Fink & Penton-Voak, 2002). Femininity in women indicates higher estrogen levels, which is associated with better reproductive qualities (Foo, Simmons, et al., 2017) and mating value (Barber, 1995; Symons, 1995).

Additionally, the preference for sexual dimorphism is also observed in other sensorial modalities. Men with lower pitch voices are perceived by women as having more social status (for a review, see Aung & Puts, 2020). Indeed, research has consistently demonstrated that women tend to rate men's voices with lower pitches as more attractive (Feinberg et al., 2006; Jones et al., 2010; O'Connor et al., 2012; Re et al., 2012; Vukovic et al., 2010). The underlying reason for that behavior is that circulating levels of testosterone negatively correlate with voice pitch, with higher testosterone indicating lower voice pitch (Aung & Puts, 2020; Evans et al., 2008). Conversely, men show a preference for women who speak with higher pitches (Feinberg et al., 2005, 2008; Re et al., 2012). In women, a higher vocal pitch has been found to correlate positively with estrogen levels (Abitbol et al., 1999). This characteristic may serve as an indicator of fertility status and underlying reproductive capability (Bryant & Haselton, 2009; Feinberg et al., 2008).

Another line of research argues that women face a trade-off between maximizing genetic qualities and parental investment. For example, Hill et al. (2013) suggest that women may prefer men with less masculine faces if they have masculine voices, and vice versa. Also, other studies have found a preference for feminized male face shapes (Carrito et al., 2016; Perret et al., 1998; Rhodes et al., 2000). The explanation for these results relies on the notion that high-quality males (higher testosterone levels) invest less in the relationship, as they have more available options when choosing their mate (for a review, see Penton-Voak & Perret, 2001). Similarly, the vocal preferences for masculinity are stronger for short-term partners than for long-term partners (Little, Connely et al., 2011; Vukovic et al., 2011).

However, this trade-off between sexual dimorphism and parental investment appears to be a more complex issue. Some studies did not find a relationship between morphological masculinity and rated attractiveness (Kleisner et al., 2021; Scott et al., 2010). For instance, Carrito et al. (2016) found a preference for feminine shapes in male faces, but a masculine preference for male skin color. Also, others even defend a threshold, expressing the trade-off between parental investment and genetic qualities, from where masculinity is no longer preferred (Ekrami et al., 2021; Holzleitner & Perrett, 2017). For example, Dixson et al. (2016) found that lower degrees of masculinization, 25%, were preferred over the typically 50% linear transformations towards an average male face to create masculine faces (for details on algorithms used to transform faces in shape, see Rowland & Perrett, 1995). Findings in the auditory modality exhibited a consistent pattern, with women showing a preference for men's voices lowered in pitch, but not those that were very low (Re et al., 2012). Furthermore, Dixson et al. (2016) showed an interaction between facial masculinity and beardedness. They found that clean-shaven faces with extreme levels of masculinity or femininity were found to be the least attractive, while stubble, and to some degree full beards, masked the impact of these extreme facial features. Therefore, potential explanations for these divergent results may be linked with differences in the stimuli selection or possible moderators.

1.2.2. Symmetry

Previous research has suggested that symmetry is also a significant predictor of facial attractiveness (Fink et al., 2006; Grammer & Thornhill, 1994; Jones et al., 2001; Mealey et al., 1999; Perrett et al., 1999; Rhodes et al., 1999; Scheib et al., 1999) and has been associated with sexual dimorphism (Gangestad & Thornhill, 2003; Little et al., 2008; Scheib et al., 1999). Men with greater symmetry typically exhibit more masculine characteristics, such as broader jaws, and elongated chins (Gangestad & Thornhill, 2003; Scheib et al., 1999). Symmetry indicates developmental stability across numerous species (Møller, 1997; Møller & Swaddle, 1997) as it is positively correlated with heterozygosity

in many animals, including humans (for a review, see Thornhill & Gangestad, 1993). Within-organisms genetic diversity is an important defense against parasites and relies on individual genetic heterozygosity (Hamilton & Zuk, 1982; Thornhill & Gangestad, 1993). In the case of humans, male body symmetry demonstrates a positive association with sperm quality, while female breast symmetry is correlated with increased fecundity (Manning et al., 1997; Møller et al., 1995).

In the context of facial attractiveness, symmetry refers to the degree to which the two halves of a face are perceived as identical or similar. Research indicates that facial symmetry is linked to fewer respiratory infections (Thornhill & Gangestad, 2006), and symmetric faces are perceived as healthier (Fink et al., 2006; Jones et al., 2001). Research has found that MHC-heterozygosity is associated with human facial attractiveness (Lie et al., 2008, 2010; Roberts et al., 2005). The major histocompatibility complex (MHC) includes genes responsible for coding cell-surface peptides that bind to foreign antigen peptides and present them to T-cells, triggering an immune response (Abbas et al., 2000). Empirical evidence using a large database of 2870 female faces corroborates those findings showing a positive correlation between perceived health and attractiveness (Singh et al., 2024). Similarly, Young et al. (2011) found that the perceived vulnerability to disease of female participants predicted a preference for both male and female symmetrical faces. Additionally, Rhodes et al. (2001) found that perceived health positively correlated with symmetry in both morphed and real facial images. Despite Zaidel et al. (2005) suggesting that symmetry may be a predictor of health, but not of attractiveness, other research has found that even "color" symmetry is often enough to guarantee both attractiveness–symmetry and perceived health–symmetry relationships when shape symmetry is diminished (Jones et al., 2004). While research on physical attractiveness has highlighted the roles of features like sexual dimorphism and facial symmetry, understanding attractiveness perception requires examining how various moderators, such as the menstrual cycle and facial expressions, shape perception across different contexts.

1.3. Moderators of attractiveness perception

1.3.1. Menstrual cycle

Hormonal changes during females' menstrual cycle may help explain the mixed findings for the sexual dimorphism hypothesis (i.e., the preference for feminine women and masculine men). The normal menstrual cycle, comprising three stages (follicular, ovulatory, and luteal), leads to the development of a mature follicle and the release of an oocyte each cycle, with menses occurring in the lack of fertilization (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). The menstrual cycle length refers to the duration from the initial day of menstrual bleeding in one cycle to the beginning of menses in the subsequent cycle

(Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). Typically, the median length of a menstrual cycle is 28 days, with the majority falling within the range of 25 to 30 days (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). Menstruation typically lasts for 5 days, and the fertile window comprises the 5 days leading up to ovulation as well as the day of ovulation itself (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). During the transition from the luteal phase to the follicular phase, all women experience a rise in follicle-stimulating hormone (FSH), which stimulates the growth of a group of follicles (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). The dominant follicle (DF) that will ultimately ovulate is chosen during the mid-follicular phase. As this dominant follicle develops, it progressively produces estradiol for about a week before ovulation occurs (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). During the late follicular period, a peak of estradiol and luteinizing hormone (LH) leads to ovulation and is followed by a rise in progesterone in the luteal phase (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000).

The menstrual cycle has been the subject of extensive research due to its impact not only on well-being but also on the emotional, sensorial, and implicit cognitive processes of women (for a review, see Farage et al., 2008; Poromaa & Gingnell, 2014). Specifically, hormonal fluctuations occurring during the fertile phase of the menstrual cycle are linked to changes in women's sexual behavior. For instance, during ovulation, women have been found to report greater desires for infidelity, accompanied by heightened levels of sexual interest in and fantasies involving non-primary partners, compared to the luteal phase (Gangestad et al., 2002). These were accompanied by a decreased sexual interest in or fantasies with primary partners during ovulation (Gangestad et al., 2002). Furthermore, women showed more flirting behaviors during the fertile than during the non-fertile phase (Cantú et al., 2014). Interestingly, this behavior was observed exclusively when interacting with men who exhibited genetic-fitness markers, rather than with other men in general (Cantú et al., 2014). The menstrual cycle also influences women's preferences for men's social behavior (Gangestad et al., 2004). Women showed an increased preference for men exhibiting social presence and direct intrasexual competitiveness during periods of high fertility compared to low-fertility days (Gangestad et al., 2004). However, both these effects were observed solely within the context of short-term mating rather than long-term relationships (Cantú et al., 2014; Gangestad et al., 2004). This is aligned with the trade-off between choosing partners with better genetic qualities (i.e., higher testosterone) or parental qualities (Ekrami et al., 2021; Holzleitner & Perrett, 2017).

Research supports a shift in preference for more masculine male faces during the fertile phase of the menstrual cycle (Frost, 1994; Johnston et al., 2001; Jones et al., 2008; Penton-Voak et al., 1999;

Penton-Voak & Perrett, 2000). Similarly, the literature indicates that females show an increased preference for masculine voices during the fertile period of the cycle than in the non-fertile phase (Feinberg et al., 2006; Pisanski et al., 2014; Puts, 2005). Additionally, an increased preference for more symmetric faces was observed at peak fertility (Little, Jones, et al., 2007). Near peak fertility, women also showed a preference for the scent of shirts worn by men with symmetrical features (Gangestad & Thornhill, 1998). However, evidence contradicting the notion of a heightened preference for symmetrical male faces during peak fertility has emerged, as no differences were found across the menstrual cycle (Cárdenas & Harris, 2007; Koehler et al., 2002; Peters et al., 2009). A possible explanation could be the use of natural photographs of symmetric men, rather than the typically manipulated versions (Peters et al., 2009). Furthermore, Peters et al. (2009) emphasize that the use of ovulation tests is essential for accurately classifying the fertile period, a detail that was lacking in prior studies (Cárdenas & Harris, 2007; Koehler et al., 2002). Despite the use of ovulation tests, they did not detect any effect of menstrual cycle shifts on preferences for symmetry or sexual dimorphism (Peters et al., 2009). Therefore, further research should aim to understand the implicit cognitive preferences associated with females' attractiveness preferences throughout the menstrual cycle.

1.3.2. Influence of facial expressions

Despite the stable properties of physical attractiveness, situational factors, such as emotional expression, influence perceived facial attractiveness. For instance, research suggests that negative facial expressions, such as anger (Garrido & Prada, 2017; Morrison et al., 2013) and sadness (Mueser et al., 1984), are perceived as less attractive than happy and neutral faces. Furthermore, Golle et al. (2014) (Experiment 1) showed that the intensity of a smile expressed on a face predicted attractiveness and that happiness could even compensate for unattractive faces. A possible explanation for this preference for happy faces stems from the positive influence of health on happiness (e.g., Dfarhud et al., 2014). Biological and health factors, including neurotransmitters like dopamine and serotonin, hormones such as cortisol and adrenaline produced by the adrenal gland, and oxytocin from the pituitary gland, significantly regulate happiness (Dfarhud et al., 2014). For instance, individuals with the 'long' (528bp) polymorphism of the gene encoding the serotonin transporter (5-HTT) reported higher levels of life satisfaction (Neve, 2011). The 'long' allele is a transcriptionally more efficient version compared to the 'short' (484bp) variation since it increases the number of serotonin transporters in the cell membrane, thus more serotonin is reintroduced into the pre-synaptic cell. A study using functional magnetic resonance imaging (fMRI) showed that individuals with the 'short' variant presented increased amygdala

activation at rest, as indicated by decreased activation to neutral faces (when compared to the fixation rest baseline) (Canli & Lesch, 2007). Importantly, serotonin moderates the relationship between stress and depression, with the less functional "short" allele being associated with increased stress reactivity (for a review, see Karg et al., 2011). Ultimately, depression is associated with low semen volume in men (Yland et al., 2021) and with miscarriage in recurrent spontaneous aborters in women (Sugiura-Ogasawara et al., 2002).

However, sex differences may emerge when studying the influence of emotional expressions on facial attractiveness. For example, Tracy and Beall (2011) demonstrated that happiness was the most attractive emotional expression among females, whereas in males, it ranked among the least attractive. Women's full-intensity smiles were found to increase men's perceived attractiveness and trustworthiness, compared to neutral expressions and half-intensity smiles (Schmidt et al., 2012). Conversely, an opposite pattern was observed for pride, as it emerged as the most attractive expression in males and one of the least attractive in females (Tracy & Beall, 2011). Women's preference for pride in men could be associated with assessments of social standing and, consequently, the perceived ability to provide essential resources. Okubo et al. (2015) found that "smiling" men were rated as more attractive for long-term relationships while men with neutral facial expressions were preferred for short-term relationships (Experiment 1). The authors showed that this pattern was due to smiling male faces being perceived as more trustworthy while neutral male faces as more masculine (Experiment 2).

Furthermore, a possible moderator role of facial expressions may elucidate the divergent findings on the relationship between sexual dimorphism and attractiveness. Carrito et al. (2023) showed that angry faces are perceived as more masculine compared to happy faces (Experiment 2) and that the preference for femininity in male faces was lower in happy faces than in neutral ones (Experiment 3). These findings support the trade-off women encounter when selecting their partner, with happiness serving as a potential mitigating factor in the negative association between masculinity and parental investment. Despite extensive research on attractiveness prediction and its moderators, the growing development of facial beauty prediction systems raises a critical question of whether these models replicate human biases in their judgments of attractiveness.

1.4. AI models – A novel approach to attractiveness research

While the notion "beauty is in the eye of the beholder" suggests that beauty is subjective and depends on individual preferences (Kwart et al., 2012; Morse et al., 1976), there is vast evidence showing that people rely on objective factors to make attractiveness judgments (Little et al., 2008; Perret et al.,

1999; Thornhill & Gangestad, 2006). Supported by these findings in the cognitive field, and with the nowadays widely available data and computing resources, the development of beauty prediction algorithms has received great interest from many researchers (for a review, see Harrar et al., 2018; Saeed & Abdulazeez, 2021).

However, new challenges arise with advancements in artificial intelligence (AI). The field of explainable AI (XAI) has received increasing attention from scientists and legislators, given its clinical implications, specifically in the field of plastic surgery (Kanevsky et al., 2016; Štěpánek et al., 2019a, 2019b) as well as its moral and ethical concerns (Angelov et al., 2021; Samek & Müller, 2019). European Parliament has recently announced that the use of AI will be regulated in the EU (European Parliament, 2023). Following the revealed framework, we believe beauty prediction algorithms should be considered under the unacceptable risk category since they threaten a possible social scoring system. The directive defines social scoring as: "classifying people based on behavior, socioeconomic status, or personal characteristics" (European Parliament, 2023). In addition to the halo effect of attractiveness, with attractive people being judged as having more socially desirable characteristics (Dion et al., 1972), research also warns for a negativity bias towards unattractive people (Griffin & Langlois, 2006). Regardless of the directionality of the effect, these findings suggest that attractiveness may influence algorithmic judgments in other areas besides beauty prediction. Also, it should be considered under the high-risk scope following its possible influence on the job selection process (Luxen & Van De Vijver, 2006; Pansu & Dubois, 2002).

Therefore, researchers should aim to understand how AI models perform attractiveness evaluations. Kagian et al. (2008) recognized this importance and demonstrated that machine learning models implicitly replicate human biases concerning symmetry and averageness preferences. A distinction between these traditional machine learning models and, more recently, deep learning techniques should be made. Machine learning models align more with initial statistical methods, which aim to quantify facial attractiveness based on specific ratios and proportions of facial features. For instance, the "golden ratio" (1.618) has been considered the standard metric to evaluate attractiveness based on facial proportions (Fan et al., 2012; Schmid et al., 2008). Machine learning methods can predict facial attractiveness by analyzing these manually designed features, such as symmetry, geometric ratios, and distances between landmarks, at the same time (Kagian et al., 2008; Sutić et al., 2010; Zhao et al., 2020).

On the other hand, with deep learning algorithms, hand-crafted features are unnecessary. Algorithms like Convolutional Neural Networks (CNNs) are commonly used for object detection (for a

review, see Zhiqiang & Jun, 2017), facial identification (Lou & Shi, 2020; Yin & Liu, 2018), and facial expression recognition (Akhand et al., 2021; Zhang et al., 2017), as they can extract useful features from the raw image. A Convolutional Neural Network (CNN) typically comprises multiple layers, with a key feature being the utilization of convolutional layers. These layers apply a kernel (a small matrix of weights) to the input grid, allowing the network to effectively extract spatial hierarchies from the raw image in an adaptive manner (for a detailed explanation, see Albawi et al., 2017). Therefore, they have been adapted for facial attractiveness prediction problems, achieving a relatively high correlation (.93) with the actual judgments of attractiveness (Gan et al., 2023).

Despite CNNs' high performance on raw images, the use of these models raises specific questions and challenges due to their "black box" characteristics. Therefore, XAI techniques often focus on tracing the image's regions of interest within each layer or computing a heat map of the image's most important areas for the overall classification (Qin et al., 2018; Wang et al., 2021). An analogy could be made between these post-hoc methods and eye-tracking data of attractiveness judgments (Griffey & Little, 2014; Yang et al., 2015). For example, recent research has suggested that sexual dimorphism positively correlates with celebrity classification (Feng et al., 2021). We believe that understanding whether beauty prediction models are implicitly learning human preferences for attractiveness, such as sexual dimorphism and emotionality, is essential for improving these models (Weber et al., 2023) and for enhancing our understanding of human cognitive processes, similar to studies on brain functioning (Kiani et al., 2022; Sudar et al., 2022). Therefore, just as in the study of the human mind, which is also considered a black box, cognitive scientists can play a crucial role in advancing the field of Explainable Artificial Intelligence (XAI) by designing experimental paradigms aimed at enhancing the interpretability, fairness, and transparency of AI systems (Srinivasan & Chander, 2020; Taylor & Taylor, 2021).

Thus far, we have reviewed the literature on the determinants of physical attractiveness, integrating traditional research from cognitive psychology with recent findings in artificial intelligence. However, while technological advancements present substantial potential for significant discoveries—particularly through the rapid analysis of extensive image datasets—it is essential for scientific discovery to pursue research on fundamental cognitive processes to address challenges in artificial intelligence, such as poor data quality and explainability (Wang et al., 2023). One fundamental cognitive process influenced by attractive (e.g., Arantes et al., 2013; Zhou et al., 2021) and emotional (e.g., Droit-Volet et al., 2004; Kliegl et al., 2015) cues is time perception. Investigating the interplay between these factors and time perception will enhance our comprehension of how we form judgments and participate in social interactions (Haigh et al., 2021).

1.5. Time perception

The human perception of time is a complex and subjective phenomenon that influences how we experience events, such as how we deal with threatening situations (Droit-Volet et al., 2010; Tipples, 2011) or how we perform long-term investments (Chen & Zhao, 2024; Kim & Zauberman, 2019; Zauberman et al., 2009). Accurate time estimation comprises a fundamental adaptation that enables living organisms to align their internal biological rhythms with the external environment, thus playing a vital role in both reproductive and survival processes (Haigh et al., 2021). A model for the "internal clock", based on a pacemaker, counter, store, and comparator was originally proposed by Treisman (1963) to provide explanations for various findings concerning time perception. Specifically, this model addresses phenomena such as Weber's law, which states that stimulus sensitivity will increase proportionally with increases in stimulus intensity (Fechner, 1964). Later, Gibbon et al. (1984) formulated the scalar expectancy theory (SET), which remains the most influential pacemaker-accumulator model of time perception although alternative models have been proposed over the years (see Killeen & Fetterman (1988) behavioral theory of timing (BeT) and Machado et al. (2009) learning-to-time (LeT) model). Despite humans' ability to make accurate time estimations within a range of milliseconds to hours (Fechner, 1964), research has listed several internal and external factors capable of distorting our sense of time (for a review, see Block & Gruber, 2014). This dissertation seeks to explore the influence of emotions (for a review, see Fayolle & Droit-Volet, 2014; Schirmer, 2011) and attractiveness (Arantes et al., 2013, 2021; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021) on time perception within the SET framework.

1.5.1. Scalar Expectancy Theory (SET)

According to SET (Gibbon et al., 1984), humans and animals possess an internal clock that subjectively assesses the passage of time. This internal clock consists of three essential components: a pacemaker, a switch, and an accumulator. The pacemaker is responsible for generating pulses at a specific rate, which then pass through a switch that closes at the onset and opens at the offset of the timed interval, allowing pulses to be stored in the accumulator. As the physical time duration increases, more pulses are retained in the accumulator, resulting in the perception of longer time intervals. For temporal judgments, a comparator mechanism evaluates the current accumulator count by comparing it with values from a previous encounter with the time interval, determining whether the timed interval has lasted for a similar duration.

Under arousal models of time perception, such as SET, the functioning of the clock is believed to be regulated by arousal. "Arousal" is defined as a continuum of sensitivity to stimuli in the surrounding environment, which helps organisms adapt to environmental changes and maintain homeostasis (Silver & LeSauter, 2008). Arousal level is modulated by the noradrenergic system, with norepinephrine enhancing the arousal levels (for a review, see Berridge, 2008), while interacting with local glutamate for an improvement of the top-down information processing (Mather et al., 2016). We speak of top-down selection when there is an active directed process (Theeuwes, 2010). For example, stimuli related to survival (e.g., threat detection; Vromen et al., 2016) or reproduction (e.g., attractiveness perception; Werheid et al., 2007). While bottom-up selection is an automatic process determined by the properties inherent in stimuli, that is, salience (e.g., flashing light) (Theeuwes, 2010).

Arousal accelerates the pacemaker, causing increased emission and accumulation of pulses in the accumulator (Droit-Volet et al., 2004), thus lengthening the experienced duration of both visual (Özoğlu & Thomaschke, 2021; Schwarz et al., 2013), auditory (Droit-Volet et al., 2013; Noulhiane et al., 2007), and audiovisual (Ansani et al., 2021; Appelqvist-Dalton et al., 2022) stimuli. Physiological arousal can be accessed via indicators such as increased heart rate activity (Wascher, 2021), variations in galvanic skin response (Sharma et al., 2016) or pupil diameter (Bradley et al., 2008). However, research suggests that contrary to perceived arousal, physiological arousal does not directly modulate the pacemaker's rhythm (Cahoon, 1969; Mella et al., 2011; Schwarz et al., 2013). In a series of three experiments, Schwarz et al. (2013) demonstrated that perceived arousal had a significant impact on time perception, whereas heart rate did not emerge as a significant predictor. Schwarz et al. (2013) argued that a possible explanation could be that heart rate response covaries with other physiological indicators, such as respiration rate and galvanic skin response (Taylor & Epstein, 1967). However, further studies did not find a significant effect of induced arousal using indices of heart rate, respiration rate, and EEG activity (Cahoon, 1969) or galvanic skin response (Mella et al., 2011) on time perception. Therefore, these findings provide intriguing insights into the role of top-down processing on time perception (Mella et al., 2011), suggesting that the slowing down of time is an adaptive mechanism that allows organisms to respond effectively to arousing specific affective cues, such as threatening (Droit-Volet et al., 2004; Noulhiane et al., 2007), or reproductive-related (Arantes et al., 2013; Tian et al., 2019) stimuli.

Research indicates that attention also interacts with arousal to influence the subjective experience of time, namely in the processing of emotional facial expressions (Fayolle & Droit-Volet, 2014; Gil & Droit-Volet, 2012) or attractive faces (Ogden, 2013; Sano et al., 2022). Cognitive models differentiate between two essential perspectives in time perception: prospective and retrospective time estimation (for a review,

see Block & Gruber, 2014). In the prospective, an individual assesses the duration of a current interval they are experiencing. Conversely, in retrospective time estimation, an individual estimates a duration that has already elapsed. The main difference between the two is that in retrospective judgments, the person is unaware in advance of the relevance of the duration, and therefore does not pay attention to time as they do in prospective durations (Zakay, 1992). To account for this possible role of attention on the pacemaker-accumulator models of time perception, the Attention-Gate Model (AGM; Zakay & Block, 1996, 1997) proposes the existence of an attentional gate that can open and close intermittently throughout the timing process substituting the switch from the SET. Since attention controls the gate, distraction to time passage may lead to a slowing down of the internal clock and shorter time estimates "time flies when you are having fun" (Danckert & Allman, 2005) or "time stands still" when experiencing pain (Rey et al., 2017).

Notwithstanding the distinct roles of arousal and attention, they frequently collaborate, with arousal influencing the pacemaker pace and attention controlling the gate (Zakay & Block, 1996, 1997). This may help explain why physiological arousal is only predictive of perceived duration for stimuli with negative valence, suggesting that alterations in our perception of time are influenced by both bottom-up (physiological arousal) and top-down (threat detection) cognitive processes (Ogden et al., 2019). Similarly, Angrilli et al. (1997) showed that neither arousal nor valence had a main effect on time perception. Instead, they found that, for low-arousal stimuli, those with negative valence were perceived as shorter than positive ones. In contrast, for high-arousal stimuli, negative-valence stimuli were perceived as longer than positive ones.

These findings suggest that the level of arousal regulates two distinct motivational mechanisms, one emotional and the other attentional (Angrilli et al., 1997). Building upon this notion, Smith et al. (2011) revealed that the intricate mechanism underpinning the interaction between arousal and valence in time estimation is more complex than initially suggested. They showed that for "short" (100–300 ms) durations, arousing negative stimuli were underestimated. On the other hand, for "long" (400–1600 ms) durations, highly arousing negative items were overestimated, whereas highly arousing positive items and less arousing negative ones were underestimated. Ultimately, Smith et al. (2011) argue that there are multiple stages at which emotion influences time perception. During an early perceptual stage (<300 ms), stimuli that activate the amygdala are quickly recognized as threats and rapidly engage the attentional system (Morris, 1998; Surguladze et al., 2003).

In contrast, items perceived as less threatening, which do not trigger the amygdala, would require more time to determine the suitable response, thus being overestimated (Smith et al., 2011). This is

supported by EEG data, revealing that the P1 and subsequent N1 components are sensitive to valence, with larger potentials observed for unpleasant stimuli, whereas for late ERPs (P300), arousing task-related stimuli (unpleasant/pleasant) elicited more activation than low-arousing stimuli, suggesting an influence of top-down processing (for a review, see Olofsson et al., 2008). Similarly, a time perception study using fMRI found that at "long" (~1,300 ms) intervals regions involved with judgment and decision-making processes, namely, the preSMA, the anterior cingulate cortex, the right inferior frontal gyrus (corresponding to Broca's area), the bilateral premotor cortex, and the right caudate nucleus, were more activated (Pouthas et al., 2005). Ultimately, this response is considered an adaptive mechanism that prepares the organism for action, with similar late ERP responses being observed for stimuli that strongly activate the appetitive (erotica) or the defensive (threat) motivational systems (Schupp et al., 2010). While the current thesis does not primarily aim to determine whether arousal or attention plays the main role in regulating the internal clock, understanding their distinct contributions to time estimation is essential for integrating divergent findings in the domain of attractiveness time perception.

1.6. Moderators of time perception

1.6.1. Attractiveness

As previously discussed, attractiveness serves as a signal of an individual's fitness and health condition, making it a crucial cue in mating behavior (Rey et al., 2017). Research revealed an association between attractiveness and immune function, specifically tied to effectively handling bacterial threats (Mengelkoch et al., 2022). Traits considered attractive encompass biologically relevant stimuli, thus, from an evolutionary standpoint, are regarded as a priority and deserving of greater attention. In this sense, there is evidence showing that amygdala activation which has been thought to play a role in the processing of biologically relevant stimuli (Pessoa & Adolphs, 2010; Sander et al., 2003; Sennwald et al., 2016) is also involved in attractiveness processing (Senior, 2003).

Therefore, given its biological relevance, it would be expected that attractiveness would engage in the appetitive motivational system inducing heightened arousal towards attractive people (Lang & Bradley, 2013). In favor of this assumption, some studies have shown, for instance, that viewing erotic photographs of attractive opposite-sex individuals results in increased skin conductance response, initial cardiac deceleration, and modulation of the startle reflex in both men and women (Bradley et al., 2001; Ikisawa et al., 2020). Moreover, ratings of arousal also prove to be associated with perceived attractiveness (Hazlett & Hoehn-Saric, 2000; Zhou et al., 2021). Other studies uncovered pupil constriction (Liao et al., 2021) and dilatation (Laeng & Falkenberg, 2007) in response to attractive

pictures. Additionally, research has reported physiological changes in facial muscle activity, with the zygomatic muscle activating when observing attractive opposite-sex individuals and the corrugator muscle activating for same-sex individuals (Hazlett & Hoehn-Saric, 2000). Similarly, in the auditory modality, individuals exhibited higher levels of physiological arousal, indicated by increased skin conductance, when speaking with more attractive opposite-sex targets (Hughes et al., 2010). In contrast, the greatest increases in galvanic skin response and heart rate in females were observed when listening to the voices of other females during their highest fertility phase (Shoup-Knox & Pipitone, 2015). Interestingly, several studies have reported increased attractiveness near the fertile phase of the cycle (e.g., Catena et al., 2019; Roberts et al., 2004).

On the other hand, not only do attractive cues elicit an autonomic arousal response, but the state of arousal also influences attractiveness preferences. For instance, sexually aroused subjects rated medium and highly attractive targets as more sexually attractive, whereas they rated low-attractive targets as less sexually attractive compared to nonaroused subjects (Istvan et al., 1983). Also, recent research showed that men with high arousal judged female faces as more attractive than men with low arousal, whereas no differences were found for women (Han et al., 2023). Moreover, Hagerman et al. (2017) found that women's physiological arousal was not related to subjective ratings of attractiveness, but it was positively correlated with men's testosterone. Further evidence proposes that when the arousal source is unambiguous (e.g., attractive face), subjects can adjust their judgments of attractiveness for this automatic effect of arousal (for a review, see Foster et al., 1998). This adjustment model supports the already discussed role of top-down cognitive processes on time perception, namely on the influence of attractiveness cues.

Research has shown that attractive faces often lead to temporal dilation (Hagerman et al., 2017), and most researchers support the notion that this effect is mediated by the increased arousal in response to attractive faces (Arantes et al., 2013; Tian et al., 2019; Tomas & Španić, 2016). Recently, the mediator role of arousal in the temporal dilation effect of attractive faces has been empirically addressed (Zhou et al., 2021). In Experiment 1, Zhou et al. (2021) showed that subjective arousal ratings mediated the temporal dilation effect of attractive faces. Furthermore, in Experiment 2, by suppressing autonomic arousal using a sentence-unscrambling task (Mauss et al., 2007), the temporal dilation of attractive faces was attenuated (Zhou et al., 2021). Importantly, the priming task is believed to passively achieve the suppression without one's awareness (Bargh et al., 2001). This is crucial, as deliberately suppressing expression requires significant attentional resources (Gross, 1998; Ohira et al., 2006; Yuan et al., 2015).

This supression could result in temporal underestimation due to attentional deficits (Zakay & Block, 1996, 1997). Therefore, the use of deliberate suppression might confound arousal and attention mechanisms.

Conversely, Ogden (2013) found shorter durations for unattractive faces and no differences between neutral and attractive faces. The author proposes that unpleasant stimuli divert attention from temporal perception, resulting in fewer ticks passing from the pacemaker to the accumulator. Additionally, Sano et al. (2022) observed an underestimation of attractive faces compared to unattractive and neutral ones. Contrary to Ogden (2013), Sano et al. (2022) discuss that the attractive faces may have captured the participants' attention, distracting them from the passage of time. Research supports this notion as attractive faces tend to capture more attention than unattractive faces (Chen et al., 2012; Liu & Chen, 2012; Sui & Liu, 2009).

Furthermore, attractive faces temporally modulate visual attention (Nakamura & Kawabata, 2014). In a study where participants were asked to recognize two female targets within a rapid sequence of face images, results showed that when the first target was an attractive face, it hindered the identification of the second target at early time points compared to neutral and unattractive faces (Broadbent & Broadbent, 1987). This effect reflects the involuntary diversion of attention caused by facial attractiveness (Nakamura & Kawabata, 2014). Also, the authors propose that this attentional bias of attractiveness may be an innate adaptive mechanism (Thornhill & Gangestad, 1999) resulting in reproductive advantages given the attractiveness cues to high genetic quality and fecundity (Johnston, 2006).

To explain their contradictory findings in relation to the existing literature, Sano et al. (2022) point out that one of two mechanisms could occur in the presence of attractive stimuli: 1) when they elicit low arousal, attention regulates the internal clock leading to shorter estimates; 2) in case arousal is high it overtakes attention and results in temporal dilation. This explanation is congruent with the AGM (Zakay & Block, 1996, 1997), and with previously discussed findings on the role of arousal in perceived attractiveness (Istvan et al., 1983). However, we posit that methodological issues may also contribute to the divergent findings within the field of time perception of attractiveness.

Firstly, standardizing the durations used for presenting stimuli is crucial. For instance, Sano et al. (2022) used intervals of 400 and 1,600 ms, referring to the former as "short" and the latter as "long". As previously discussed, earlier research shows that top-down cognitive processes may emerge around the 300-400 ms mark (for a review, see Olofsson et al., 2008). Hence, this may clarify why the attractiveness effect was observed solely for durations surpassing 500 ms (Arantes et al., 2013), and why certain studies chose to exclusively employ longer durations (>1,000 ms) (Tian et al., 2019; Zhou et al.,

2021). Additionally, depending on the type of paradigm utilized, such as temporal bisection and reproduction tasks which are among the most common, attention or arousal mechanisms may be involved, as evidenced in the time perception of angry faces (Gil & Droit-Volet, 2011). It is noteworthy that Sano et al. (2022) suggest that their results could be explained by the use of a temporal bisection task. However, other research, while investigating the interaction effect between attractiveness and facial expressions using the temporal bisection task, found a main effect of attractiveness (Tomas & Španić, 2016). Therefore, it is crucial to elucidate these divergent findings, particularly regarding the type of task employed, the spectrum of durations examined, and notably, the moderating influence of facial expressions on the time dilation effect observed with attractive faces.

1.6.2. Emotions

Much like attractiveness, emotions also represent biologically relevant stimuli, encompassing the activity and interaction of various psychological and physiological phenomena (Scherer, 2005). These include perception, attention, memory, physiological reactions, and reflexes (e.g., heart rate, endocrine function, or gamete release) (Tooby & Cosmides, 2008). Cognitive processes involved in emotional processing also influence our perception of time. For example, researchers have shown significant interest in understanding how threatening stimuli are perceived over time (Droit-Volet et al., 2004; Droit-Volet & Meck, 2007; Gil et al., 2007; Kliegl et al., 2015). These studies found that angry and fearful faces were associated with longer perceived durations compared to neutral faces, a finding likely related to the anticipatory and defensive functions of these emotions (Baumeister et al., 2007). Anticipating the emotions of others and adapting our emotional responses based on their facial expressions are indispensable mechanisms for facilitating effective social interactions (Russell & Fernández-Dols, 1997). For instance, in the eminence of a threat, the internal clock accelerates, and dopamine is released, preparing the organism for action (Darwin, 1872).

Despite the vast literature on the effect of angry facial expressions on time perception, there is a lack of studies exploring the role of other facial expressions on the perception of time. A study by Droit-Volet et al. (2004) discovered that emotional faces, including anger, happiness, and sadness, were perceived as lasting longer than neutral ones. However, the overestimation was more pronounced for anger and happiness than sadness, while no significant difference was observed between the former. Tipples (2008), on the other hand, found that angry faces led to a greater overestimation of time than happy and fearful expressions. Although these findings support arousal-based models of time perception, with emotional faces being perceived for longer, Tipples (2008) argues that heightened arousal of the

sender alone cannot fully account for the results, as fearful faces are often perceived as more aroused than angry faces. Research suggests that viewing angry faces was associated with an increased startle response relative to viewing fearful, happy, and neutral facial stimuli (Springer et al., 2007). This finding suggests that even if angry and fearful faces are perceived as threatening, their priming influence on the startle circuitry differs (Springer et al., 2007).

In contrast to fear, anger is frequently exhibited to alter the behavior of the individual it is directed towards (Frijda, 1986). Therefore, research suggests that angry faces attract attention to the observer, whereas fearful faces signal threats elsewhere in the environment, thus diverting attention away from the face and towards the source of the threat (Williams et al., 2005). Compared to neutral stimuli, the observation of fear and anger behaviors results in similar increases in activity in the left amygdala, temporal cortices, ventrolateral prefrontal cortex, and dorsomedial prefrontal cortex (Pichon et al., 2009). However, while fear perception specifically activates the right temporoparietal junction, anger perception leads to condition-specific activation in a broader range of regions including the anterior temporal lobe, premotor cortex, and ventromedial prefrontal cortex (Pichon et al., 2009).

Moreover, Eberhardt et al. (2016) who aimed to dissociate the influence of stimulus and state emotionality on time perception showed that inducing a fearful mood after a neutral mood lengthened subjective duration regardless of stimulus type (Experiment 1). Also, fearful faces were overestimated compared to neutral ones in neutral but not fearful moods. However, no differences were observed in mood or emotions when a fearful mood was first induced (Experiment 2). These results suggest that a fearful mood may accelerate an internal pacemaker but do not increase differences between neutral and fearful faces. Overall, these findings support Tipples's (2008) claim that a fear-specific adaptive defense mechanism (Öhman & Mineka, 2001) is elicited by angry expressions in a neutral state, resulting in longer time estimates.

Consistent with this hypothesis, Fayolle and Droit-Volet (2014) found longer perceived durations when dynamic faces and high-arousal emotional expressions (expressing anger) were presented when compared to static faces and low-arousal expressions (expressing sadness). Although dynamic displays enhanced the effect of high-arousal emotional expressions on time perception, the subjective experienced arousal did not differ between the dynamic and static expressions. Fayolle & Droit-Volet (2014) discuss that despite evidence supporting the notion that high-arousing expressions lengthen time perception, it is important to consider that increased attention also plays a significant role (Anelli et al., 2013; Carretié et al., 2009). Additional evidence suggests that the perception of longer durations for angry faces is context-specific. For instance, Grondin et al. (2015) found that female participants overestimated the duration of

angry faces compared to shameful faces, but only for male faces. Moreover, the duration of opposite-sex faces compared to female faces was only overestimated by female participants for the angry faces. The authors suggest that when female participants evaluate the mating potential of male faces, they may become distracted from the timing task, resulting in temporal underestimation. However, in the case of angry faces, this attentional effect might have been counterbalanced by the arousal effect triggered by the perception of threat, as suggested by Sano et al. (2022).

1.6.3. Interaction between emotional facial expressions and attractiveness on time perception

As previously discussed, emotional facial expressions influence perceived attractiveness. Happiness is an indicator of a good health condition (Dfarhud et al., 2014) and enhances facial attractiveness (Garrido & Prada, 2017; Golle et al., 2014; Morrison et al., 2013; Mueser et al., 1984). Conversely, facial attractiveness also plays a role in the assessment of happiness, as happy expressions are typically more readily and rapidly recognized in attractive faces (Golle et al., 2014; Li et al., 2019; Lindeberg et al., 2019; Mertens et al., 2021). However, despite this interrelationship, to the best of our knowledge, only one study (Tomas & Španić, 2016) has addressed the interaction effect between emotional facial expressions and attractiveness on time perception. The authors found that female participants overestimated the duration of viewing same-sex angry faces compared to neutral ones for the attractive faces but not for the unattractive ones. These findings align with arousal-based models and are consistent with prior research indicating heightened arousal in women when observing other highly attractive women (Hazlett & Hoehn-Saric, 2000). This heightened arousal may be attributed to a defensive reaction to perceiving high-status competitors as potential threats (Fink et al., 2014; Vaillancourt & Sharma, 2011).

However, it is necessary to clarify whether this moderator effect also applies to opposite-sex faces and whether it extends to other facial expressions. As previously discussed, exposure to images of attractive individuals of the opposite sex elicits automatic or implicit cognitive processes (e.g., Bradley et al., 2001; Laeng and Falkenberg, 2007). Consequently, building upon prior findings concerning the interrelationship between attractiveness processing and facial expression recognition (Garrido & Prada, 2017; Golle et al., 2014; Hester, 2019; Li et al., 2019; Lindeberg et al., 2019; Mertens et al., 2021; Morrison et al., 2013), one could hypothesize that attractiveness interacts with the fear-specific adaptive defense mechanism (Öhman & Mineka, 2001). The fear-specific adaptive defense mechanism encompasses a range of autonomic responses, including heightened arousal, designed to prepare the

organism for action in the presence of an imminent threat. This increase in arousal, which can be elicited by viewing angry faces, often leads to an overestimation of time, attributed to an acceleration of the pacemaker (Gil & Droit-Volet, 2012).

However, attractiveness has been found to negatively influence threat perception, thus it could also modulate the lengthening effect of viewing angry faces on time perception. Meng et al. (2020) work on the interaction between "pain" and "attractiveness" elucidates the dichotomy between the "beauty-is-good" stereotype and the "threat value of pain" hypothesis. Physical attractiveness is associated with good health (Foo, Simmons, et al., 2017) and positive personality traits, such as intelligence and morality (Feingold, 1992). Whereas the "threat value of pain" hypothesis posits that the perception of another's pain activates the individual's survival mechanisms, leading to avoidance behaviors similar to those triggered by real or perceived danger (Ibáñez et al., 2011; Yamada & Decety, 2009). Meng et al. (2020) provided evidence supporting the "threat value of pain" hypothesis. They observed distinctions in the N170 and P2 amplitudes when participants viewed non-painful faces, indicating heightened neural sensitivity. However, no such differences were noted for painful faces. Indeed, Meng et al. (2020) uncovered intriguing evidence supporting the "beauty-is-good" notion. They observed that for more attractive faces, the N170 and P2 amplitudes in response to painful pictures were larger compared to non-painful pictures. However, no such differences were evident for less attractive faces. The N170 and P2 components, as highlighted by studies such as those by Han et al. (2020) and Trujillo et al. (2014), are known to be evoked by the observation of attractive faces. Moreover, these components have been linked to the automatic processing of both facial identity and emotionality (Blau et al., 2007; Meng et al., 2012). Therefore, it is reasonable to hypothesize that these findings may extend to the time perception of emotional facial expressions. Specifically, one might expect a tendency to overestimate the duration or intensity of emotional expressions, particularly angry faces, especially in conditions where facial attractiveness is perceived to be lower.

Further evidence supports these findings and suggests that sexual dimorphism could also influence time perception of emotional faces. For instance, McElvaney et al. (2021) showed that body mass was positively associated with perceived threat. Also, masculinity correlates positively with dominance (Pivonkova et al., 2011), which is associated with men's perceived facial threat potential (Han et al., 2017). Although, gender differences may emerge regarding the interrelationship between threat and attractiveness. Building upon the hypothesis that males possess a greater potential for aggression compared to females, Leder et al. (2010) demonstrated that when confronted with a threatening situation, there were no differences in fixation durations between attractive and unattractive male faces. In contrast,

during a social approach scenario, both female and male attractive faces obtained prolonged attention. Furthermore, Hester (2019) found evidence indicating a negative correlation between perceived resting negative emotion (PRNE) and the attractiveness of women. This implies a mediating mechanism wherein perceived threat impacts attractiveness perception. Conversely, for men, PRNE solely predicted threat. Additionally, research has found that male participants' trust behavior is affected equally by attractiveness and threat, while female participants are more strongly affected by threat than attractiveness (Brustkern et al., 2021). This evidence suggests that facial attractiveness might compensate for high facial threat depending on the viewer's sex and the stimulus (Brustkern et al., 2021). Hence, changes in the cognitive processing of attractive faces instead of unattractive faces could potentially impact time perception of emotional facial expressions.

1.7. The Present Dissertation

Considering everything mentioned above and framed under an evolutionary referential, the first major line of this work seeks to uncover some of the underpinning cognitive mechanisms involved in attractiveness perception. Specifically, we will focus our efforts on extending prior knowledge on time perception, namely whether and how hormonal changes across the menstrual cycle and different facial expressions shape the role of attractiveness in time perception. Secondly, we will explore whether evolutionary preferences for attractiveness, such as sexual dimorphism and facial expressions, extend to machine judgments. In this way, we expect to observe whether AI will perpetuate human biases in the future.

This thesis has two primary objectives: first, to understand how cues of attractiveness influence our perception of time, and second, to examine whether the attractiveness ratings generated by facial beauty prediction algorithms align with evolutionary theories regarding preferences for sexual dimorphism and facial expressions. We hypothesize that: a) during the fertile phase of the menstrual cycle, but not during the non-fertile phase, women will judge the duration of attractive stimuli to be longer than unattractive stimuli; b) angry faces will be perceived as lasting longer compared to happy and neutral faces, for the unattractive faces, but not for the attractive ones; c) sexually dimorphic (masculinized males and feminized females) and symmetrized faces will be predicted as more attractive; d) positive facial expressions (happiness) will be predicted as more attractive, but the effect will be stronger for female faces compared to male faces; e) happy expressions will be predicted as more attractive in the masculinized versions compared to the expected differences in the feminized versions.

This thesis is composed of six chapters. The current chapter comprises the introduction where it addresses the major lines of attractiveness research. In the following chapters (Chapters 2-5) we introduce our four empirical studies, detailing their methodologies and results. The final chapter (Chapter 6) discusses the results and summarizes our findings.

In the first study, we tested whether hormonal changes occurring during the menstrual cycle moderate the effect of attractiveness on time perception. Female participants completed a time reproduction task during both the ovulatory (fertile) and the menstrual (non-fertile) phases of their cycles. This task consisted of visual and auditory oddball tasks. For the visual task, the test stimuli consisted of images of attractive and unattractive males (attractiveness condition) or masculinized and feminized male faces (indirect manipulation of facial attractiveness – sexual dimorphism condition). The auditory task involved male voices with raised and lowered pitch.

The second study aims to investigate whether there is an interaction effect between facial expressions and facial attractiveness on time perception. In this experiment, both male and female participants were recruited. This study uses a similar time reproduction task to study 1, with the difference that participants viewed different emotional facial expressions (anger, happiness, and neutral) of attractive/unattractive (attractiveness) or masculinized/feminized (sexual dimorphism) opposite-sex faces.

The third study explored whether beauty prediction algorithms replicate human biases in facial attractiveness evaluations. We tested if state-of-the-art deep learning algorithms implicitly learned humans' sexual dimorphic and symmetry preferences, as supported by evolutionary theories. To do so, we trained a CNN using a transfer learning methodology and tested whether it predicted sexually dimorphic versions of male and female-neutral faces as more attractive.

In our final study, we tested the extent to which the algorithm would exhibit bias towards positive facial expressions in its attractiveness predictions, aiming to explain the unexpected patterns observed in our prior study. Thus, the algorithm evaluated the manipulated (masculinized/feminized) images with different facial expressions (anger, happiness, and neutral) used in Study 2, as well as original (non-manipulated) photos that varied in emotional expression. Finally, we compared the algorithm's predictions with the evaluations made by human participants.

1.8. References

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CHAPTER 2

Empirical Study 1:

Time perception of attractive male faces and voices:

The role of women's menstrual cycle

2. Time perception of attractive male faces and voices: The role of women's menstrual cycle

Fernandes, N., Soares, S., Arantes, M., & Arantes, J. (submitted). Time perception of attractive male faces and voices: The role of women's menstrual cycle.

In addition, results from this empirical work were presented in the following scientific events:

Fernandes, N., Pereira, S., & Arantes, J. (2022, May 5-7). The effect of the menstrual cycle on women's time perception [Poster Presentation]. First Joint International APPE-SEPEX Metting. Faro, Portugal.

Fernandes, N., Soares, S., & Arantes, J. (2023, 31 March – 1 Abril). Beyond the realms of attractiveness: Time perception and algorithmic preferences [Conference Presentation]. 17.º Encontro Nacional da Associação Portuguesa de Psicologia Experimental [17th National Meeting of the Portuguese Association of Experimental Psychology]. Lisboa, Portugal.

Fernandes, N., Pereira, S., & Arantes, J. (2023, May 14-16). The effect of the menstrual cycle on women's time perception [Poster Presentation]. 2º Simpósio Doutoral PSI.UNorte [2nd PSI.UNorte Doctoral Symposium]. Braga, Portugal.

All data, analysis code, and research materials are available at:

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Additionally, supplemental materials can be found in Appendix A.

2.1. Abstract

Accurate time measurement is essential for organisms to synchronize their internal biological cycles with the external environment, crucial for reproductive success and survival. This study examines fluctuations in time perception across different phases of the menstrual cycle in response to visual and vocal attractiveness, building on previous research showing that women estimate longer viewing times for attractive male photos compared to unattractive ones. Forty-eight females participated in the experiment during both the menstruation and ovulation phases of their menstrual cycles, completing visual and auditory oddball tasks. Participants viewed a series of five stimuli and reproduced the duration of the last stimulus by pressing a mouse button. The final stimulus could be identical to the previous four (control trials), an attractive or unattractive male photo (visual attractiveness block), a masculinized or feminized male face (visual sexually dimorphic block), or a masculinized or feminized male voice (auditory sexually dimorphic block). Results indicated that duration estimates for masculinized male voices were significantly longer compared to feminized voices, while no differences were found for the menstruation phase. However, no differences were observed between the phases of the menstrual cycle in the visual conditions. Nevertheless, we replicate the temporal dilation effect associated with viewing attractive stimuli, suggesting an acceleration of the internal clock related to attractiveness perception. Our findings align with the literature on this phenomenon and provide initial evidence for an adaptive time perception mechanism influenced by the menstrual cycle, contributing to the understanding of the complex interactions between biological cycles and perceptual processes.

Keywords: attractiveness; auditory; menstrual cycle; sexual dimorphism; time perception; vision

2.2. Introduction

The accurate measurement of time allows organisms to align their internal biological cycles with the external environment, which is crucial for reproductive and survival purposes (Haigh et al., 2021). Yet, pop culture often describes feelings of time freezing when people are in love or attracted to others. But do these assertions find scientific support? Previous research has indicated that women's estimated viewing time of attractive male photos was longer than corresponding estimates for unattractive ones (Arantes et al., 2013, 2021; Tian et al., 2019). Does the perception of time fluctuate across different phases of the menstrual cycle, similar to how judgments of attractiveness do (Little, Jones & Burriss, 2007; Little, Jones, Burt, et al., 2007). Additionally, to what extent can these results be extrapolated to other sensory domains?

2.2.1. The human experience of time

A model for the "internal clock" based on a pacemaker, counter, store, and comparator was initially proposed by Treisman (1963) to provide explanations for many findings concerning time perception, such as the notion of Weber's law, which suggests that stimulus sensitivity will increase proportionally with increases in stimulus intensity (Fechner, 1964). Later, Gibbon et al. (1984) formulated the Scalar Expectancy Theory (SET), which remains the most influential pacemaker-accumulator model of time perception. According to SET, pulses are generated by an arousal-related pacemaker and counted by an accumulator. These counts are stored in memory when an attention-controlled switch closes. For temporal judgments, a comparator assesses the accumulator's current count against values from previous exposures to the timed interval, determining whether the duration is similar. Many factors influence the perception of time, such as attractiveness (Arantes et al., 2013, 2021; Ogden, 2013; Sano et al., 2022; Tian et al., 2019; Zhou et al., 2021).

2.2.2. Time perception of attractive photos

Recent studies have investigated the duration estimates of viewing attractive opposite-sex photos (Arantes et al., 2013; Tian et al., 2019). Arantes et al. (2013) showed that females' duration estimates of attractive male photos were significantly longer than corresponding estimates for unattractive male images. Later, Tian et al. (2019) found that, for both sexes, the duration estimates of attractive opposite-sex faces were longer than for unattractive opposite-sex faces. Also, Arantes et al. (2021) using a speed

dating methodology found that when there is a holistic perception of the partner as physically more attractive, time seems to slow down for women.

Moreover, Tomas and Španić (2016) showed a females' overestimation of same-sex attractive photos compared to unattractive ones, and that angry facial expressions were overestimated, but only for attractive faces. Similar to the suggested mechanism by which emotional arousal stimuli, like angry faces (Droit-Volet et al., 2004; Gil & Droit-Volet, 2011; Tipples, 2008), or auditory stimuli, such as unpleasant music (Droit-Volet et al., 2013), are believed to impact time perception by elevating the pacemaker rate (Droit-Volet et al., 2004), the same mechanism is thought to come into play when viewing attractive stimuli (Arantes et al., 2013). Zhou et al. (2021) empirically examined the role of arousal in the effect of attractiveness on time perception, showing that increased arousal mediated the temporal dilation effect of attractive faces. However, their study included only male participants.

Alternative explanations for the phenomenon may also be considered. For instance, Ogden (2013) observed that female participants underestimated the duration of same-sex unattractive faces in comparison to attractive and neutral faces. The author attributed these findings to attention being diverted from time perception. On the other hand, Sano et al. (2022) observed that attractive faces were underestimated compared to unattractive and neutral ones, suggesting that attractive faces captured participants' attention and distracted them from perceiving the passage of time. Both explanations can be framed under the Attention-Gate Model (AGM; Zakay & Block, 1996, 1997). The AGM suggests the use of an attentional gate instead of the switch observed in the SET. In contrast to the SET switch, presumed to remain closed once activated during a specific timing instance, the AGM gate can open and close intermittently throughout the timing process, being influenced by the level of attention allocated to the timing task. Therefore, alongside arousal, attention emerges as one of the most influential determinants of time perception (Lake et al., 2016).

2.2.3. The impact of menstrual cycle dynamics on attractiveness perception

For women, seeing an attractive man is likely to engage the appetitive motivational system by eliciting physiological reflexes that mobilize the organism for action (for a review, see Lang & Bradley, 2010). Accordingly, there is substantial evidence that viewing photos of attractive opposite-sex individuals elicits automatic or implicit cognitive processes. For instance, Bradley et al. (2001) found that viewing erotic photographs elicited autonomic physiological responses (e.g., increased skin conductance, cardiac deceleration, and startle reflex modulation). Additionally, Laeng and Falkenberg (2007) observed that women's autonomic arousal (pupils dilated) was higher when viewing photos of their boyfriends and

famous male actors compared to pictures of female actresses or other participants' boyfriends. Interestingly, this effect was increased during the ovulatory phase of the menstrual cycle and not obtained for women who were taking oral contraceptives, suggesting an influence of the menstrual cycle hormones on these physiological responses. Furthermore, using a GO/NOGO paradigm with functional MRI, Roberts et al. (2008) found evidence for changes in women's brain activity across the menstrual cycle when processing attractive male faces. The study identified instances of both successful inhibitions and commission errors that were exclusive to the male stimuli (attractive female photos were also used) during the fertile phase of the menstrual cycle.

The menstrual cycle comprises different hormonal arrangements (Itriyeva, 2022). Precisely, during the late follicular period, a peak of estradiol is followed by a rise in progesterone. Consequently, females experience several motivational (Haselton et al., 2007; Roney & Simmons, 2013), perceptual (Johnston et al., 2001; Krug et al., 2003), and cognitive (Kimura, 1999; Le et al., 2020) changes. On the realm of mating preferences, although findings are mixed, there is evidence supporting the good genes ovulatory shift hypothesis (for a review, see Gangestad & Thornhill, 2008; Jones et al., 2008). This hypothesis suggests that in the fertile phase of the cycle, women exhibit stronger preferences for men with masculine traits compared to when they are in their lowest-fertile phase. Additionally, it is theorized that when women are at a lower risk of conception, they tend to prefer a less masculine partner who may be more likely to provide resources for offspring (Jones et al., 2008). A meta-analysis conducted by Gildersleeve et al. (2014) supported these claims, revealing that women showed a shift in preferences during their menstrual cycle when assessing potential short-term partners (e.g., for a one-night stand) or when assessing the attractiveness of male stimuli without specifying a relationship context, but not when evaluating male stimuli as potential long-term partners (e.g., for marriage).

Despite mixed findings, masculinity in men is generally believed to signal health and "good genes" (i.e., a better immune system; Folstad & Karter, 1992; Foo et al., 2017, 2020; Hamilton & Zuk, 1982; Jones et al., 2008). This is based on the idea that masculinity indicates higher basal testosterone levels (Penton-Voak & Chen, 2004; Pound et al., 2008). Therefore, a key rationale for predicting hormone-linked changes in women's preferences for facial masculinity is the assertion that facial masculinity reflects men's heritable immunocompetence (Penton-Voak et al., 1999). Although exploring the underlying motives for sexually dimorphic preferences among women is not the focus of the present work, there is evidence challenging the immunocompetence handicap hypothesis (intersexual competition) (Lee et al., 2014; Nowak et al., 2020; Scott et al., 2014; Zaidi et al., 2019). Instead of serving as an indicator

of men's immunocompetence, men's masculinity may primarily signal their intrasexual competitiveness (for a review, see Puts, 2010; Scott, 2012).

Additionally, menstrual cycle shift preferences are also observed for other sensory modalities. Men with higher testosterone levels speak with lower fundamental frequencies (F0) and are judged as being more masculine (Cartei et al., 2014), attractive (Feinberg et al., 2005; Schild et al., 2020), and have higher mating success (Hughes et al., 2004). Also, researchers found that masculine voices are associated with better disease resistance, contrasting with the immunocompetence hypothesis predictions (Arnocky et al., 2018; Hodges-Simeon et al., 2024). However, the authors warn that further studies, including testosterone level manipulation, are necessary to determine whether androgens should be treated as immunomodulators rather than implicit immunosuppressants, as suggested by Nowak et al. (2018).

Despite the theoretical framework employed, there is evidence suggesting that the preference for masculine voices is heightened during the late follicular (fertile) phase of the menstrual cycle compared to the early follicular and luteal (non-fertile) phases (Puts, 2005). In a subsequent study, using estimated hormonal measures based on the menstrual cycle, Puts (2006) found that preferences for vocal masculinity in naturally cycling women decreased with higher predicted progesterone levels and increased with higher predicted prolactin levels. This pattern did not appear in women using hormonal contraceptives. Moreover, Pisanski et al. (2014) corroborate these findings, revealing that women's preference for masculine voices was strongest when estradiol levels were high.

Extending the effect of attractiveness on time perception to auditory stimuli is particularly relevant given the disparities in the literature regarding preferences for masculinity in faces and voices. For instance, a recent meta-analysis by Lidborg et al. (2022) found no clear evidence that facial masculinity predicts mating success, whereas male voice pitch and testosterone levels were significant predictors. Additionally, time judgment differs between auditory and visual stimuli, with auditory stimuli generally perceived as longer than visual stimuli of comparable duration (for a review, see Goldstone & Lhamon, 1974). Although Farjampour and Hellström (2000) demonstrated that women exhibited decreased accuracy in discriminating tone durations during the premenstrual phase, no previous studies have explored women's estimates of the duration of masculine voices across different phases of the menstrual cycle.

Despite the rationale of the good genes ovulatory shift hypothesis presented in this work, there is an ongoing debate in the literature about whether women's hormonal status influences their preferences for masculinity. In contrast to the findings of Gildersleeve et al. (2014), another meta-analysis conducted

by Wood et al. (2014) found no evidence that women in their fertile phase exhibit a stronger preference for short-term relationships with men presumed to have high genetic quality (i.e., high testosterone, masculinity, dominance). The authors attribute these conflicting findings to research that used broader, less precise methods of determining the fertile phase.

For instance, Harris (2011, 2012) failed to find support for the hypothesis that women are attracted to men with masculine faces when conception is likely but prefer men with feminine faces during other phases of the menstrual cycle. Despite some criticism of Harris's research, primarily concerning the small sample size and the use of counting methods to estimate fertility (DeBruine et al., 2010; Gildersleeve et al., 2013), other researchers have failed to support this effect (Jones, Hahn, Fisher, Wang, Kandrik, Han, Fasolt, et al., 2018; Peters et al., 2009; Stern et al., 2021). Moreover, the largest longitudinal study carried out to date on the hormonal correlates of women's preferences for facial masculinity (n = 584) did not find significant evidence that changes in women's salivary steroid hormone levels were related to their preferences for facial masculinity (Jones, Hahn, Fisher, Wang, Kandrik, Han, Fasolt, et al., 2018). Additionally, Stern et al. (2021) conducted a large within-subject study (n = 257), which included salivary hormone measurements and luteinizing hormone tests, but found no evidence of shifts in attraction to men's bodies throughout the menstrual cycle. There is also mixed evidence regarding preferences for masculinity in voices throughout the menstrual cycle. For instance, Jünger et al. (2018) found no evidence that cycle phase, conception risk, or steroid hormone levels influence women's preferences for masculine voices.

Overall, despite the mixed findings in the literature, there are reasons to believe that these discrepancies could be attributed to the method of hormonal measurement, the types of stimuli used, or both. For instance, Dixson et al. (2018) found that preferences for facial masculinity during the fertile phase were not captured using LH tests. However, consistent with the ovulatory shift hypothesis, rising estradiol (linked to increased fecundability) predicted a preference for more masculine faces, while high progesterone (linked to decreased fecundability) predicted a preference for more feminine faces (Dixson et al., 2018). Additionally, ovulatory shifts in women's preferences for masculinity in men were also observed in a speed-dating scenario, by estimating the probability of conception (Wu et al., 2022). This presents evidence against the notion that, if the effect exists, it would be too small to appear outside of a carefully controlled scenario using artificial stimuli. Therefore, during ovulation, one might expect a slowing down of subjective time (i.e., increased subjective duration) when in the presence of an attractive mate to collect and process as much information as possible about the potential partner.

2.2.4. The present study

Accordingly, the present study aims to test whether females' duration estimates of brief exposures to masculine faces and voices change during different phases of the menstrual cycle (fertile vs. non-fertile phase). In the fertile phase of the menstrual cycle, when women unexpectedly meet a masculine man, increased arousal levels should lead to longer perceived durations of that encounter. Therefore, our first hypothesis (H1) is that during the fertile phase of the cycle, women will judge the duration of briefly viewed attractive male photos to be longer than unattractive male photos, but not during the non-fertile phase. In addition, we expect that during the fertile phase, women will reproduce the recently viewed masculinized male photos longer than feminized male photos (H2). Finally, we predict that in the fertile phase of the cycle, the same effect will occur when exposed to auditory stimuli (i.e., longer perceived durations of briefly heard masculinized male voices than femininized male voices) but not during the non-fertile phase (H3).

2.3. Method

2.3.1. Participants

We recruited a total of 78 female participants. Of these, 14 attended the screening session but dropped out before the first experimental session. An additional nine participants dropped out after completing the menstruation phase, and five more dropped out after the ovulation phase. Reasons for dropout included difficulties obtaining a positive ovulation test (e.g., anovulatory cycle, unexpected cycle length variations) and participants' inability to attend the lab during specific periods (e.g., weekends, holidays, exams). This dropout rate (36%) is consistent with previous studies using similar methods (e.g., 42% in Gildersleeve et al., 2012, 39% in Gangestad et al., 2002, and 28% in Durante et al., 2008). Of the 50 participants who completed both phases of the experiment, two were excluded from the analysis because they did not meet the inclusion criteria for sexual orientation.

Therefore, our final sample consisted of 48 female participants aged 18 to 25 years (M_{age} = 20.78; SD = 1.90). An a priori power analysis was conducted using G*Power software (Faul et al., 2007) to determine the necessary sample size. The significance level (alpha) was set at 0.05, and the power was set at 0.80. The analysis revealed that a sample of 18 participants would provide sufficient power ($1-\beta \geq 0.80$) to detect a medium effect size (i.e., 0.25, Arantes et al., 2013; Tian et al., 2019; Zhou et al., 2021). For a more conservative effect size (i.e., 0.15), a sample of 49 participants would be required. A

posteriori power analysis using simr (Green & MacLeod, 2016), for 1000 simulations, revealed that our study had 80.40% power.

The participants met the following criteria: they were heterosexual or bisexual, were not using hormonal contraception (and had not been using hormonal contraceptives for at least one month), reported having a regular menstrual cycle (M_{days} = 29.3; SD = 2.5), and reported no hearing or visual uncorrected problems. Detailed characteristics of the participants are publicly available (Fernandes, 2024). The main characteristics can also be consulted in Appendix A (Table A.1). All participants gave their written informed consent, according to the Helsinki Declaration. They were recruited through institutional email and online social networks (e.g., Facebook), and each received a 30-euro voucher as compensation for their participation. Psychology students (n = 22) were granted course credits for their participation in addition to receiving the voucher (post-hoc analysis suggests no influence on the results).

2.3.2. Apparatus and stimulus

The experiment was conducted on an IBM-compatible PC, and responses were recorded using the mouse. The stimuli were presented on a gray background in the center of a 17″ LCD screen (1,920 × 1,080 pixels, 60 Hz). The experimental task was programmed in PsychoPy (v2022.1) (Peirce et al., 2022).

For the visual blocks, the neutral stimuli were circular Gabor discs, which are sinusoidal gratings modified by a Gaussian filter (Yao et al., 1995). In the present study, Gabor discs were identical, measuring 5 cm in diameter, oriented 10° clockwise from the vertical axis, and with a 3 cycles/disc frequency. The test stimuli comprised either color photos of attractive and unattractive adult males (attractiveness condition) or masculinized or feminized versions of adult male faces (sexually dimorphic condition).

The visual attractiveness block consisted of five attractive and five unattractive head and head-and-torso male photos as previously employed by Arantes et al. (2013). The visual sexually dimorphic set consisted of five individual male faces with neutral expressions that were masculinized and feminized using Psychomorph's (version 6) prototype-based computer graphics transformations (Rowland & Perret, 1995). Photos for both conditions were resized to 500 x 500 pixels and were displayed in the center of the screen at the same size as the Gabor discs. The photos used in the sexual dimorphism manipulation were selected from the Face Research Lab London Set (DeBruine & Jones, 2017). The female and male prototypes were created by averaging the shape, color, and texture of 30 female and 30 male faces. Then, masculinized and feminized versions were manufactured by adding or subtracting 50% of the linear

spatial differences between female and male prototypes to (or from) each male photo (see Tiddeman et al., 2001 for technical details).

All photos were assessed by a sample of 10 female raters (M_{age} = 21.9; SD = 3.24), who were asked to rate the attractiveness of each photo on a 10-point scale (1 = extremely unattractive; 10 = extremely attractive). The photos were presented in one of two random orders. The average rating of the attractive images was 8.32, while the unattractive photos received an average rating of 1.54, $t(9) = 28.03$, $p < .001$. The average attractiveness rating for the masculinized faces was 4.68, whereas, for the feminized faces, it was 3.70, $t(9) = 2.82$, $p = .006$. During debriefing, none of the raters or participants reported having recognized any of the men in the photos. Moreover, none of the participants involved in the validation process participated in the study.

For the auditory block, five men's voices were recorded, uttering the monophthong vowel /i/ with an iPhone 14 Pro in a soundproof booth from a distance of approximately 20 cm. To ensure the neutrality of the men's voices (neither masculine nor feminine), six female raters (M_{age} = 21.20; SD = 2.36) were asked to rate 10 male voices in terms of masculinity on a 10-point scale (1 = extremely feminine; 10 = extremely masculine). The voices were presented in a random order. The five voices classified as the most neutral were retained (M = 5.24; SD = 1.91). Upon debriefing, none of the raters or participants reported recognizing any voices. The voices were directly encoded onto a computer hard disk in mono at a 48.0 kHz sampling rate and 32-bit quantization using Audacity (Audacity Team, 2023). All acoustic manipulations were performed with the Praat Software version 6.1.50 (Boersma & Weenink, 2001).

Firstly, voices were compressed or stretched to values between 0.133 s and 2.1 s. Subsequently, voices were transformed by raising or lowering the fundamental frequency (pitch) (Feinberg et al., 2005). The fundamental frequencies were reduced by 20 Hz to masculinize the voices and raised by 20 Hz to feminize them. Finally, the amplitude of each sound was normalized to 70 dB. These manipulated voices were then presented to seven female raters (M = 21.03; SD = 2.23), who were asked to rate the voices for attractiveness on a 10-point scale (1 = extremely unattractive; 10 = extremely attractive). The voices were presented in a random order. The average rating of the masculinized voices was 5.80, while the average rating for the feminized voices was 4.17, $t(6) = 3.48$, $p < .001$. Upon debriefing, none of the raters or participants reported having recognized any of the male voices. Furthermore, none of the participants involved in the validation process participated in the study.

2.3.3. Ethics

This study was approved by the Ethics Committee for Research in Social and Human Sciences of the University of Minho (CEICSH 056/2021; Appendix E).

2.3.3. Procedure

Before the experimental sessions, participants completed questions related to the inclusion criteria and received instructions regarding the experimental procedure and the ClearBlue© Digital Ovulation Test. These tests measure luteinizing hormone (LH) in urine, which rises approximately 24-48 hours before ovulation (Testart & Frydman, 1982). The manufacturer, Swiss Precision Diagnostics, asserts that this product can identify the two most fertile days with an accuracy rate of over 99%. This claim is supported by independent research showing that LH tests are 97% accurate in confirming ovulation as detected by ultrasound (Guermandi et al., 2001). Subsequently, participants performed the experimental task during their menstruation and ovulation phases of the menstrual cycle. For the menstruation phase, participants came to the lab within 3 days after the onset of menses. Regarding the ovulation phase, participants took an ovulation test every morning on specific days.

The calculation for the first day's test involved dividing the average length of the participant's menstrual cycle by two (indicating theoretical ovulation occurrence) and then subtracting 5 days from that result. Upon receiving a positive result on the test, participants came to the lab to perform the experimental task corresponding to the ovulation phase. If they could not come to the lab within 48 hours after the positive result (when the chances of pregnancy were highest), the ovulation experimental task would be postponed until the next ovulation cycle. Out of the 48 participants, 28 began the experiment during the menstruation phase, while 20 started during the ovulation phase.

For the experimental task, participants were tested in individual sound-isolated booths and seated approximately 60 cm away from the monitor while wearing headphones. They were informed that they would see or hear sequences of five stimuli and were instructed to reproduce the duration of the fifth stimulus in each sequence by pressing the left mouse button for as long as they thought the stimulus was presented to them. After the duration reproduction of the fifth stimulus, the following trial would start precisely 2 seconds (s) later. Before beginning the experimental trials, participants completed three practice trials. These practice trials involved stimuli that were either Gabor discs or neutral auditory stimuli, depending on the block.

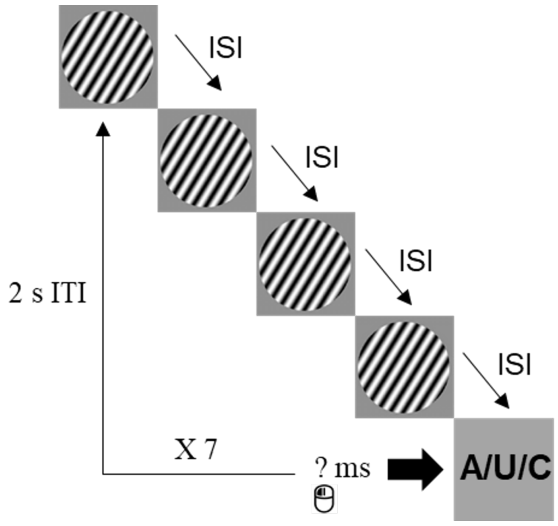
The experimental task consisted of three test blocks, each consisting of 105 trials, with a 5-minute interval between blocks in which participants engaged in a filler task. In each test block, either

attractive/unattractive male photos or masculinized/feminized male photos or voices were used as test stimuli. The order of the blocks was counterbalanced across participants. In the visual stimuli blocks, in each trial four Gabor discs were displayed for a similar duration, separated by an inter-stimulus interval (ISI), and followed by a test stimulus. In one-third of the trials, the test stimulus was either a Gabor disc (neutral condition), an attractive/masculinized male photo (attractiveness/sexual dimorphism conditions), or an unattractive/feminized male photo (attractiveness/sexual dimorphism condition). In the auditory stimuli block, four 600 Hz sine wave sounds were played for a similar duration, separated by an ISI and followed by a test stimulus. In one-third of the trials, the test stimuli were either the 600 Hz sine wave sound (neutral condition), a masculinized male voice (masculinized condition), or a feminized male voice (femininized condition).

Similar to Arantes et al.'s (2013) study, we used seven possible stimulus durations in millisecond intervals: 133 ms, 233 ms, 300 ms, 383 ms, 533 ms, 1050 ms, and 2100 ms, each occurring on an equal number of times (pseudorandomly distributed). Moreover, each of the three conditions (neutral, attractive/masculinized, unattractive/feminized) had five replications at each duration per block. The five attractive/masculinized and unattractive/feminized stimuli were presented once at each duration. The ISIs within a trial varied by +/- 10% of the stimuli duration to ensure that participants would respond to the stimuli duration and not a beat or rhythm that might occur if the ISI was kept constant throughout the trial (Tse et al., 2004). The experimental task for the visual attractiveness condition is illustrated in Figure 1.

Figure 1

The oddball task for the visual attractiveness condition



Note. A – attractive male photo; U – unattractive male photo; C – control (Gabor disc); ISI – inter-stimulus interval; ITI – inter-trial interval; ms – milliseconds.

2.3.4. Data Analysis

In a preprocessing stage, following Tukey's (1977) method of outlier detection, trials that were larger than the third quartile plus 1.5 times the Interquartile range (IQR) ($>_{q0.75}$ + 1.5×IQR) or smaller than the first quartile minus 1.5 times the IQR ($<_{q0.25}$–1.5×IQR) were removed from the analysis (5% of the visual attractiveness and auditory dimorphic block; and 7% of the visual dimorphic block), to increase the signal to noise ratio. However, results regarding statistical comparisons were unchanged if these trials were included. Statistical analysis was performed using R (R Core Team, 2022) in RStudio Version 2022.2.2.485 (RStudio Team, 2022). The data and reproducible code are publicly available (Fernandes, 2024).

The log-transformed reproduced duration was entered as the dependent variable in a linear mixed-effects model (LMM), with by-subject random intercepts. Multilevel modeling was used to account for the nesting of the choice data. The triple interaction term of block (visual attractiveness vs. visual dimorphic vs. auditory dimorphic), trial type (attractive/masculinized vs. unattractive/feminized vs. control), and phase of the cycle (menstruation vs. ovulation), as well as the three main effects, were included as fixed terms. We also tested additional models, controlling for the order of the menstrual cycle phase in which the participant completed the experiment and their relationship status, but these factors did not influence our results. Therefore, the most parsimonious model was kept.

2.4. Results

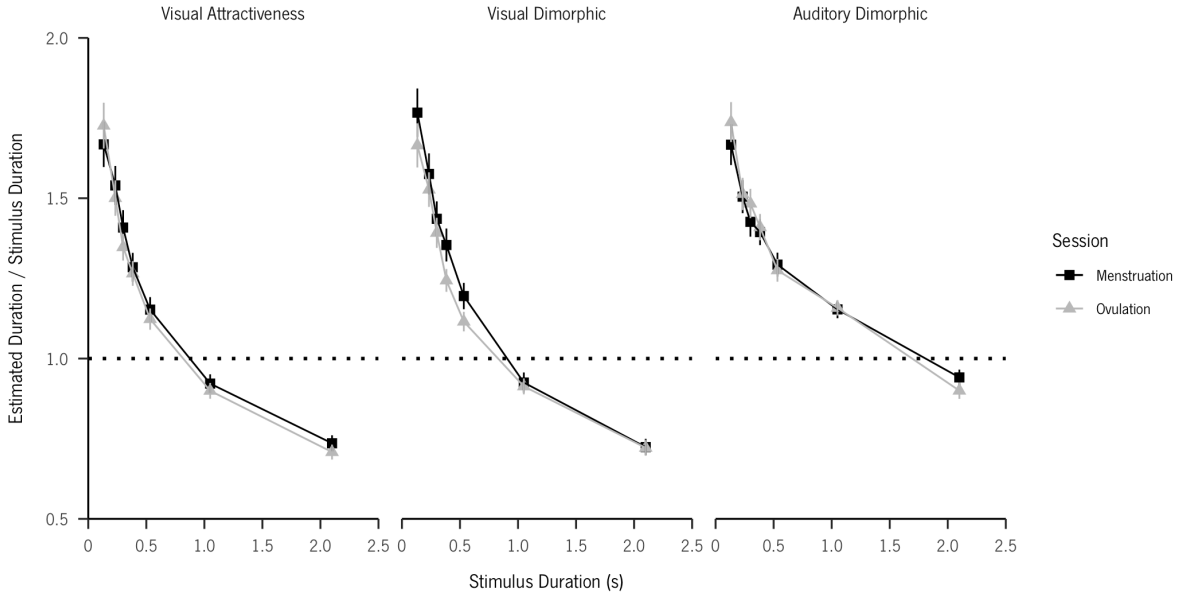
2.4.1. Vierordt's Law

We initially assessed whether reproduced durations in both phases of the cycle conformed to Vierordt's Law (1868), which states that shorter intervals are typically overestimated, while longer intervals are underestimated (for a review, see Lejeune & Wearden, 2009). For each phase (ovulation/menstruation) and block (visual attractiveness/visual dimorphic/auditory dimorphic), we calculated the ratio of each estimated duration to the objective duration and averaged these ratios over condition (neutral/attractive/unattractive) for each participant. Results are shown in Figure 2. In the visual blocks (attractiveness and dimorphic), durations were overestimated for stimuli shorter than 1.05 s and underestimated for stimuli lasting 1.05 s or 2.1 s in both phases, aligning with expectations based on Vierordt's Law. In the auditory dimorphic block, durations were overestimated for stimuli shorter than 2.1 s and underestimated for stimuli lasting 2.1 s for both phases, which also conforms to Vierordt's Law,

and is consistent with previous findings reporting longer perceived durations of auditory stimuli (e.g., Goldstone & Goldfarb, 1964; Noulhiane et al., 2009; Wearden et al., 1998).

Figure 2

The ratio of estimated duration to stimulus duration for each block averaged across test and control trials



Note. Bars indicate one SE.

2.4.2. Linear mixed-effects model (LMM)

The Linear mixed-effects model (LMM) included the main effects of block type, trial type, menstrual cycle phase, and their three-way interaction term, as fixed terms. Also, we controlled for trial duration, by including this factor as a fixed term in the model. The log-transformed time reproduction was entered as the dependent variable. Participant code was entered as a random intercept. The analysis revealed that 56.9% of the variance ($R^2_{marginal}$ = 0.569) could be attributed to the fixed effects alone. The $R^2_{conditional}$ was found to be 0.701, suggesting that 70.1% of the variance is explained by the combined fixed and random effects.

The model showed a significant main effect for trial type, $F(2, 28348) = 39.53$, $p < .001$, for block, $F(2, 28349) = 286.59$, $p < .001$, and for trial duration, $F(7, 28348) = 7609.74$, $p < .001$. Additionally, the two-way interaction between trial type and block was statistically significant, $F(4, 28348) = 24.37$, $p < .001$. The main effect of session was not statistically significant, $F(1, 28352) = 0.64$, $p = .42$. Also, neither the interaction of session and trial type, $F(2, 28348) = 2.40$, $p = .09$, nor the interaction of session and block, $F(2, 28349) = 2.19$, $p = .11$, However, the three-way interaction of session, trial type and block showed significant results, $F(4, 28355) = 3.09$, $p = .01$. The average reproduction

durations across all conditions in both phases of the menstrual cycle are illustrated in Figure 3. Also, visualizations of time reproductions for each of the seven durations across the various conditions are provided in Appendix A (Figure A.1, Figure A.2, Figure A.3).

Since a significant three-way interaction was found between session, trial type, and block, post-hoc comparisons using the Tukey adjustment were performed (Table 1). Post-hocs revealed that the influence of the cycle phase was only observed for the auditory sexually dimorphic block, with masculinized voices being perceived for longer than feminized ones exclusively in the ovulation phase ($p < .001$). While for the visual attractiveness block, attractive faces were perceived as longer than unattractive ones, both for the ovulation ($p < .001$) and menstruation phase ($p < .001$). No differences were found for the visual sexually dimorphic block.

Table 1

*Tukey HSD Comparison for Block Type*Trial Type*

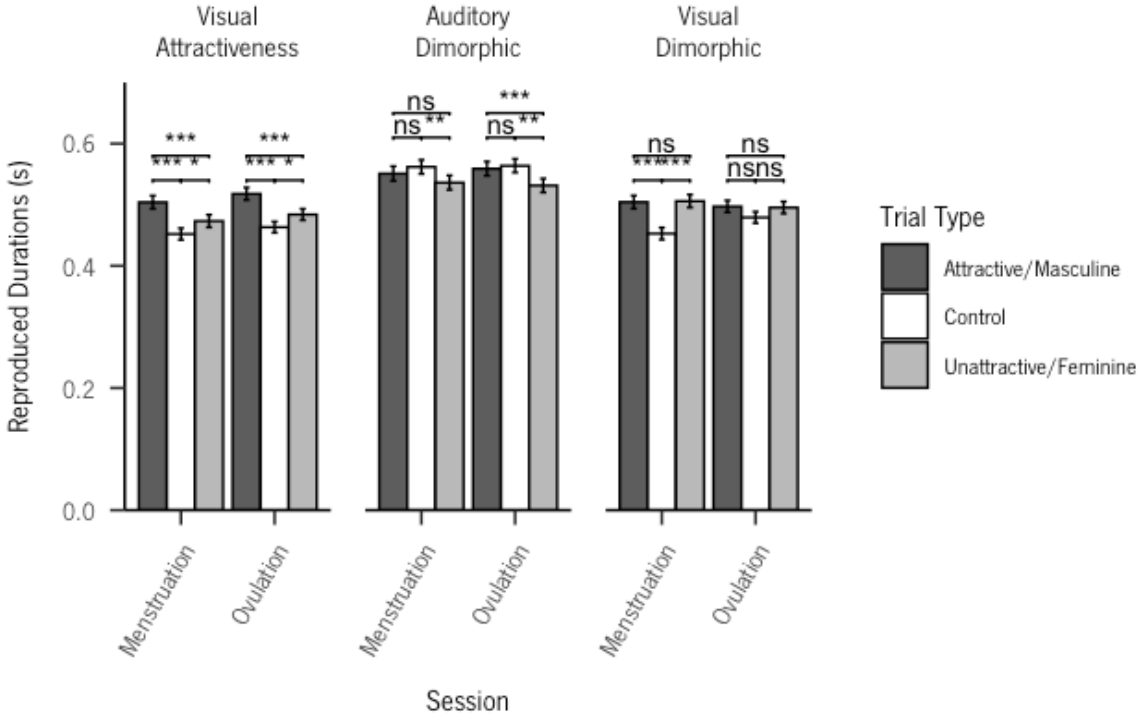
Session	Block Type	(I) Trial Type	(J) Trial Type	Mean Diff (I-J)	Std. Error	*d*	*t*	95% Confidence Interval	
								Lower Bound	Upper Bound
Ovulation									
	Visual Attractiveness	attractive	control	.11***	0.02	0.25	7.12	0.18	0.32
		attractive	unattractive	.07***	0.02	0.15	4.48	0.09	0.23
		control	unattractive	-.04*	0.02	-0.09	-2.64	-0.16	-0.02
	Visual Dimorphic	masculine	control	.04	0.02	0.08	2.33	0.01	0.15
		masculine	feminine	.01	0.02	0.01	0.28	-0.06	0.08
		control	feminine	-.03	0.02	-0.07	-2.04	-0.14	-0.01
	Auditory Dimorphic	masculine	control	.01	0.02	0.01	0.15	-0.06	0.07
		masculine	feminine	.06***	0.02	0.13	3.65	0.06	0.20
		control	feminine	.06**	0.02	0.12	3.51	0.05	0.19
Menstruation									
	Visual Attractiveness	attractive	control	.11***	0.02	0.24	6.79	0.17	0.31
		attractive	unattractive	.06***	0.02	0.14	3.88	0.07	0.21
		control	unattractive	-.05*	0.02	-0.1	-2.91	-0.17	-0.03
	Visual Dimorphic	masculine	control	.11***	0.02	0.24	6.74	0.17	0.31
		masculine	feminine	-.01	0.02	-0.01	-0.12	-0.7	0.07

	control	feminine	-.11***	0.02	-.0.25	-6.85	-0.32	-0.18
Auditory Dimorphic	masculine	control	-.03	0.02	-0.06	-1.58	-0.13	0.01
	masculine	feminine	.03	0.02	0.06	1.68	-0.01	0.13
	control	feminine	.05**	0.02	0.11	3.25	0.05	0.19

Note. * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 3

Average reproduced durations by menstrual and ovulation phases across all conditions



Note. Bars indicate 95% CI; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

2.5. Discussion

The current study aimed to investigate whether females' estimated duration of 1) briefly viewing opposite-sex attractive/unattractive faces and 2) briefly viewing and hearing opposite-sex sexually dimorphic (masculinized/feminized) faces and voices would depend on the menstrual cycle phase. Based on an evolutionary perspective, we expected that during the fertile phase of the cycle, attractive and masculinized stimuli would be perceived as longer than unattractive ones, but not during the non-fertile phase.

This prediction was tested in a visual and auditory oddball task in which participants viewed and heard series of five stimuli of equal duration and had to reproduce the duration of the last stimulus by

pressing the mouse button. The first four stimuli on each trial were either circular sine-wave gratings (visual oddball) or 600 Hz sine waves (auditory oddball). The last stimulus could be either an identical stimulus (control condition), an attractive/unattractive male photo (attractiveness block), a masculinized/feminized male facial picture (visual sexually dimorphic block), or a feminized/masculinized male voice (auditory sexually dimorphic block).

We found evidence supporting a shift in time perception during the menstrual cycle regarding sexually dimorphic voices (H3). Specifically, we observed that masculinized male voices were reproduced for longer durations than feminized voices during ovulation, but this effect was not present during menstruation. However, we did not find evidence supporting a shift in the time perception of visual stimuli related to attractiveness across the menstrual cycle, neither in the attractiveness block (H1) nor in the sexually dimorphic block (H2). Nonetheless, we successfully replicated previous findings in the literature, demonstrating that briefly viewed attractive faces were reproduced for longer durations than unattractive ones.

2.5.1. Visual Attractiveness

Our first hypothesis (H1) posited that during the fertile phase of the cycle, women would perceive the duration of briefly viewed attractive male photos as longer than unattractive male photos, but not during the non-fertile phase. We observed an overestimation of attractive images in both phases of the cycle. Our results replicate previous findings that support the role of arousal mechanisms in the temporal dilation effect of attractiveness (Arantes et al., 2013, 2021; Tian et al., 2019; Zhou et al., 2021) and contrast to previous research suggesting either an underestimation of unattractive faces (Ogden, 2013) or attractive faces (Sano et al., 2022). However, contrary to our hypothesis and Arantes et al.'s (2013) suggestion, our data does not provide evidence to support the influence of the menstrual cycle on the effect of attractiveness on time perception.

The lack of a moderating role for the menstrual cycle could be attributed to the specific phases in which the participants were tested (ovulation and menstruation) or to the nature of the experimental task employed. In a study of electroencephalography (EEG) activity related to the perception of visual stimuli during different phases of the menstrual cycle (Makarchouk et al., 2011), higher activation was found for both negative and positive emotional visual stimuli during the follicular phase, while minimum activation during ovulation was observed. Conversely, erotically colored visual stimuli induced the most intense changes in the EEG during the ovulatory phase. Surprisingly, these brain activity changes were restricted to the post-stimulus time interval and were not observed while viewing the pictures. Therefore,

during our experiment, participants may have experienced heightened arousal in response to emotional stimuli during the menstruation phase, potentially explaining the observed longer perceived durations. Finally, since participants estimated the reproduced duration immediately after the stimulus onset, we may not have captured the prolonged and sustained effects of erotic stimuli during the ovulatory phase.

It is important to note that the literature does not clarify the hypothesis that changes in the visual perceptual system across the menstrual cycle are directly linked to patterns of fluctuating hormone levels. Kopell et al. (1969) found that women tend toward higher values for a two-flash threshold task premenstrually, indicating decreased perceptual ability. This result suggests lower arousal during the premenstrual phase of the cycle but not during the ovulation or the menstrual phase. Similarly, Ward et al. (1978) found an impaired performance in visual detection, both in threshold and sensitivity, during the premenstrual phase. Additionally, they rejected the hypothesis that performance deterioration could be explained by mood changes associated with the menstrual cycle, pointing to physiological changes instead. Thus, these findings might provide alternative explanations for the lack of interaction between the effect of attractiveness on time perception and the menstrual cycle phase.

2.5.2. Visual Sexually Dimorphic

Our second hypothesis (H2) stated that during the fertile phase, women would perceive masculinized male photos as being presented for longer than feminized male photos. However, no differences were found between masculine and feminine male faces. In fact, although not statistically significant, the average reproductions for feminine faces were higher than those for masculine faces. Considering this, we would like to discuss the absence of evidence supporting differences in time reproduction between viewing masculine and feminine faces.

Although many studies have reported that women prefer masculine faces (Feinberg et al., 2005; Little, Jones, et al., 2008; Stower et al., 2020), some studies challenge these findings. For instance, Perret et al. (1998) suggested a stronger preference for feminine male faces. The authors found that enhancing masculinity in male faces increased perceived dominance and negative attributions (coldness or dishonesty). Further research revealed that under conditions of environmental harshness, such as scarcity of resources or high stress, women tend to prefer less masculine male faces for long-term relationships (Little, Cohen, et al., 2007; Little, Burriss, et al., 2008). Additionally, a cross-cultural study (Marcinkowska et al., 2019) showed that women's preference for more masculine men is more robust in countries with higher economic and national health indexes, which also supports the idea that men with higher levels of testosterone are believed to invest less in relationships.

The notion that women's preferences for facial masculinity are related to their hormonal status is also highly controversial in the literature. For example, neither Harris (2011) found evidence for a greater preference for masculine faces when fertilization was likely, nor support for a link between women's preferences for facial masculinity and their hormonal status was found (Jones, Hahn, Fisher, Wang, Kandrik, Han, Fasolt, et al., 2018). Similarly, in a recent study using an eye-tracking paradigm, Garza and Byrd-Craven (2023) failed to find shifts in women's visual attention to facial masculinity across the menstrual cycle. DeBruine et al. (2010) highlight that the absence of an effect could be attributed to either the use of hormonal contraceptives or the reliance on conventional estimation techniques (i.e., counting methods for ovulation detection). Although we used ovulation test kits to accurately detect the fertile phase, we did not collect other hormonal measures.

2.5.3. Auditory Sexually Dimorphic

Our results support our third hypothesis (H3), that during the fertile phase, participants would perceive the durations of briefly heard masculinized male voices as longer than femininized male voices, but not during the non-fertile phase. Our findings align with previous research concerning women's cycle shift preference towards men's voices (Pisanski et al., 2014; Puts, 2005, 2006). This may be explained by the notion that during ovulation, women may aim to maximize their chances of conception by preferring men with better genetic traits (for a review, see Gildersleeve et al., 2014). Since this cycle's shift was not observed in the visual modality, one might reason that women's heightened speech perception during ovulation could account for this difference (Anderson et al., 2020; Guimaraes et al., 2006; Sao & Jain, 2016).

On the other hand, our findings contrast with recent research, which has found no evidence that cycle phase, conception risk, or steroid hormone levels affect women's preferences for masculine voices (Jünger et al., 2018). Instead, the authors found an increased attraction to men's voices during ovulation, regardless of how masculine they sounded. This general shift in women's voice preferences is supported by additional studies suggesting that hormonal changes during the menstrual cycle influence overall sexual desire but not a desire for uncommitted sexual relationships (Jones, Hahn, Fisher, Wang, Kandrik, & DeBruine, 2018; Roney & Simmons, 2016). However, our results do not support these findings, as they did not indicate an overall overestimation of male voices during the fertile phase. Specifically, there were no significant differences in temporal reproduction between male voices and the control stimulus (600 Hz sine wave sounds).

Although we cannot directly compare our results with those of previous studies on cyclical shifts in preferences for masculine voices, as our focus was on time perception rather than attractiveness perception per se, some distinctions should still be addressed. Puts (2005, 2006) recorded male participants attempting to attract a female, while in our study, participants heard just the vowel /i/. This difference is noteworthy, as the length and type of auditory stimuli are known to influence attractiveness perception. For instance, Ferdenzi et al. (2013) demonstrated that the perceived attractiveness of hearing the word "hello" was higher than that of hearing a single vowel. However, Jünger et al. (2018) recorded male voices reading an excerpt from a standard voice passage and found no evidence of a cycle shift in women's preferences for masculinized voices. Therefore, the content of the message (e.g., attempting to attract a female) and its duration may interact to influence perceived attractiveness, thereby affecting the perceived duration.

2.5.4. Limitations and further studies

Some limitations of the present study should be mentioned. First, our sample was primarily comprised of relatively young Portuguese bisexual or heterosexual females. Additional research should explore the possible moderator role of the menstrual cycle in the effect of attractiveness on time perception across different cultural settings and age groups.

Also, the study of additional sexual orientations, such as homosexuality, may provide significant contributions to the underlying mechanisms regarding the influence of hormonal changes on cognitive processes. For example, testing whether homosexual women show differences in time reproductions during different phases of the cycle when viewing/hearing male or female faces/voices compared to heterosexual ones.

Additionally, by manipulating attractiveness/sexual dimorphism within blocks of trials but manipulating the type of stimuli/modality (visual attractiveness/visual dimorphic/ auditory dimorphic) between blocks, we used the most convenient design to address our research questions. These questions centered on whether perceived attractiveness would influence time perception during ovulation. However, this design limits our ability to address other questions, such as whether the perceived duration between viewing attractive vs. masculinized male photos would differ for a given phase of the cycle.

Furthermore, future studies should explore a possible interaction effect between facial expressions and attractiveness on time perception. The influence of angry faces on time perception, which has been shown to increase duration estimates, is well established (Droit-Volet et al., 2004). Moreover, the interaction between angry faces and attractiveness has been explored, suggesting an overestimation

of angry attractive faces, but not of unattractive faces, compared to neutral ones (Tomas & Španić, 2016). However, there is no evidence of a possible interaction between happiness and attractiveness on time perception. Although the type of facial expressions was controlled for each set of stimuli (attractive/unattractive), emotions with positive valence may have enhanced the subjects' arousal toward the attractive male models but not toward the unattractive photos (Main et al., 2010). Therefore, a ceiling effect on the preference for attractive faces might have occurred, and this should be investigated in future studies.

In the present study, voices were stretched or compressed to achieve the desired time interval ranges, which respectively lowers or raises the pitch. This adjustment was made before pitch manipulation to ensure objective differences between masculinized and feminized male voices. However, future research should investigate whether using more natural stimuli, such as reading text excerpts of varying lengths and collecting testosterone measurements from male vocal donors, might influence women's time perception of male voices. Additionally, further research should explore whether differences in time perception emerge in cross-modal scenarios by presenting videos that combine attractive visual and auditory features of males. Moreover, the research field of attractiveness time perception could be extended to other sensory modalities. For example, olfactory cues have been linked to influence both visual attractiveness (Demattе et al., 2007) and time perception (Millot et al., 2016). Furthermore, the menstrual cycle may play an important role in these effects, as positive associations between body odor and attractiveness were found only when female odor raters were in the most fertile phase of their menstrual cycle (Jan et al., 2005; Rikowski & Grammer, 1999).

Another important question for future research is whether results would vary for other phases of the hormonal cycle, for example, pre-menstrual, mid-luteal, and mid-follicular. Our design only compared the ovulatory and menstrual phases, which may not fully capture the hormonal variation throughout the cycle. Estradiol levels are significantly higher during the ovulation phase than in the menstrual phase, while progesterone levels remain relatively low in both phases. Although evidence suggests that changes in estradiol during the cycle predict shifts in preferences for masculinity cues (Dixson et al., 2018; Pisanski et al., 2014), other researchers have not found support for this effect (Jones et al., 2019; Marcinkowska et al., 2019). An alternative explanation is that preferences for femininity may be strongest when progesterone levels are elevated (Jones et al., 2005). Additionally, there is some concern that women's awareness of their menstrual status could influence the results (Durante et al., 2008; Kowalski & Chapple, 2000; Wister et al., 2013), rather than hormonal changes per se. Therefore, further studies should collect

salivary samples to compare hormonal differences (e.g., estradiol, and progesterone) within participants across different phases of the cycle.

Finally, we suggest that future studies attempt to replicate our findings using different time perception tasks, such as temporal bisection or verbal estimation tasks. When replicating the present work, it may be interesting to include some psychophysiological measures, like eye-tracking, EEG, skin conductance response (SCR), and heart rate (HR), to gain additional insights on the additive or multiplicative influence of arousal and attention on time perception. Moreover, researchers have shown that more attractive women will show stronger preferences for both facial (Docherty et al., 2020) and vocal masculinity in men (Vukovic et al., 2010). Hence, future studies should explore whether the attractiveness of participants has an impact on the observed results.

2.5.5. Conclusions

The results of the present study indicate that hormonal changes associated with the menstrual cycle modulate women's auditory perception of sexually dimorphic male voices. Longer time estimates were observed for masculinized male voices during the fertile phase but not during menstruation. Additionally, we replicated previous findings regarding the dilation effect of attractive faces on time perception. However, no differences in time estimations were found between masculine and feminine male faces. Future research could build on these findings by exploring alternative methodologies, such as collecting hormonal salivary samples and extending data collection to other phases of the menstrual cycle. Overall, our findings align with the literature on the acceleration of the internal clock related to attractiveness perception. Lastly, this study provides initial evidence for an adaptive time perception mechanism influenced by the menstrual cycle.

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CHAPTER 3

Empirical Study 2:
Time Perception and Emotional Facial Expressions:
The Influence of Attractiveness and Sexual Dimorphism

3. Time Perception and Emotional Facial Expressions: The Influence of Attractiveness and Sexual Dimorphism

Fernandes, N., Costa, D., & Arantes, J. (submitted). Time Perception and Emotional Facial Expressions: The Influence of Attractiveness and Sexual Dimorphism.

In addition, results from this empirical work were presented in the following scientific event:

Fernandes, N., Costa, D., Mello, B., & Arantes, J. (2023, 31 March – 1 Abril). The interaction effect between attractiveness and emotions on time perception [Poster Presentation]. 17.º Encontro Nacional da Associação Portuguesa de Psicologia Experimental [17th National Meeting of the Portuguese Association of Experimental Psychology]. Lisboa, Portugal.

All data, analysis code, and research materials are available at:

Fernandes, N. F. R. (2024). Time Perception and Emotional Facial Expressions: The Influence of Attractiveness and Sexual Dimorphism. https://doi.org/10.17605/OSF.IO/6VXRW

Additionally, supplemental materials can be found in Appendix B.

3.1. Abstract

Accurately perceiving the passage of time is crucial for adaptive behavior, yet the factors influencing this perception, such as emotional and physical cues, remain poorly understood. Research suggests that emotional facial expressions are associated with a lengthening of perceived time, likely due to a physiological arousal response to emotional stimuli. Similarly, attractive stimuli, such as viewing attractive opposite-sex faces, engage our appetitive motivational system, resulting in a time-dilation effect. Furthermore, previous research has identified that attractiveness moderates the overestimation of time for angry faces compared to neutral ones. This study extends these findings by investigating whether this effect occurs in both sexes and across a broader range of facial expressions. Additionally, we examined the influence of sexual dimorphism on this effect. A total of 144 participants (82 females, 62 males) were enrolled in the attractiveness or sexual dimorphism group. They were presented with a series of five stimuli and were asked to reproduce the duration of the last stimulus by pressing a mouse button. The final stimulus in the series included attractive and unattractive (attractiveness group) or masculinized and feminized (sexual dimorphism group) opposite-sex faces displaying anger, happiness, or neutral expressions. The results did not reveal significant differences in time perception across the various conditions, contradicting previous findings on the time dilation effect associated with emotionality and attractiveness. However, participants' evaluations of attractiveness and arousal were consistent with previous findings. Angry faces elicited higher arousal, while happy faces were perceived as the most attractive. Feminized female faces were rated as more attractive than their masculinized counterparts, whereas no significant differences were observed between the feminized and masculinized versions of male faces. Further research is needed to determine whether the time dilation effect reported in earlier studies is specific to certain experimental tasks or stimuli, as its relevance to everyday situations may be limited.

Keywords: arousal; attractiveness; facial expressions; sexual dimorphism; time perception

3.2. Introduction

The human experience of time is a complex and subjective phenomenon that profoundly shapes how we perceive and engage with events. The ability to estimate time accurately is essential for a wide range of activities, including planning and pursuing long-term goals (Buhusi & Meck, 2005; Chen & Zhao, 2024). Time perception allows living organisms to synchronize their internal biological cycles with the external environment cues, a crucial adaptation for both reproductive success and survival (Haigh et al., 2020).

Research indicates that humans can make precise time estimations within the range of milliseconds to hours (Buhusi & Meck, 2005). It is commonly believed that positive experiences make time seem to pass quickly, while negative or unpleasant moments are often perceived as dragging Arantes et al. (2021). Numerous studies have shown that our sense of time is influenced by both internal and external factors (for a review, see Block & Gruber, 2014). For example, research has indicated that emotions (for a review, see Droit-Volet & Gil, 2009; Schirmer, 2011) and attraction (Arantes et al., 2013, 2021; Ogden, 2013; Sano et al., 2022; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021) play an important role in shaping time perception.

3.2.1. The Scalar Expectancy Theory

The scalar expectancy theory (SET), proposed by Gibbon et al. (1984), remains the most influential model for understanding time perception. According to SET, both humans and animals have an internal clock responsible for the subjective evaluation of time. This clock is constituted by three core components: a pacemaker, a switch, and an accumulator. The pacemaker generates pulses at a specific rate which must pass a switch that closes at the onset and opens at the offset of the timed interval, thereby allowing the pulses to be stored in the accumulator. As the physical time duration increases, more pulses gather in the accumulator, leading to the perception of longer time intervals. To make temporal judgments, a comparator mechanism assesses the current pulse count in the accumulator and compares it to stored values in memory from prior experiences. This comparison determines whether the timed interval has lasted for a similar duration.

3.2.2. Emotions and Time Perception

The complex interaction between emotions and time perception is a well-studied area in time perception literature (for a review, see Droit-Volet & Gil, 2009). Research suggests that negative or

stressful situations tend to lengthen subjective time perception (Anderson et al., 2007; Campbell & Bryant, 2007; Danckert, 2005; Droit-Volet et al., 2013; Langer et al., 1961; Noulhiane et al., 2007; Thayer & Schiff, 1975). From an evolutionary perspective, when facing a threat, the internal clock accelerates under the influence of dopamine, preparing the organism for action (Darwin, 1872).

Considerable research has focused on the perceived duration of faces displaying different emotions, with findings that angry and fearful faces are perceived as lasting longer than neutral ones (Droit-Volet et al. 2004; Droit-Volet & Meck 2007; Gil et al. 2007; Kliegl et al., 2015). These studies report longer perceived durations of angry and fearful faces than the neutral ones. The early emergence and cross-cultural aspect of emotion recognition suggest that this is an innate mechanism (Ekman, 1993) that modulates social interactions (Russel & Fernandez-Dols, 1997). The ability to anticipate others' emotions and adjust our emotional response to those facial expressions is essential for efficient social interactions (Russel & Fernandez-Dols, 1997). Thus, the longer perceived length of threatening facial expressions suggests an automatic process linked to the activity of dopaminergic pathways, as discussed by Droit-Volet and Gil (2009).

Despite substantial literature on the effect of angry facial expressions on time perception, fewer studies have investigated the impact of other facial expressions on time perception. Droit-Volet et al. (2004) found that emotional faces (anger, happiness, and sadness) were overestimated compared to neutral ones. However, these differences were greater for anger and happiness than for sadness, whereas no difference was found between anger and happiness. However, Tipples (2008) reported unexpected findings, showing that angry facial expressions led to a greater overestimation of time compared to both happy and fearful expressions. The author states that angry expressions have a greater effect on time perception by evoking a fear-specific adaptative defense mechanism (Ohman & Mineka, 2001), which is relevant to human survival by preparing the organism to face eminent threats (Tipples, 2008).

Consistent with this adaptative mechanism, Tomas and Španić (2016) found that angry faces were overestimated compared to neutral ones, but only for attractive faces. This effect was not observed for the unattractive faces. Recent research demonstrated attractiveness influences emotion recognition. Li et al. (2019) found a recognition bias toward attractive happy faces in both static and dynamic conditions. Similarly, Qiongsi et al. (2022) reported that participants recognized micro-expressions, which are rapid and involuntary facial movements lasting 40–200 ms, more quickly on attractive faces compared to unattractive ones. Furthermore, several studies have explored the impact of emotional expressions on perceived facial attractiveness, raising questions about the stability of physical attractiveness as a trait (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984). For example,

negative emotions like anger can reduce the perceived attractiveness of facial images, while happiness enhances it compared to the same person displaying a neutral expression (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984). From an evolutionary standpoint, the preference for happy faces could be explained by the positive influence of health on happiness. Biological and health factors such as neurotransmitters (e.g., dopamine and serotonin), cortisol and adrenaline (adrenal gland), and oxytocin (pituitary gland) play an important role in controlling happiness (Dfarhud et al., 2014).

3.2.3. Attractiveness and Time Perception

Physical attractiveness plays a significant role in various aspects of our lives, influencing initial impressions and social interactions. This attractiveness halo effect was first discovered by Dion et al.'s (1972), who found that physically attractive people were judged to possess more socially desirable characteristics, such as happiness, marital competence, and future occupational success. Viewing attractive individuals of the opposite sex triggers automatic cognitive processes, leading to rapid attractiveness judgments (Kaiser & Nyga, 2020). Indeed, Bradley et al. (2001) found that viewing erotic photographs leads to increased skin conductance, cardiac deceleration, and startle reflex modulation, in both men and women. Moreover, when women viewed photos of their boyfriends and famous male actors, their pupils dilated, indicating an increase in their autonomic arousal (Laeng & Falkenberg, 2007). This response aligns with the arousal models of attractiveness and time perception (Arantes et al., 2013, 2021; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021). This occurs because higher arousal levels accelerate the pacemaker, causing more pulses to be emitted and gathered in the accumulator (Droit-Volet et al., 2004).

Studies on attractiveness and time perception have used various types of stimuli, including same-sex faces (Ogen et al., 2013; Tomas & Španić, 2016), opposite-sex faces (Arantes et al., 2013; Tian et al., 2019), and even meaningless figures (Sano et al., 2022) to investigate this effect. For example, Arantes et al. (2013) found that female participants overestimated the duration of attractive opposite-sex faces compared to unattractive ones. Later, Tian et al. (2019) replicated this time dilation effect for attractive opposite-sex faces using a sample consisting of both male and female participants. Additionally, in a real-life speed dating context, Arantes et al. (2021) observed that women overestimated the duration of encounters with attractive opposite-sex partners, while men underestimated it. The authors suggest that women allocate more cognitive resources to selecting a potential partner than men (Arantes et al., 2021). Building on this, Zhou et al. (2021) empirically investigated whether arousal influences the

relationship between attractiveness and time perception in male participants, showing that increased arousal mediates the temporal dilation effect when viewing attractive opposite-sex faces.

Contrary to these findings, Ogden (2013) reported that female participants underestimated the duration of viewing unattractive same-sex faces compared to attractive and neutral ones, suggesting a potential role of attention in time perception (Block et al., 2010; Zakay & Block, 1996, 1997). Supporting the role of attention on time estimation, but in contrast to Ogden's (2013) findings, Sano et al. (2022) found an underestimation of attractive faces, suggesting that attention to attractive stimuli distracted participants from time estimates (Experiment 1). Also, the authors explored whether presenting meaningless attractive and unattractive figures would yield similar results, but no differences in time perception were found (Experiment 2). This suggests that time perception related to attractiveness may be shaped by specific stimuli, reflecting an underlying evolutionary mechanism, while null findings might be explained by confounds such as perceived threat and indicators of sex differences in the figure's shape. For example, research has shown that angular shapes convey threat (Aronoff et al., 1992; Blazhenkova & Kumar, 2018), eliciting an avoidance response comparatively to curved shapes (Palumbo et al., 2015).

These angular and curved geometric shapes are present in facial expressions of anger and happiness, respectively (Aronoff et al., 1992). Thus, angular shapes may convey physical threat and social dominance, whereas curved shapes are associated with cooperativeness, acceptance, and alliance formation (Aronoff et al., 1992). Supporting this, Blazhenkova and Kumar (2018) found that curved shapes were more strongly associated with females, while angular shapes were linked to males. These observed sex differences align with sexual dimorphism (i.e., masculinized or feminized traits), with masculine traits often associated with dominance and feminine traits with nurturing and affiliation (Costa et al., 2001; Geniole et al., 2012; Mazur & Booth, 1998; Pound et al., 2009). However, previous research has not fully explored the manipulation of sexual dimorphism as an indirect method for studying the influence of attractiveness on time perception, which may provide key insights into the divergent findings in the literature.

3.2.4. Sexual Dimorphism and Attractiveness Preferences

Attraction preferences have been shown to vary based on evolutionary factors linked to reproductive success and resource acquisition (Buss, 1989), highlighting the importance of understanding these cues in the context of time perception. Men are generally attracted to traits in women that signal good reproductive health, such as femininity and body cues associated with reproductive potential (Buss, 1989). This includes a preference for feminine facial features, like a narrower face and

smaller jawline (Little et al., 2011), as well as a lower waist-to-hip ratio (WHR; Furnham et al., 2006; Henss et al., 2000), which are considered markers of elevated estrogen levels and reproductive fitness (Foo et al., 2017). Men also demonstrate a cross-modal preference for femininity, showing a preference for feminine voices that align with facial features in women (Fraccaro et al., 2010; O'Connor et al., 2013). Furthermore, research consistently shows a male preference for feminine female faces across cultures (Kleisner et al., 2024; Nakamura & Watanabe, 2020; Marcinkowska et al., 2014; Perrett et al., 1998), highlighting sexual dimorphism as a key factor in perceived attractiveness.

Conversely, women tend to prefer men who display dominant (Neave et al., 2003) and masculine traits (Feinberg et al., 2005; Johnston et al., 2001; Little et al., 2008; Penton-Voak et al., 1999, 2001; Stower et al., 2020). These traits include a wider face, pronounced brow ridge, and thicker jawline, and are associated with higher basal testosterone levels (Penton-Voak & Chen, 2004; Pound et al., 2009). Such characteristics suggest robust immune function and favorable genetic quality, as only males with strong health can allocate resources to developing these secondary sexual characteristics (Folstad & Karter, 1992). Hence, males exhibiting increased masculine traits are perceived as healthier and more attractive to potential partners (Jones et al., 2018; Penton-Voak & Chen, 2004; Thornhill et al., 1999, Thornhill & Gangestad, 2006). Additionally, dominance and masculinity in men are associated with higher social status, which suggests an ability to provide essential resources for reproduction (Geary et al., 2004).

Nevertheless, there is evidence challenging the immunocompetence handicap hypothesis (intersexual competition) (Lee et al., 2014; Nowak et al., 2020; Scott et al., 2014; Zaidi et al., 2019). Instead of serving as an indicator of men's immunocompetence, men's masculinity may primarily signal their intrasexual competitiveness (for a review, see Puts, 2010; Scott, 2012). Additionally, evidence suggests that there is no consistent link between face-shape masculinity and mating success (Lidborg et al., 2022; Scott et al., 2010). Alternatively, the association may be context-specific, such as for short-term relationships (Holzleitner & Perrett, 2017; Little, Cohen, et al., 2007; Little, Jones, et al., 2007, 2011), or there may be a preference for more feminine male faces (DeBruine et al., 2010; Little et al., 2001; Marcinkowska et al., 2019; Nakamura & Watanabe, 2020; Penton-Voak et al., 1999; Perret et al., 1998; Rhodes et al., 2003). A potential factor that could help explain these divergent findings is emotional expression. Recent research suggests that the supposed avoidance response to masculinity diminishes with smiling expressions (Carrito et al., 2023).

3.2.5. The Present study

In light of the findings discussed, the present study was designed to examine how viewing faces with varying levels of attractiveness, displaying either anger or happiness, influences time perception. These two facial expressions were selected due to their paradoxical impact on perceived attractiveness and time perception: both angry and attractive faces tend to lengthen perceived time. However, given that anger negatively affects perceived attractiveness, while happiness has a positive effect on attractiveness, an interaction between facial expression and perceived attractiveness on time perception is expected.

Prior research has already explored the interaction between same-sex angry faces and perceived attractiveness on time perception, suggesting an overestimation of angry attractive faces compared to neutral ones, but not for unattractive faces (Tomas & Španić, 2016). The authors suggest that attractiveness may act as a moderating factor by triggering a defensive response to high-status competitors. However, it remains unclear if this moderator effect applies to opposite-sex faces as well. Numerous studies indicate that viewing attractive opposite-sex faces triggers automatic or implicit cognitive processes (e.g. Bradley et al., 2001; Laeng and Falkenberg, 2007). Hence, based on prior findings about the influence of attractive opposite-sex faces on time perception, it is plausible that viewing such faces interacts with a fear-specific adaptative defense mechanism (Ohman & Mineka, 2001).

This study aims not only to replicate the observed time overestimation associated with emotional facial expressions but also to determine whether the perceived attractiveness of opposite-sex faces moderates this effect. Therefore, we will address some of the limitations present in Tomas and Španić's (2016) study. Firstly, our sample will be comprised of both male and female participants, addressing the mixed results concerning gender differences in time perception (Arantes et al., 2021; Tian et al., 2019). Also, we will use opposite-sex photos, like Arantes et al. (2013) and Tian et al. (2019), and include happy facial expressions known to influence time perception (Droit-Volet et al., 2004; Effron et al., 2006). Moreover, as a novel approach to explore the influence of sexual dimorphic traits on time perception, we will include not only pre-rated attractive and unattractive photos but also manipulate sexual dimorphism as an indirect indicator of facial attractiveness (Perret et al., 1998; Marcinkowska, 2014).

Our goal is to further explore the interaction effect between emotionality and facial attractiveness on time perception, using a sample comprising both sexes, incorporating happiness expressions, and manipulating sexual dimorphism as an indirect cue to attractiveness. Based on evolutionary theories regarding responses to both threatening and arousing stimuli, we hypothesize that angry faces will be perceived as lasting longer than happy and neutral faces when unattractive, but this effect will not occur for attractive faces (H1). The rationale is that attractive opposite-sex happy faces will be highly desired,

inducing the appetitive motivational system to accelerate the internal clock. For sexually dimorphic faces, we anticipate the same effect: angry faces will be perceived as lasting longer than happy and neutral faces in incongruent manipulations (feminized males or masculinized females) but not in congruent ones (feminized females or masculinized males) (H2).

3.3. Method

3.3.1. Participants

A convenience sampling method was applied in this study. A total of 144 participants took part in our study. A priori power analysis was conducted using G*Power software (Faul et al., 2007) to determine the necessary sample size. The significance level (alpha) was set at 0.05, the power was set at 0.80, and the correlation between measures was set at 0.17 (Garrido & Prada, 2017). The analysis indicated that a sample of 120 participants would be adequate to achieve sufficient power ($1-\beta \geq 0.80$) for detecting a small effect size (i.e., 0.15), consistent with the effect sizes observed in Study 1.

All participants were caucasian with ages ranging from 18 to 33 years old ($M = 21.54;3$ $SD = 3.66$), heterosexuals ($n = 131$) or bisexuals ($n = 13$) and reported no uncorrected visual problems. The final sample consisted of 82 females (40 in the attractiveness group; 42 in the sexual dimorphic group) and 62 males (31 in each group). Of the 144 participants, 110 were students, 14 were working students, and 20 were workers. Among students and working students, 122 were recruited via Sona Systems (https://www.sona-systems.com/) in exchange for course credits. All participants provided their informed consent, according to the Helsinki Declaration.

3.3.2. Apparatus and stimulus

The experiment was conducted on an IBM-compatible PC, and responses were registered through a mouse. The stimuli appeared in the center of the screen (13.3" diameter) on a gray background. The experimental task was programmed in PsychoPy (Peirce et al., 2022).

3.3.3. Stimuli

The neutral stimuli were circular Gabor discs (sinusoidal gratings modified by a Gaussian filter; Yao et al., 1995). All Gabor discs were uniform, having a diameter of 5 cm, oriented 10 degrees clockwise from the vertical axis, and featuring a frequency of 3 cycles per disc. The experimental stimuli included facial color photographs portraying adults categorized under two groups: one depicting attractiveness

(featuring attractive and unattractive individuals) and the other portraying sexually dimorphic characteristics (with masculinized or feminized versions of adult faces). Images in both groups were resized to dimensions of 500 x 500 pixels and were presented at the center of the screen, matching the size of the Gabor discs.

The photographs for the two groups were retrieved from the Karolinska Directed Emotional Faces Database (KDEF; Goeven et al., 2008). The photographs were retrieved from the Karolinska Directed Emotional Faces Database (KDEF; Goeven et al., 2008). Each group included images of 20 individuals (10 males and 10 females), each displaying two emotional facial expressions (anger and happiness), and neutrality. In the attractiveness group, half of the photos were from the most attractive people in the database, while the other half were from the least attractive ones. These photos were selected based on previous validated ratings for the Portuguese population (Garrido & Prada 2017).

In the sexually dimorphic group, participants were presented with photos of medium levels of attractiveness that had been masculinized and feminized using Psychomorph's (version 6) prototype-based computer graphics transformations (Tiddeman & Perrett, 2002). To achieve sexually dimorphic manipulations, a female and a male avatar (average male/female face) was created by averaging the shape, color, and texture of 30 female faces and 30 male faces. The images used to create the avatars were chosen from the Face Research Lab London Set (FRL-London; DeBruine & Jones, 2017). Subsequently, masculinized and feminized versions were created by shape-transforming each photo through the addition or subtraction of 50% of the linear spatial differences between female and male avatars (for technical details, see Tiddeman et al., 2001).

3.3.4. Ethics

This study was approved by the Ethics Committee for Research in Social and Human Sciences of the University of Minho (CEICSH 055/2022; Appendix F).

3.3.5. Procedure

During the experimental task, participants were individually assessed in sound-isolated cabins, seated 60 cm from the monitor. They were informed that they would view sequences of five stimuli and were instructed to reproduce the duration of the fifth stimulus by pressing and holding down the left mouse button. In the middle of the experiment, a break was provided, allowing participants to rest as needed. At the end of the experiment, participants completed a brief questionnaire concerning sociodemographic data and rated arousal, valence, and dominance using the self-assessment manikin

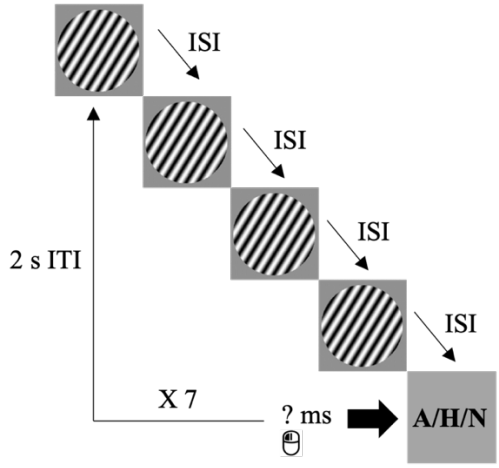
(SAM; Bradley & Lang, 1994) on a 1-9 scale. They also evaluated the attractiveness and familiarity of each of the previously viewed photos on a 1-7 Likert scale (i.e., "1" – extremely unattractive/unfamiliar and "7" – extremely attractive/familiar).

We used a mixed design, with attractiveness/sexual dimorphism groups as a between-subjects factor, and emotionality (anger, happiness, and neutral facial expressions) as a within-subjects factor. The selection of groups was counterbalanced across participants. In each trial, four Gabor discs were displayed for a similar duration, separated by an inter-stimulus interval (ISI), and followed by a test stimulus. On one-third of the trials, the test stimulus was either a facial photo of an attractive/unattractive (attractiveness group) or a masculinized/feminized (sexual dimorphism group) of the opposite sex with a neutral facial expression (neutral condition) or an emotional facial expression (happiness or anger).

Following Arantes's et al. (2013) study, there were seven possible stimulus durations: 133 ms, 233ms, 300 ms, 383 ms, 533 ms, 1050 ms, and 2100 ms, each presented an equal number of times across trials in a pseudorandom distribution. Moreover, each photo was presented once for each of its three different facial expressions across seven durations. Hence, the experiment consisted of 210 trials (10 photos x 3 different facial expressions x 7 durations). The ISIs within a trial were set to vary within a range of +/- 10% of the stimulus duration. This aimed to ensure that participants would respond to the actual stimulus duration and not to a consistent beat or rhythm that might occur if the ISI remained constant throughout the trial (Tse et al., 2004). Following the presentation of the sequence of five stimuli, participants reproduced the duration of the fifth stimulus by pressing the left mouse button for the estimated duration. The subsequent trial started 2 seconds after their response. The experimental task for both groups is illustrated in Figure 4.

Figure 4

The oddball task for the attractiveness and sexual dimorphism groups



Note. A – anger; H – happiness; N – neutral.

3.3.6. Data Analysis

In a preprocessing stage, following Tukey's (1977) method of outlier detection, trials that were larger than the third quartile plus 1.5 times the Interquartile range (IQR) ($>_{q0.75}$ + 1.5×IQR) or smaller than the first quartile minus 1.5 times the IQR ($<_{q0.25}$−1.5×IQR) were excluded from the analysis to increase signal to noise ratio. This resulted in the removal of 8% of trials in the attractiveness group, and 9% in the dimorphic group. After the outliers removal, one participant was excluded from the analysis due to its mean duration reproductions (2.03 s) being approximate to the highest trial duration. However, the results remained unchanged when including these trials. Statistical analysis was performed using R (R Core Team, 2022) in RStudio Version 2022.2.2.485 (RStudio Team, 2022). The data and reproducible code are publicly available (Fernandes, 2024).

The log-transformed reproduced duration was entered as the dependent variable in a linear mixed-effects model (LMMs). The triple interaction effect of trial type (attractive vs. unattractive vs. masculinized vs. feminized), facial expression (anger vs. happiness vs. neutral), sex (male vs. female), as well as its main effects were entered as fixed terms. We controlled for trial duration. Also, we controlled for attractiveness, arousal, dominance, and familiarity by including these standardized ratings as fixed terms in the model. The participant's code was entered as a random effect with a random intercept. Multilevel modeling was chosen to account for the nested nature of the choice data. Additionally, we ran the model using only the three longest durations and filtered the data by the two most attractive and two least attractive faces per participant. No differences were observed compared to the initial model.

Finally, we evaluated differences in attractiveness, arousal, valence, dominance, and familiarity ratings across all conditions, using five separate LMM. We opted to present these results only for the attractiveness and arousal evaluations, but results for the other dimensions may be seen in Appendix B in the form of graphic visualizations (Figure B.1, Figure B.2). Additionally, in the results section, we evaluated differences in facial expression recognition across the different dimensions, using a Generalized Linear Mixed Model (GLMM), with the binary choice (correct/incorrect) emotion classification as the dependent variable.

3.4. Results

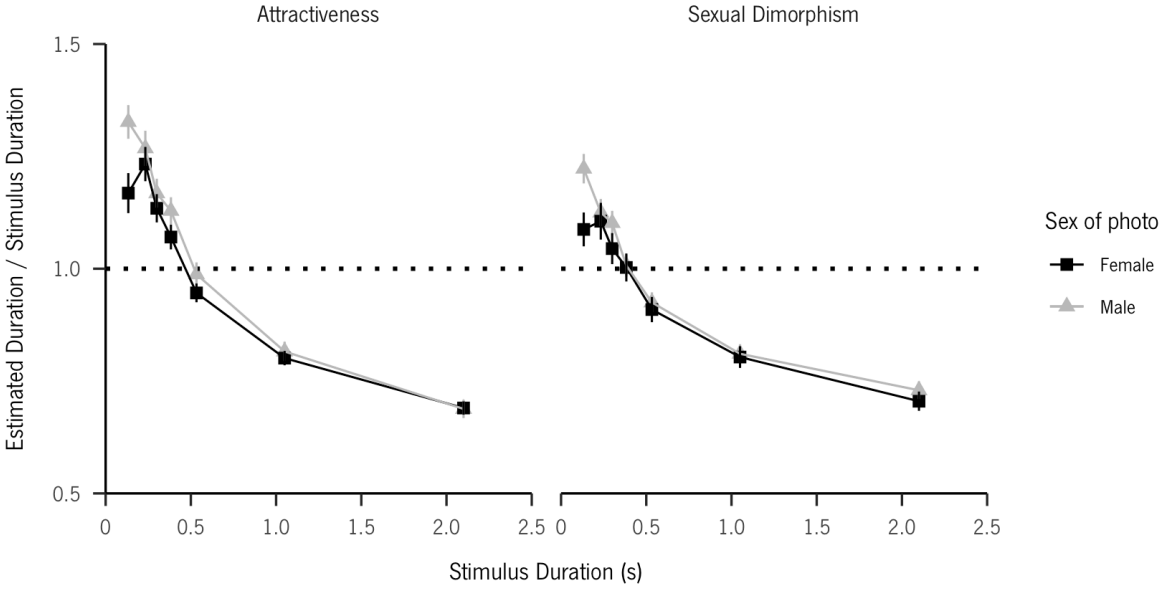
3.4.1. Vierordt's Law

To test whether the reproduced durations in the two experimental groups conformed to Vierordt's Law (1868) – which states that shorter intervals are overestimated and longer intervals are

underestimated (for a review, see Lejeune & Wearden, 2009) – we analyzed the ratio of each estimated duration to the objective duration. Following a similar approach to Arantes et al. (2013), we calculated this ratio for each sex and group (attractiveness/sexual dimorphism) and averaged the results over facial expression (neutral/anger/happy) and attractiveness condition (attractive/unattractive) or dimorphic manipulation (feminized/masculinized) for each participant. Both males and females overestimated the duration for stimuli lasting less than 0.5 s and underestimated for stimuli lasting 1.05 s or 2.1 s, across both conditions. This pattern aligns with the expectations based on Vierordt's Law. Results are shown in Figure 5.

Figure 5

The ratio of estimated duration to stimulus duration for each condition averaged across facial expression and type of trial



Note. Bars indicate one SE.

3.4.2. Reproduced durations

The linear mixed-effects model (LMM) comprised the main effects of condition (attractive vs. unattractive vs. feminized vs. masculinized), facial expression (anger vs. happiness vs. neutral), and sex (male vs. female), along with the three-way interaction term, as fixed effects. The trial duration was included as a fixed term. Moreover, we controlled for trial duration, arousal, valence, attractiveness, dominance, and familiarity. The log-transformed time reproduction was entered as the dependent variable. The participant code was included as a random effect with a random intercept. No significant

results were found for the main effects or their interactions (Table 1). Since the condition's main effect approached the significance level (p = .05), post-hocs using Tukey adjustments were conducted. No significant effects were found, with only the comparison between the sexually dimorphic versions (feminized - masculinized) approaching the significance level (b = -.02, p = .06). The average reproduction durations across all conditions are illustrated in Figure 6 while time reproductions visualizations for each of the seven durations across the various conditions are provided in Appendix B (Figure B.7, Figure B.8)

Table 1

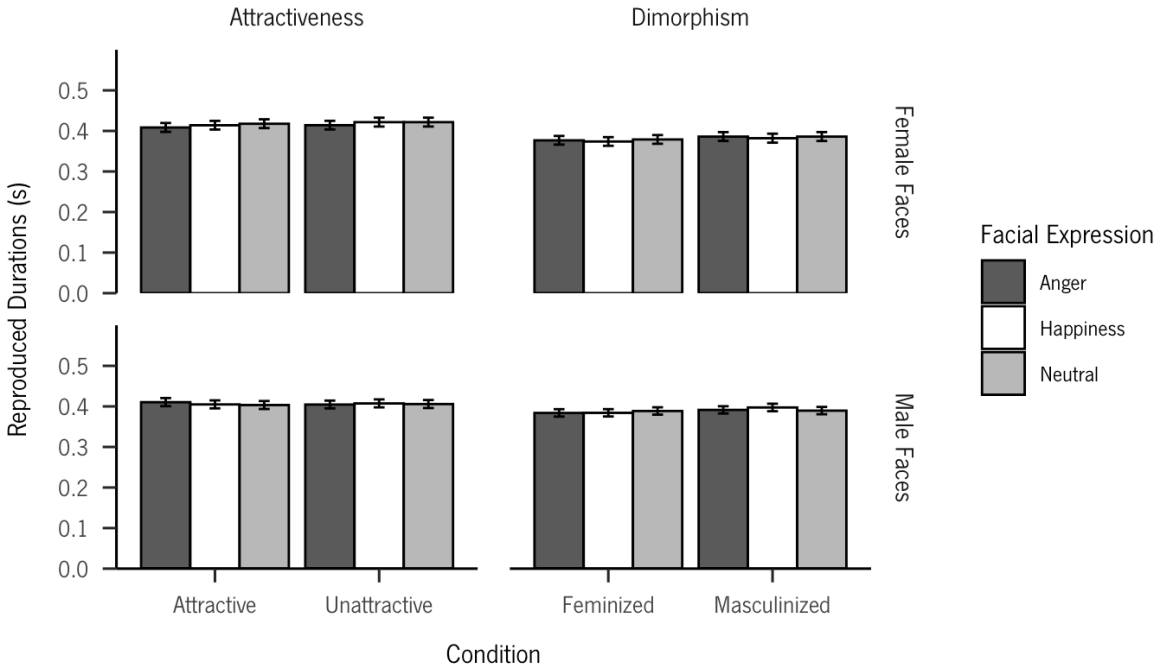
*ANOVA for the Regression Equation, Condition*Emotion*Sex on time reproductions*

	Sum of Squares	Mean Square	NumDf, DenDf	*F*	*p*
Condition	1.60	0.53	3,416	2.60	.05
Emotion	0.01	0.02	2,29130	0.02	.98
Sex	0.01	0.01	1,140	0.01	.97
Condition*Emotion	0.40	0.06	6,29110	0.31	.93
Condition*Sex	0.20	0.06	3,415	0.28	.84
Emotion*Sex	0.50	0.27	2,29111	1.34	.26
Condition*Emotion*Sex	0.70	0.12	6,29110	0.56	.76
$R^2_{marginal}$ = 0.55					
$R^2_{conditional}$ = 0.74					

Note. NumDf = Numerator degrees of freedom; DenDF = Denominator degrees of freedom; F = F-statistic; p = p-value.

Figure 6.

Average reproduced durations by attractiveness and dimorphism groups across all conditions



Note. Bars indicate 95% CI.

3.4.3. Attractiveness Evaluations

The attractiveness evaluations were analyzed using a linear mixed-effects model (LMM) that included the main effects of condition (attractive vs. unattractive vs. feminized vs. masculinized), facial expression (anger vs. happiness vs. neutral), sex (male vs. female), and the three-way interaction term, as fixed effects. The participant code was entered as a random effect with a random intercept. The model revealed that all the main effects and the two and three-level interactions were significant predictors of attractiveness (Table 2). The distribution of attractiveness ratings, for the attractiveness (Figure B.3) and sexual dimorphic (Figure B.4) groups are available in Appendix B.

Table 2

*ANOVA for the LMM, Condition*Emotion*Sex on attractiveness evaluations*

	Sum of Squares	Mean Square	NumDf, DenDf	*F*	*p*
Condition	589.83	196.61	3,413	175.64	<.001
Emotion	497.79	248.90	2,4156	222.35	<.001
Sex	37.03	37.03	1,140	33.08	<.001
Condition*Emotion	43.94	7.32	6,4156	6.54	<.001
Condition*Sex	111.16	37.05	3,413	33.10	<.001
Emotion*Sex	26.57	13.29	2,4156	11.87	<.001
Condition*Emotion*Sex	23.80	3.97	6,4156	3.54	.002
$R^2_{marginal}$ = 0.21					
$R^2_{conditional}$ = 0.50					

Note. NumDf = Numerator degrees of freedom; DenDF = Denominator degrees of freedom; *F* = F-statistic; *p* = p-value.

Pairwise comparisons using Tukey corrections showed that the two-way interaction of condition and gender indicated that attractive photos were judged as more attractive than unattractive photos, for both female (M_{diff}= 0.96, *SE* = 0.07, $p < .001$) and male (M_{diff}= 0.91, *SE* = 0.06, $p < .001$) facial pictures. However, for the sexually dimorphic manipulations, feminized versions of the female faces were rated as more attractive than masculinized female faces (M_{diff}= 0.95, *SE* = 0.07, $p < .001$), no differences were found between feminized and masculinized versions of male faces (M_{diff}= 0.04, *SE* = 0.06, $p = .93$).

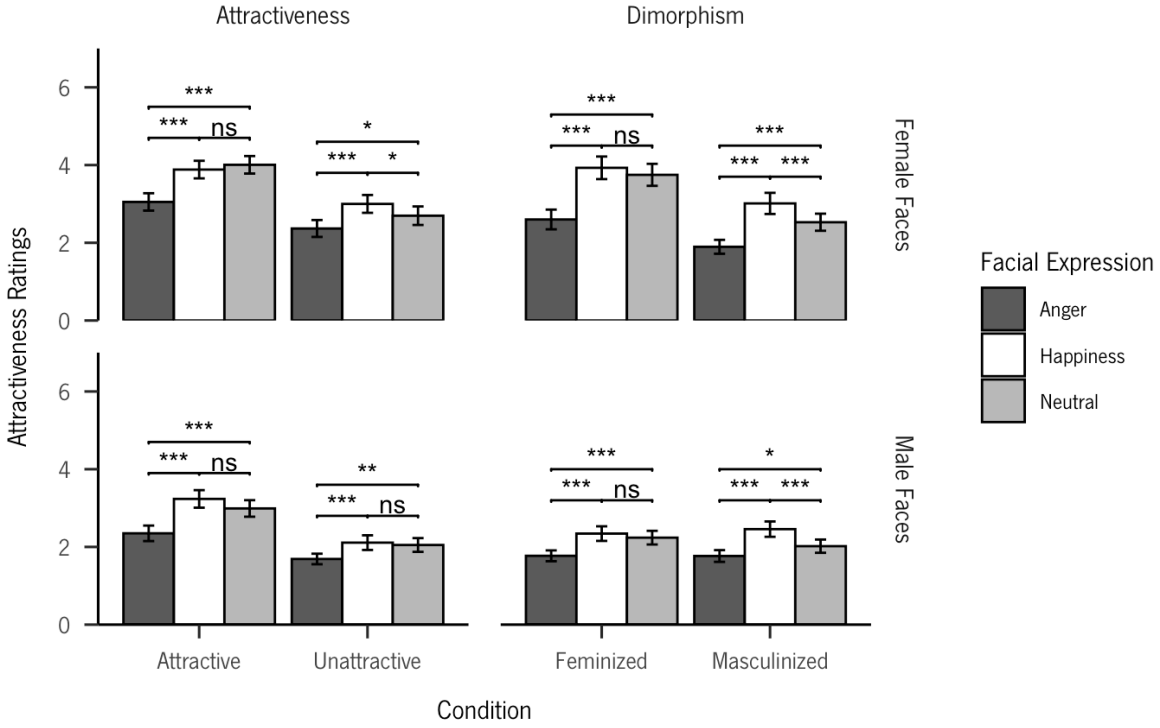
Post-hoc analyses for the two-way interaction of facial expression and gender revealed that happy faces were rated as more attractive than angry ones, for both female (M_{diff}= 0.98, *SE* = 0.06, $p < .001$), and male faces (M_{diff}= 0.64, *SE* = 0.05, $p < .001$). Also, happy faces were more attractive than neutral faces, both for female (M_{diff}= 0.21, *SE* = 0.06, $p = .001$), and male faces (M_{diff}= 0.21, *SE* = 0.05, $p < .001$). Angry faces were rated as less attractive than neutral facial expressions, both for female (M_{diff}= -0.77, *SE* = 0.06, $p < .001$), and male faces (M_{diff}= -0.43, *SE* = 0.05, $p < .001$).

However, the three-way interaction of condition, facial expression, and gender revealed that while anger was the least attractive facial expression for both genders across all conditions, statistical differences between happiness and neutral facial expressions were only observed for specific conditions (Figure 7). For the female faces, attractiveness differences between happy and neutral faces were

observed for the unattractive (M_{diff} = -0.63, SE = 0.12, p < .001), and masculinized (M_{diff} = -1.12, SE = 0.12, p < .001) faces. For male photos, differences between happy and neutral faces were only found for the masculinized faces (M_{diff} = 0.44, SE = 0.10, p < .001).

Figure 7

Average attractiveness evaluations by attractiveness and dimorphism groups across all conditions



Note. Bars indicate one SE; * p < .05, ** p < .01, *** p < .001, ns = non-significant ($p \geq .05$).

3.4.4. Arousal Evaluations

The arousal evaluations were entered in a LMM with the main effects of condition (attractive vs. unattractive vs. feminized vs. masculinized), facial expression (anger vs. happiness vs. neutral), sex (male vs. female), and the three-way interaction term, as fixed effects. The participant code was entered as a random effect with a random intercept. The model's statistics are presented in Table 3.

Table 3

*ANOVA for the LMM, Condition*Emotion*Sex on arousal evaluations*

	Sum of Squares	Mean Square	NumDf, DenDf	*F*	*p*
Condition	25.00	8.33	3,439	3.64	.01
Emotion	1530.89	765.45	2,4156	334.41	<.001
Sex	5.82	5.82	1,140	2.54	.11
Condition*Emotion	121.60	20.27	6,4156	8.85	<.001
Condition*Sex	39.63	13.21	3,438	5.77	<.001
Emotion*Sex	57.81	28.91	2,4156	12.63	<.001
Condition*Emotion*Sex	17.71	2.95	6,4156	1.29	.26
$R^2_{marginal}$ = 0.131					
$R^2_{conditional}$ = 0.326					

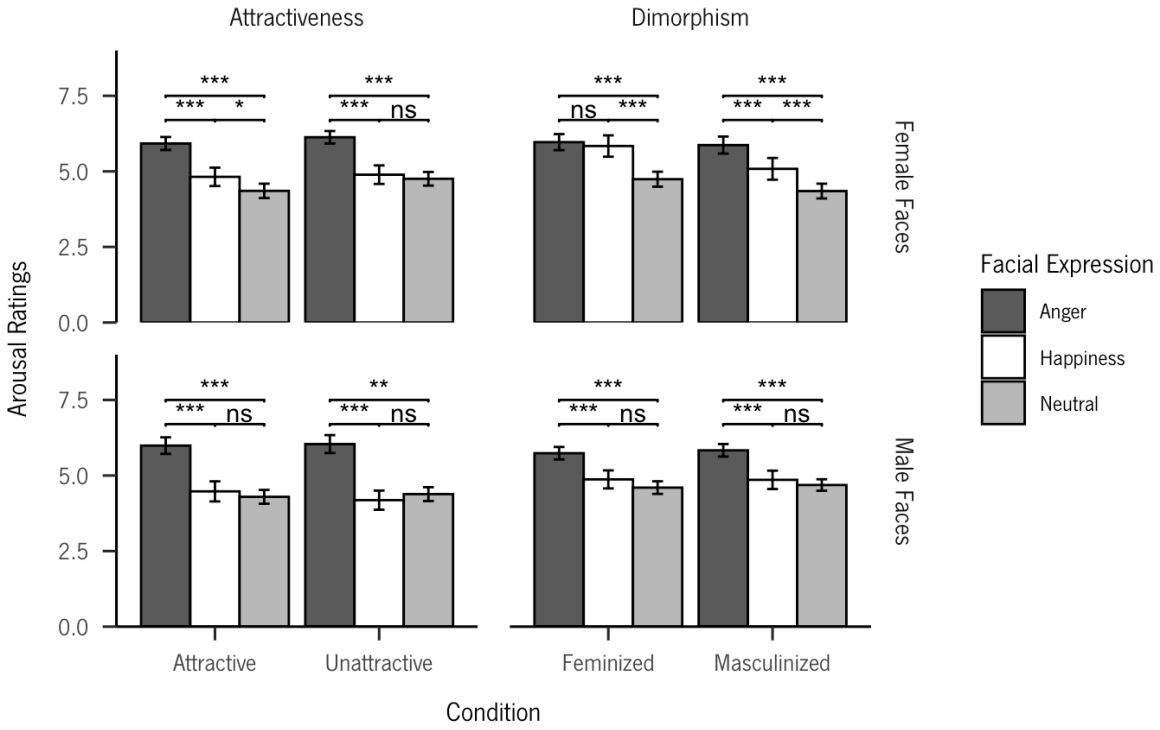
Note. NumDf = Numerator degrees of freedom; DenDF = Denominator degrees of freedom; *F* = F-statistic; *p* = p-value.

Pairwise comparisons using Tukey corrections revealed that differences at the two-way level interaction of sex and condition were only observed between feminized and masculinized versions of the female photos (M_{diff} = 0.42, *SE* = 0.10, $p < .001$). No significant differences were observed between the attractive and unattractive photos for either sex ($p > .05$).

Post-hoc analyses for the two-way interaction of facial expression and sex showed that anger faces elicited higher levels of arousal than happy ones, both for female (M_{diff} = 0.82, *SE* = 0.09, $p < .001$), and male faces (M_{diff} = 1.30, *SE* = 0.07, $p < .001$). Angry faces received higher ratings of arousal than neutral faces, both for female (M_{diff} = 1.42, *SE* = 0.09, $p = .001$), and male faces (M_{diff} = 1.41, *SE* = 0.07, $p < .001$). Also, happy expressions elicited more arousal than neutral ones for female faces (M_{diff} = 0.61, *SE* = 0.09, $p < .001$), but not for male faces (M_{diff} = 0.11, *SE* = 0.07, $p = .33$). The three-way interaction of condition, facial expression, and sex suggests that arousal differences between happy and neutral expressions for female faces were observed in all conditions except for the unattractive faces (Figure 8). The distribution of arousal ratings, for the attractiveness (Figure B.5) and sexual dimorphic (Figure B.6) groups are available in Appendix B.

Figure 8

Average arousal evaluations by attractiveness and dimorphism groups across all conditions



Note. Bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

3.4.5. Hits

The binary classification of facial expression classification (correct/incorrect) was entered as the dependent variable in a generalized linear mixed model (GLMM). The interaction term of facial expression, condition, and sex of the photo, as well as its main effects, were entered as fixed effects. The rater's code was entered as a random effect with a random intercept. The model's statistics are presented in Table 4.

Table 4

*Chi-square for the GLMM, Condition*Emotion*Sex on correctly classified emotions*

	X^2	Df	*p*
Condition	48.66	3	<.001
Emotion	220.30	2	<.001
Sex	0.56	1	.45
Condition*Emotion	29.16	6	<.001
Condition*Sex	21.98	3	<.001

Emotion*Sex	31.42	2	<.001
Condition*Emotion*Sex	11.11	6	.08
$R^2_{marginal}$ = 0.186			
$R^2_{conditional}$ = 0.265			

Note. X^2 = Chi-square; Df = Degrees of freedom; *p* = p-value.

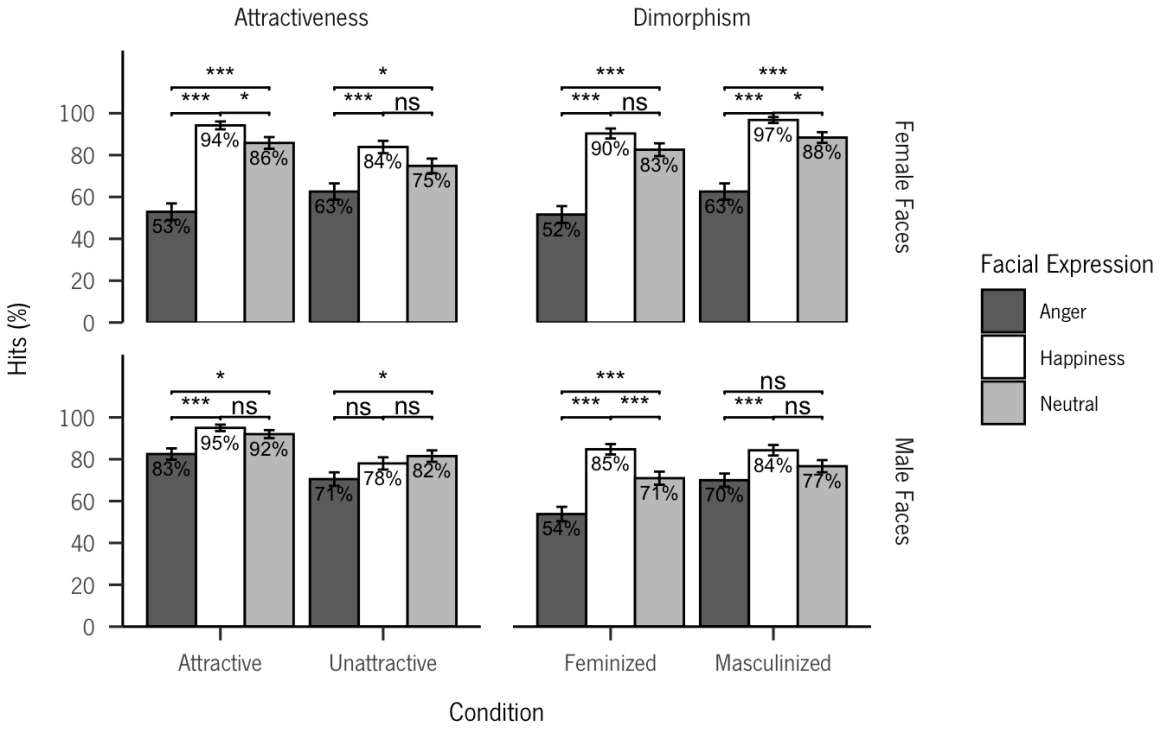
Pairwise comparisons using Tukey corrections showed that the two-way interaction of condition and photo's sex, indicated that the percentage of correct emotion classification was higher for attractive than unattractive photos, for both males (*OR* = 3.2, *SE* = 0.18, *p* < .001), and females, (*OR* = 1.67, *SE* = 0.19, *p* = .036), faces. Also, masculinized faces obtained a higher rate of correct emotion classification than feminized faces for female photos (*OR* = 2.1, *SE* = 0.23, *p* = .006), but for male photos, the difference only approached the significance level (*OR* = 1.39, *SE* = 0.14, *p* = .071).

The two-way interaction of facial expression and photo's sex showed that angry faces had lower classification accuracies in comparison to happy faces for both female photos (*OR* = 0.09, *SE* = 0.19, *p* < .001) and male photos (*OR* = 0.34, *SE* = 0.14, *p* < .001), as well as for neutral expressions, for female (*OR* = 0.24, *SE* = 0.14, *p* < .001) and male faces (*OR* = 0.51, *SE* = 0.13, *p* < .001). In contrast, happy expressions improved classification accuracy in comparison to neutral expressions, both for female (*OR* = 2.56, *SE* = 0.20, *p* < .001) and male (*OR* = 1.51, *SE* = 0.15, *p* = .02) faces. Also, for the happiness condition, female faces were more correctly identified than male faces (*OR* = 1.97, *SE* = 0.23, *p* = .003), while for the angry faces, the opposite was found (*OR* = 0.55, *SE* = 0.16, *p* < .001). No significant differences were observed between female and male faces for neutral expressions (p > .05).

Post-hoc analyses for the three-way interaction revealed that while differences in facial expression identification between happy and angry faces were observed across all conditions, differences between happy and neutral expressions were exclusive to the attractive (*OR* = 2.83, *SE* = 0.42, *p* = .04) and masculinized female faces (*OR* = 4.10, *SE* = 0.52, *p* = .02). It is noteworthy that facial expression recognition of neutral faces remained relatively high in these two conditions, 86% and 88% respectively, as illustrated in Figure 9.

Figure 9

The proportion of correctly classified emotions by attractiveness and dimorphism groups across all conditions



Note. Bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

3.5. Discussion

We conducted an experiment to investigate whether males' and females' time estimates for viewing opposite-sex faces with varying facial expressions (anger, happiness, neutral) would be influenced by the attractiveness of the faces. The study included two main conditions: attractiveness (attractive vs. unattractive facial images) and sexual dimorphism (feminized vs. masculinized faces). We hypothesized that angry faces would be perceived as having a longer duration compared to happy and neutral faces, but only for unattractive faces (H1) or incongruent sexually dimorphic manipulations (H2). These hypotheses were tested using a visual oddball task, where participants viewed a series of five stimuli of equal duration and were required to reproduce the duration of the last stimulus by pressing a mouse button. The first four stimuli in each trial were circular sine-wave gratings, while the last stimulus was either a neutral, angry, or happy face, categorized as either attractive/unattractive (attractiveness condition) or masculinized/feminized (sexual dimorphism condition), and depicted an opposite-sex individual. Following the experimental task, participants rated the images for attractiveness, arousal,

valence, dominance, and familiarity. Contrary to expectations, the time perception task yielded no significant results. We will discuss possible reasons for our null findings.

3.5.1. Time perception

A possible explanation for not observing temporal overestimation for angry faces (Droit-Volet et al., 2004; Fayolle & Droit-Volet, 2014; Kliegl et al., 2015; Li & Yuen, 2015; Tipples, 2008) may relate to embodiment (Effron et al., 2006). Effron et al. (2006) found that overestimation of angry faces occurred only when spontaneous imitation was allowed, suggesting that perceived arousal increases with embodiment. Additionally, Zhou et al. (2021) found that automatic expression suppression attenuated the arousal rating for both attractive and unattractive faces, with a more notable reduction for attractive faces. However, this embodiment perspective has its limitations since people are more likely to mimic positive emotions than negative ones (Rymarczyk et al., 2016). Furthermore, it does not explain our null findings, as angry faces elicited relatively high arousal (Angrilli et al., 1997; Yin et al., 2021). An alternative explanation for prior findings might be that embodiment shifts attention away from time perception, leading to a faster perceived passage of time compared to low-embodiment conditions (Unruh et al., 2023).

Moreover, evidence suggests that facial reactions to emotional expressions are driven by mimicry only when individuals are making judgments about the valence of those expressions (Hess et al., 1998). Although our study lacks physiological data to confirm whether facial mimicry occurred, it is plausible that attractiveness may have interacted with emotional processing, shifting the focus from valence to attractiveness judgments. As Grondin et al. (2015) also noted in explaining their null findings regarding time dilation of angry faces, mimicry alone does not fully account for the effect of emotional facial expressions on time perception. Context plays a significant role, such as whether the observer feels empathy for or desires to associate with the person whose face is being shown (Mondillon et al., 2007). Therefore, the design of our study, which presents facial expressions at varying levels of attractiveness, may have influenced emotional time perception.

To the best of our knowledge, only one previous study has explored the interaction between attractiveness and emotionality on time perception (Tomas & Španić, 2016). In this study, the authors found that female participants overestimated the duration (400 – 1,600 ms) of angry faces compared to neutral ones, but only when the faces were perceived as attractive. However, several factors may explain why our study fails to replicate these findings. Firstly, the original study involved only female participants who viewed same-sex photos. According to the imitation hypothesis, mimic behavior and empathy are

closely related (Dimberg et al., 2011), and the sex of both the participant and the target may influence the impact of emotion on perceived duration. Empathy, which plays a role in how well individuals can imitate and thus perceive emotional expressions, may vary based on the sex of both the participant and the target. For example, Stuijfzand et al. (2016) found that females reported greater empathic sadness towards same-sex targets than towards opposite-sex targets, whereas males reported less empathic sadness towards same-sex targets compared to other-sex targets. This suggests that the sex of both the participant and the target could influence the effect of emotion on time perception, which may partly explain the failure to replicate the findings of Tomas and Španić (2016).

Contrary to previous findings, we did not observe an overestimation of attractive (Arantes et al., 2013; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021) or unattractive (Sano et al., 2022) faces. One possible explanation for our null findings is that the attractive faces in our study may not have been deemed attractive enough. Although attractive faces were rated as more attractive compared to unattractive ones, the average attractiveness ratings in our study (3.41 for the attractive females and 2.86 for the attractive males) were relatively low compared to those of prior studies: 5.82 for the attractive females and 5.63 for the attractive males (Arantes et al., 2013); 5.86 (Experiment 1) and 6.00 (Experiment 2) for attractive females, and 5.84 (Experiment 1) and 6.03 (Experiment 2) for attractive males (Tian et al., 2019); 5.13 for attractive females (Tomas & Španić, 2016); 5.72 for attractive females and 5.86 for attractive males (Sano et al., 2022).

Therefore, it is possible that our stimuli were not perceived as sufficiently attractive to induce the necessary physiological arousal (Maner et al., 2003; Nakamura & Kawabata, 2014) required to accelerate the internal clock (Arantes et al., 2013; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021). Our data did reveal differences in arousal between feminized and masculinized female faces. However, Zhou et al. (2021) found that arousal only mediated the temporal effect for female faces rated as highly attractive (above 4.13 on a 1-7 scale). This may explain why we did not observe differences in time estimation between sexually dimorphic versions of female faces in our study, as their mean attractiveness ratings were relatively low (3.43 for feminized and 2.48 for masculinized versions).

Furthermore, the type of time perception task may also account for our null findings. A recent meta-analysis by Cui et al. (2023) found that temporal reproduction tasks tend to have lower power compared to temporal bisection tasks. Some studies have shown that angry faces are overestimated using the temporal bisection task, but not when using temporal reproduction (Gil & Droit-Volet, 2011; Malva et al., 2023). Cui et al. (2023) suggest that this discrepancy arises because, during temporal reproduction, emotion-induced arousal gradually decreases, reducing its effect on perceived duration.

However, this explanation is challenged by earlier temporal reproduction studies that did find an overestimation effect for longer durations, such as 2, 4, and 6 seconds (Angrilli et al., 1997; Noulhiane et al., 2007; Yin et al., 2021). In contrast, in our study and the experiment by Lee et al. (2011), using conditions up to 2 seconds, no overestimation for angry faces occurred. Also, Tian et al. (2013) and Zhou et al. (2021) found the time dilation effect using the temporal reproduction task but used intervals longer than 1 s. This may suggest that time perception varies depending on the specific intervals being assessed, supporting the notion that time perception is relative (Woodrow, 1934).

Nevertheless, since we used the same durations as Arantes et al. (2013) and still did not find an effect, it is possible that the attractiveness levels were insufficient to elicit time dilation for attractive faces. Additionally, the attractiveness dimension might have interacted with emotional processing, potentially masking the effect of facial expressions. However, if the time dilation effect reported in previous studies is specific to particular experimental tasks or types of stimuli, its relevance to everyday situations may be limited.

3.5.2. Evaluations

We observed an advantage for happy faces (compared to angry and neutral faces) in emotion labeling, which aligns with existing literature, including the original KDEF validation (Goeleven et al., 2008) and the validation for the Portuguese population (Garrido & Prada, 2017). Also, we found that participants were more accurate in identifying anger in male faces compared to female faces and more accurate in identifying happiness in female faces compared to male faces, while no sex differences were observed for neutral expressions. Garrido and Prada (2017) suggested that their results may have been influenced by an unbalanced sample in terms of participant sex. Since participants in our study rated only opposite-sex photos, our results reinforce their findings. Moreover, emotion classification was more accurate for attractive faces than for unattractive ones, consistent with previous research that found faster emotion identification for attractive faces compared to unattractive ones (Taylor & Bryant, 2016).

While happy faces were perceived as the most attractive, supporting previous studies (Golle et al., 2014; Garrido & Prada, 2017), the overall attractiveness ratings in our study were lower than those reported by Garrido and Prada (2017). Regarding the sexually dimorphic manipulations, we found that feminized female faces were rated as more attractive than their masculinized counterparts (Fraccaro et al., 2010; Kleisner et al., 2024; Marcinkowska et al., 2014; O'Connor et al., 2013; Perret et al., 1998). However, no differences were observed between feminized and masculinized versions of male faces. A possible explanation is that preferences for masculine features in male faces may be limited to highly

attractive males (Hu et al., 2018; Yang et al., 2015). Although evolutionary models predict a stronger preference for more masculine male faces (Feinberg et al., 2005; Johnston et al., 2001; Little et al., 2008; Penton-Voak et al., 1999, 2001; Stower et al., 2020), other studies report a preference for more feminine male faces (DeBruine et al., 2010; Little et al., 2001; Marcinkowska et al., 2019; Nakamura & Watanabe, 2020; Penton-Voak et al., 1999; Perret et al., 1998; Rhodes et al., 2003). Indeed, our null results may reflect the lack of influence of sexual dimorphism on male facial attractiveness, as suggested by studies that have reported no significant effect of masculinity on face preferences (Cornwell et al., 2004; Kleisner et al., 2024; Swaddle & Riersen, 2002).

For instance, Perrett et al. (1998) reported that increasing masculinity in faces led to higher perceptions of negative attributes, such as coldness or dishonesty. Recent research indicates that women prefer less feminization in happy faces compared to neutral or angry faces, suggesting that the presumed avoidance response to masculinity is reduced by a smiling expression (Carrito et al., 2023). Our results are consistent with this finding. Although masculinized happy faces were not rated as more attractive than feminized happy faces, happy faces were judged as more attractive than neutral expressions in the masculinized condition, but not in the feminized one.

3.5.3. Limitations/Future studies

Some limitations of the present study should be noted. Firstly, our sample primarily consisted of relatively young Portuguese participants who identified as bisexual or heterosexual. Future research should explore the potential interaction between attractiveness and facial expressions on time perception in different cultural contexts, sexual orientations, and across a wider range of age groups.

Additionally, our study only examined two emotional expressions, anger and happiness. Future studies should consider a broader range of emotions, such as sadness, shame, fear, or disgust, to explore how different emotional states interact with attractiveness and impact time perception. The current research also focused on a limited categorization of attractiveness. Future studies could incorporate more nuanced categories of attractiveness (e.g., high, moderate, low) to explore whether varying levels of perceived attractiveness interact with different emotional states and influence time perception.

Moreover, we manipulated sexual dimorphism as an indirect indicator of attractiveness by applying a 50% vectorization approach. Future research could explore the effects of varying levels of vectorization on perceived attractiveness. It is also important to include non-manipulated faces in future research. In our study, the control was related to facial expressions, but incorporating non-manipulated faces would establish a baseline for attractiveness and facilitate comparisons with manipulated faces.

Additionally, future studies should collect hormone samples, such as testosterone and estradiol, to use as quantitative and objective measures of masculinity and femininity. This approach would provide a more direct and measurable understanding of hormonal influences on attractiveness.

The present study relied on self-report measures of arousal. Incorporating physiological measures, such as skin conductance response (SCR) and electrocardiograms (ECG), could offer a better understanding of how different facial stimuli influence arousal. Additionally, using neuroimaging techniques, such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) could help elucidate the neural mechanisms underlying the time perception of emotional and attractiveness cues.

Finally, future research should consider our suggestions on stimuli and measurements and apply them to different time perception tasks, like temporal bisection. These can help clarify how attractiveness and emotionality influence time perception and whether past findings are tied to specific stimuli or tasks. Also, future studies may consider using wider ranges of time intervals. Testing with extended intervals will help determine if effects are consistent across conditions or influenced by the relative length of exposure.

3.5.4. Conclusions

This study explored the effects of facial attractiveness and emotional expressions on time perception of opposite-sex faces. Contrary to previous findings, we did not observe significant differences in time perception based on attractiveness or emotional expressions. While happy faces were rated as more attractive, and angry faces as eliciting higher subjective arousal levels, these factors did not significantly influence participants' time estimates, as prior studies have shown. Similarly, neither attractiveness nor sexual dimorphism influenced time perception, despite the differences in attractiveness observed within these conditions. Future research should explore alternative time perception paradigms, such as using different tasks, longer intervals, varying levels of facial attractiveness and sexual dimorphism, and incorporating physiological measures, to clarify the conditions under which emotional expressions and attractiveness may influence time perception. Since we failed to replicate previous findings regarding the influence of facial expressions and attractiveness on time perception, we provide theoretical justifications grounded in arousal and attractiveness evaluations that future investigations should consider when exploring their effects on time perception.

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CHAPTER 4

Empirical Study 3:
Analyzing VGG-19's Bias in Facial Beauty Prediction:
Preference for Feminine Features

4. Analyzing VGG-19's Bias in Facial Beauty Prediction: Preference for Feminine Features

This empirical work was adapted from the published work in the Journal of Advanced Computer Science and Applications (IJACSA).

Fernandes, N., Soares, S., & Arantes, J. (2024). Analyzing VGG-19's bias in facial beauty prediction: Preference for feminine features. *Journal of Advanced Computer Science and Applications (IJACSA), 15*(10). https://dx.doi.org/10.14569/IJACSA.2024.0151089

In addition, results from this empirical work were presented in the following scientific events:

Fernandes, N., Soares, S., & Arantes, J. (2023, 31 March – 1 Abril). Beyond the realms of attractiveness: Time perception and algorithmic preferences [Conference Presentation]. 17.º Encontro Nacional da Associação Portuguesa de Psicologia Experimental [17th National Meeting of the Portuguese Association of Experimental Psychology]. Lisboa, Portugal.

Fernandes, N., Coimbra, M., Oliveira, M., Soares, S., & Arantes, J. The effect of sexual dimorphism on facial attractiveness: A deep learning approach [Conference presentation] (2023, May 10 – 12).16º Encontro de Investigação Jovem da UPorto (IJUP) [16th Young Researchers Meeting at Uporto]. Porto, Portugal.

Analyses developed within this empirical study can be found at:

Fernandes, N. F. R. (2024). Analyzing VGG-19's Bias in Facial Beauty Prediction: Preference for Feminine Features. https://doi.org/10.17605/OSF.IO/RW4D3

Additionally, supplemental materials can be found in Appendix C.

4.1. Abstract

From an evolutionary perspective, sexual dimorphism has been linked to perceived attractiveness, with masculine traits preferred in men and feminine traits in women. Moreover, symmetry is a strong predictor of facial attractiveness across both genders. Recent advancements in the field of artificial intelligence have enabled algorithms to accurately predict facial attractiveness. This study aims to investigate whether these algorithms accurately replicate human judgments of attractiveness. We hypothesized that sexually dimorphic manipulations (masculinized men and feminized women) (H1), as well as symmetrized versions (H2), would elicit higher attractiveness ratings from a facial beauty prediction algorithm. Employing transfer learning, we trained six deep learning models using four facial databases with attractiveness ratings (n = 6848). The top-performing model, VGG-19, demonstrated a high prediction correlation of .86 on the test set. Surprisingly, our findings revealed an interaction effect between gender and sexual dimorphism. Feminized versions of both men's and women's faces obtained higher attractiveness ratings than their masculinized counterparts. For symmetry, our results indicated that symmetrized faces were perceived as more attractive, albeit exclusively among women. These findings offer novel insights into the understanding of facial attractiveness from both algorithmic and human behavioral perspectives.

Keywords: deep learning; facial attractiveness; sexual dimorphism; symmetry; VGG-19

4.2. Introduction

What makes a pretty face? The study of facial attractiveness is a multidisciplinary field that draws on knowledge from diverse disciplines, such as psychology, sociology, anthropology, and computer science (Frevert et al., 2014; Saeed & Abdulazeez, 2021; Thornhill & Gangestad, 1999). Researchers in these disciplines employ diverse methods and approaches to explore the contributing factors to facial attractiveness and its impact on social interactions and relationships.

In psychology, researchers investigate how people perceive and evaluate facial attractiveness, as well as the cognitive and neural mechanisms underlying this process (for a review, see Thornhill & Gangestad, 1999). They also explore the relationship between facial attractiveness and social cognition, such as impression formation and romantic relationships (Dion et al., 1972; Talamas et al., 2016). Studies have shown that humans prefer associating with, dating, and mating with individuals considered facially attractive (Buss, 1994; Rhodes et al., 2005; Riggio & Woll, 1984). Additionally, attractive people tend to be perceived as more successful, enjoyable, and intelligent than unattractive people (Dion et al., 1972). Specifically, research on human preferences for sexually dimorphic faces has garnered significant attention (Barber, 1995; Perret et al., 1998). Sexual dimorphism in facial attractiveness refers to the physical differences in facial features that are considered more attractive in men and women. These differences in facial attractiveness are thought to be influenced by both evolutionary and cultural factors (for a comparison across five populations, see Fiala et al., 2021).

In sociology and anthropology, researchers explore how facial attractiveness and sexual dimorphism are related to cultural norms and values and how they shape social interactions regarding social status, power, and privilege (for a review, see Frevert et al., 2014). Cross-cultural studies suggest a high consensus in facial attractiveness judgments across different populations (Cunningham et al., 1995; Jones & Hill, 1993). However, research also indicates that cultural factors can shape perceptions of facial attractiveness, with different societies having distinct standards for what is considered attractive. For example, Penton-Voak et al. (2004) found an interaction effect between culture and sexual dimorphism, showing that Jamaican women preferred more masculine male faces than their British counterparts. Additionally, the authors found that Jamaican men preferred more masculine female faces than British men did, but feminized faces were preferred within the culture.

In computer science, computer vision researchers study how to create algorithms and models to predict facial attractiveness (for a review, see Saeed & Abdulazeez, 2021). Explaining the functioning of deep learning models has recently gathered increasing attention from researchers and the wider public, including regulators and politicians (Angelov et al., 2021; Samek & Müller, 2019). While attractiveness

prediction is of great use for the human-computer interaction field, it also raises significant moral and ethical questions. One of the primary concerns is whether beauty prediction algorithms reveal human-like psychophysical biases (Kagian et al., 2008; Tong et al., 2021). Kagian et al. (2008) found that machine judgments of attractiveness displayed a preference for averaged and symmetrical faces, mirroring human judgments of attractiveness (Grammer & Thornhill, 1994; Jones & Jaeger, 2019). Additionally, the prediction of facial attractiveness holds clinical significance, particularly in the realm of plastic surgery (Kanevsky et al., 2016; Štěpánek et al., 2019a, 2019b). To gain a comprehensive understanding of the complex issue of facial attractiveness, advancements in facial beauty prediction algorithms offer valuable insights. Furthermore, incorporating input from cognitive scientists in experimental design can enhance our understanding, especially in uncovering the decision-making processes behind algorithmic outputs.

4.2.1. Sexual dimorphism and attractiveness

From an evolutionary standpoint, males and females have evolved unique differences in their secondary sexual characteristics over time (Darwin, 1871). The development of more pronounced sexual dimorphic phenotypes – feminine traits for women and masculine traits for men – is considered attractive (Barber, 1995; Symons, 1995) because it implies the inheritance of advantageous genes favorable to offspring survival or reproductive success (Little et al., 2011; Puts, 2010).

Evolutionary theories suggest that preferences for sexually dimorphic traits are associated with specific mating functions. For example, men may possess facial characteristics to indicate strength and dominance, such as an enlarged brow ridge, a thicker jawline, and a wider face (Scott et al., 2013). Dominant men are considered more attractive by women (Neave et al., 2003; Townsend, 1993), as they often achieve higher social status, thereby enhancing their ability to provide essential resources for reproduction (Geary et al., 2004). Additionally, masculinity is desirable as it signals higher testosterone levels (Penton-Voak & Chen, 2004; Pound et al., 2009). Since testosterone is immunosuppressive, compromising the body's ability to fight infections (Foo, Nakagawa, et al., 2017), only men with high genetic quality and robust immune systems can afford to invest in secondary sexual traits (Folstad & Karter, 1992; Hamilton & Zuk, 1982). Therefore, men with more masculine traits are often perceived as healthier (Dixson & Brooks, 2013; Rhodes et al., 2003) and more attractive to potential mates (Little, Jones, et al., 2007; Little, Cohen, et al., 2007; Rennels et al., 2008; Thornhill & Gangestad, 2006).

Conversely, women may signal youth and fertility (Fink & Penton-Voak, 2002). Feminine facial traits, such as a smaller jawline and a narrower face (Little et al., 2011), indicate higher levels of estrogen, which correlate with superior reproductive qualities (Foo, Simmons, et al., 2017) and mating desirability

(Barber, 1995; Symons, 1995). For instance, research has shown that both men and women rated photographs of women's faces captured during the fertile window of the menstrual cycle (late follicular) as more appealing compared to photographs taken during the non-fertile (luteal) phase (Roberts et al., 2004). Similarly, Bobst and Lobmaier (2012) explored the impact of facial shape transformations towards late follicular and luteal prototypes on male perceptions of attractiveness. Their findings revealed a distinct preference for faces resembling the late follicular phase, suggesting that subtle shape differences can affect men's preferences depending on a woman's menstrual cycle phase. During the late follicular period, a peak of estrogen and luteinizing hormone (LH) leads to ovulation and is followed by a rise in progesterone in the luteal phase (Itriyeva, 2022; Mihm et al., 2011; Reed & Carr, 2000). This increased attractiveness may serve as an adaptive mechanism to enhance a female's perceived value in the mating pool during the phase of the cycle when the likelihood of conception is at its peak (Roberts et al., 2004). Ultimately, the preference for women's feminine facial features remains robust across the literature (Fraccaro et al., 2010; Jones et al., 1995; Kleisner et al., 2024; Moore et al., 2011; Perret et al., 1994, 1998).

4.2.2. Algorithms and attractiveness

Early approaches to quantifying facial attractiveness were grounded in the notion that specific ratios and proportions of facial features are more appealing (Kagian et al., 2008, Sutić et al., 2010, Zaidel & Cohen, 2005). For example, the "golden ratio" or "phi" (1.618) has been used to measure facial proportions and attractiveness (Fan et al., 2012; Schmid et al., 2008). The idea is that if specific facial ratios, such as the distance between the eyes and the distance between the mouth and eyes, conform to phi, the face is more attractive. However, contemporary computer-based methods, including machine learning and deep learning algorithms, have shown more promising outcomes.

Machine learning offers a method that can be used to predict facial attractiveness by analyzing patterns in predefined facial features known to be associated with attractiveness (Kagian et al., 2008, Sutić et al., 2010, Zaidel & Cohen, 2005). These models assess multiple hand-crafted features, such as symmetry, geometric ratios, and distances between landmarks. Another approach uses deep learning algorithms, such as Convolutional Neural Networks (CNNs), which also predict facial attractiveness. One advantage of CNNs is that they do not require pre-defined facial attributes, as they can extract useful features directly from raw images. Consequently, these models have achieved a relatively high correlation with the actual judgments of attractiveness (Bougourzi et al., 2022; Gan et al., 2023; Gao et al., 2018).

Furthermore, leveraging transfer learning eliminates the need to develop an algorithm from the ground up, as it allows for the use of pre-existing models trained on large datasets, such as architectures from the Visual Geometry Group Network (VGG; Simonyan & Zisserman, 2014) or residual networks (ResNet) (He et al., 2015). Although these models were initially designed for image classification tasks, they can be fine-tuned for facial beauty prediction (Gan et al., 2020; Vahdati et al., 2019; Zhai et al., 2020). The fine-tuning process involves adjusting the model's parameters to better fit the new task, typically by training the final layers of the model on the new dataset. Once the model is fine-tuned, it can predict the attractiveness of new facial images. This approach has been widely used in attractiveness prediction tasks as it saves computational time and resources while improving performance (Gan et al., 2020; Vahdati et al., 2019; Zhai et al., 2020).

The benchmark for training and evaluating facial beauty prediction algorithms is the SCUT-FBP5500 (Liang et al., 2018), with cutting-edge models achieving a Pearson correlation of .93 with human judgments of attractiveness (Gan et al., 2023). However, despite the large number of images (n = 5500), attractiveness ratings were performed only by Asian raters. Therefore, this could be a potential limitation for generalizing the beauty prediction algorithms. Additionally, the high accuracy observed could be attributed to greater internal consistency in attractiveness judgments within the Asian population (Perret et al., 1998).

4.2.3. The present study

Despite significant advancements in facial beauty prediction algorithms, a gap remains in the literature regarding how these algorithms make their decisions. The main objective of this study is to investigate whether beauty prediction algorithms replicate human biases toward sexually dimorphic facial traits. We hypothesize that sexually dimorphic versions of male (masculinized) and female (feminized) facial images will be perceived as more attractive (H1). Moreover, we will manipulate symmetry, which is a well-established predictor of facial attractiveness (Fink et al., 2006; Grammer & Thornhill, 1994; Jones et al., 2001; Perret et al., 1999). We expect that symmetrized facial images of both men and women will be rated as more attractive (H2). Our secondary aim is to provide a benchmark for facial attractiveness prediction using multiple databases. This novel approach aims to enhance our understanding of how facial beauty prediction algorithms assess attractiveness and whether they support the sexual dimorphism and symmetry hypotheses.

4.3. Method

4.3.1. Materials

For the transfer learning phase, four databases were used: SCUT-FBP5500 (Liang et al., 2018); Chicago Face Database (CFD) (Ma et al., 2015); Karolinska Directed Emotional Faces (KDEF) (Lundqvist et al., 1998); and FACES (Ebner et al., 2010), resulting in a total of 6,848 images. Attractiveness ratings across all datasets were normalized to a scale from 0 to 1. An additional database, the Face Research Lab London (FRL-London; DeBruine & Benedict., 2017), was used to create sexually dimorphic and symmetrized versions of faces, which were then evaluated for facial attractiveness by the trained model. Following common preprocessing practices for image data in deep learning tasks (He et al., 2015; Simonyan & Zisserman, 2014), pixel values were rescaled to the range of [0, 1] by dividing each pixel intensity value by 255. This normalization step ensures that the input features are appropriately scaled and facilitates efficient training of machine learning models, particularly neural networks, by mitigating issues such as vanishing or exploding gradients (Hochreiter, 1998; Khan et al., 2018).

4.3.1.1. SCUT-FBP5500 (Liang et al., 2018). The dataset consists of 5500 frontal face images, including 2000 Asian females, 2000 Asian males, 750 Caucasian females, and 750 Caucasian males. Most of the faces have neutral expressions and simple backgrounds. The faces in the dataset were labeled with attractiveness ratings from 1 to 5 by 60 Asian raters aged 15 to 60.

4.3.1.2. Chicago Face Database (CFD; Ma et al., 2015). The dataset consists of 970 facial images displaying neutral, happy, threatening, and fearful expressions. The 158 volunteers who photographed included 37 Black males, 48 Black females, 36 White males, and 37 White females, ranging in age from 18 to 40 years. A sample of 1,087 raters made subjective ratings of the image's attractiveness on a 1–7 Likert scale, with each subject rating only 15 faces. Participants included 552 females, 308 males, and 227 who preferred not to disclose their gender, with an average age of 26.75 (SD_{age} = 10.54). They came from diverse racial backgrounds: 516 White, 117 Asian, 74 Black, 72 biracial or multiracial, 57 Latino, 18 other, and 233 who did not report their race.

4.3.1.3. Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998). The KDEF is one of the most widely used databases of human facial expressions. Garrido and Prada (2017) presented subjective attractiveness ratings for a subset of 210 pictures from 70 Caucasian amateur actors (35 women and 35 men, aged between 20 and 30 years) with different facial expressions: angry, happy, and neutral. The sample of raters included 155 students from Portuguese universities (83.20%

female; M_{age} = 23.73; SD_{age} = 7.24). Each participant rated the facial attractiveness of 36 pictures on a 1-7 Likert scale.

4.3.1.4. FACES (Ebner et al., 2010). This dataset consists of a set of facial images from 171 women and men categorized into three age groups: young (n = 58; age range: 19–31; M_{age} = 24.3; SD_{age} = 3.5), middle-aged (n = 56; age range: 39-55; M_{age} = 49.0; SD_{age} = 3.9), and older (n = 57; age range: 69-80; M_{age} = 73.2; SD_{age} = 2.8). Each individual displays six facial expressions: neutrality, sadness, disgust, fear, anger, and happiness, resulting in a total of 1026 pictures. Facial attractiveness evaluations were performed by 154 raters, all of whom were Caucasian and German. Each participant was randomly assigned to either set A or set B, which consisted of identical pictures of the same subjects and facial expressions, with only minor differences (e.g., head inclination angle). For the present work, only set A was considered. Each image was rated by a minimum of 8 and a maximum of 14 raters per age group by gender. Therefore, six attractiveness ratings were provided in the metadata of the original work. In our case, we used the average of these ratings on a scale from 1 to 100.

4.3.1.5. Face Research Lab London (FRL-London; DeBruine & Benedict, 2017). The database chosen for the sexual dimorphic transformations was the FRL-London, which consists of 102 neutral front faces (male = 52; female = 50; M_{age} = 26.9; SD_{age} = 7.07) from different ethnicities (69 White, 13 Black, and 20 Asian). We used only 100 photos from this database due to problems manipulating two male images (codes 005_03 Asian and 114_03 Black), resulting in an equal number of male and female facial images. This dataset included pre-delineated face shape templates of 189 coordinates for each image. Attractiveness ratings (on a 1-7 scale) were made by 2,513 people (age range: 17-90).

4.3.1.6. Algorithms. A set of six facial recognition models was used to determine which of these models would be the most adequate for facial attractiveness prediction. The selected models were: InceptionResNetV2 (Szegedy et al., 2016), MobileNetV2 (Howard et al., 2017), EfficientNetV2B0 (Tan & Le, 2021), ResNet50 (He et al., 2015), Xception (Chollet, 2016), and VGG-19 (Simonyan & Zisserman, 2014).

4.3.2. Procedure

The procedure was divided into three phases. Initially, we employed a transfer learning methodology across a range of models, followed by fine-tuning the one that yielded the most favorable results. In the second phase, we applied sexual dimorphic and symmetrical transformations of the images from the FRL-London dataset for further evaluation. Finally, we utilized the fine-tuned model to predict the

facial attractiveness of the original, sexually dimorphic, and symmetrized versions of both female and male facial photos.

We selected a set of six commonly used architectures with pre-trained weights for image classification problems from the Keras Applications Module: tf.keras.applications (Chollet, 2015). Then, we applied transfer learning to each model to predict facial attractiveness, similar to previous studies (Gan et al., 2020; Vahdati et al., 2019; Zhai et al., 2020). This involved freezing all layers except the last one, and transforming the initial classification problem into a regression problem by incorporating a final dense layer.

The models were trained for 100 epochs with patience set to 30 epochs, using the Adam optimizer with a learning rate of 0.001 and weight decay of 0.004. Adam is an "algorithm for first-order gradient-based optimization of stochastic objective functions, based on adaptive estimates of lower-order moments" (Kingma & Ba, 2014, p. 1). A train/validation/test split of 60/20/20 size was used, resulting in 4110/1369/1369 images for the corresponding set. The model with the best results was the VGG-19 with a Pearson's correlation of .76 (*RMSE* = 0.094; *MAE* = 0.07). Detailed results between the different models for the test set can be found in Table C.1 of Appendix C.

The VGG-19 belongs to a series of deep neural networks from the Visual Geometry Group Network (VGG), also including VGG-11, VGG-13, and VGG-16 (Simonyan & Zisserman, 2014). These networks share their structure by having several blocks of convolutional layers connected to a final block consisted of three fully connected layers. The VGGNet has been trained on over 1 million images in 1000 classes (Simonyan & Zisserman, 2014). Specifically, VGG-19 has five blocks of convolution layers and one last block of three fully connected layers. A 3x3 Max Pooling layer connects all blocks. The first (size 64x64x64) and second (size 128x128x128) blocks have two convolutional layers, while the third (size 256x256x256), fourth (size 512x512x512) and fifth (size 512x512x512) blocks have four convolutional layers.

Since VGG-19 showed the best performance for predicting facial attractiveness compared to the other architectures, we fine-tuned this model. Therefore, we unfroze the 3-fully connected layers, whereas in the previous phase only the last regression layer was trainable. We used the same hyperparameters and train/validation/test sets. The model's performance on the test set increased from a Pearson's correlation of .76 to .84 (*RMSE* = 0.12; *MAE* = 0.10). Finally, we fine-tuned the model with the best parameters by unfreezing all the model's layers. We set the training for 10 epochs (patience of 5), using Adam optimizer with a learning rate of 0.00001 and weight decay of 0.004, to prevent overfitting (see Li

et al., 2020 for a revision on hyperparameter optimization for fine-tuning). A final correlation of .86 ($p <$ .001) was achieved between the model's predictions and the test set (*RMSE* = 0.10; *MAE* = 0.08).

To achieve sexual dimorphic and symmetric transformations, we used the FRL-London (DeBruine & Benedict, 2017) database. All image manipulations were performed using computer vision techniques provided by the Psychomorph software (Tiddeman & Perret, 2002) and its web-based version, WebMorph (DeBruine, 2018). Following previous research (DeBruine et al., 2006; Penton-Voak et al., 2003; Perret et al., 1994), sexually dimorphic versions of each image were created using a 50% spatial linear transformation towards either a female avatar (feminized version) or a male avatar (masculinized version). The avatars (average faces) were generated by averaging 30 male faces (male avatar) and 30 female faces (female avatar). Additional information regarding these methods can be found in Rowland and Perrett (1995). Symmetrized versions of both the original and manipulated photos (feminized and masculinized faces) were created by mirror reversing the image and then combining one side of the original non-symmetrized photo with the opposite side of the reversed photo (Gangestad & Thornhill, 2003; Perrett et al., 1999).

4.3.3. Data analysis

The algorithm's prediction of attractiveness was used as the dependent variable in a linear mixed-effects model (LME) with three fixed main effects: sexual dimorphism manipulation (masculinized/feminized), symmetry (original/symmetric), and sex (male/female), along with the three-way interaction term. The photo's code was entered as a random factor, as the model predicted attractiveness for multiple versions (sexually dimorphic and symmetric transformations) of the same individual (for a detailed explanation on LME models, see Pinheiro & Bates, 2000). A post-hoc analysis using Bonferroni adjustment was performed for the observed significant effects. All statistical analyses were conducted using R Statistical Software (v4.3.1; R Core Team, 2023) using lme4 (v.1.1.34; Bates et al., 2015) and ggplot2 (v.3.4.4.9000; Wickham, 2016) for plotting. The data and reproducible code are publicly available at Fernandes (2024).

4.4. Results

The LME (estimated using REML) was composed of both main effects (sexual dimorphism manipulation, symmetry, and sex) and its three-way interaction term (Figure 10). The model included the image's code as a random factor. The model's total explanatory power was substantial (conditional R^2 = .93), and the part related to the fixed effects alone (marginal R^2) was equal to .33. The model showed a

statistically significant main effect of sexual dimorphism, $F(2, 490) = 64.02$, $p < .001$, symmetry, $F(2, 490) = 32.07$, $p < .001$, and sex, $F(1,98) = 49.74$, $p < .001$. For the interaction terms, the two-way interaction of sexual dimorphism by symmetry manipulation was shown to be statistically significant, $F(2,490) = 5.40$, $p = .005$, while the two-way interaction of sexual dimorphism and sex, $F(2,490) = 2.73$, $p = .066$, or the triple interaction of sexual dimorphism*symmetry*sex, $F(2,490) = 0.91$, $p = .40$, showed no significant results.

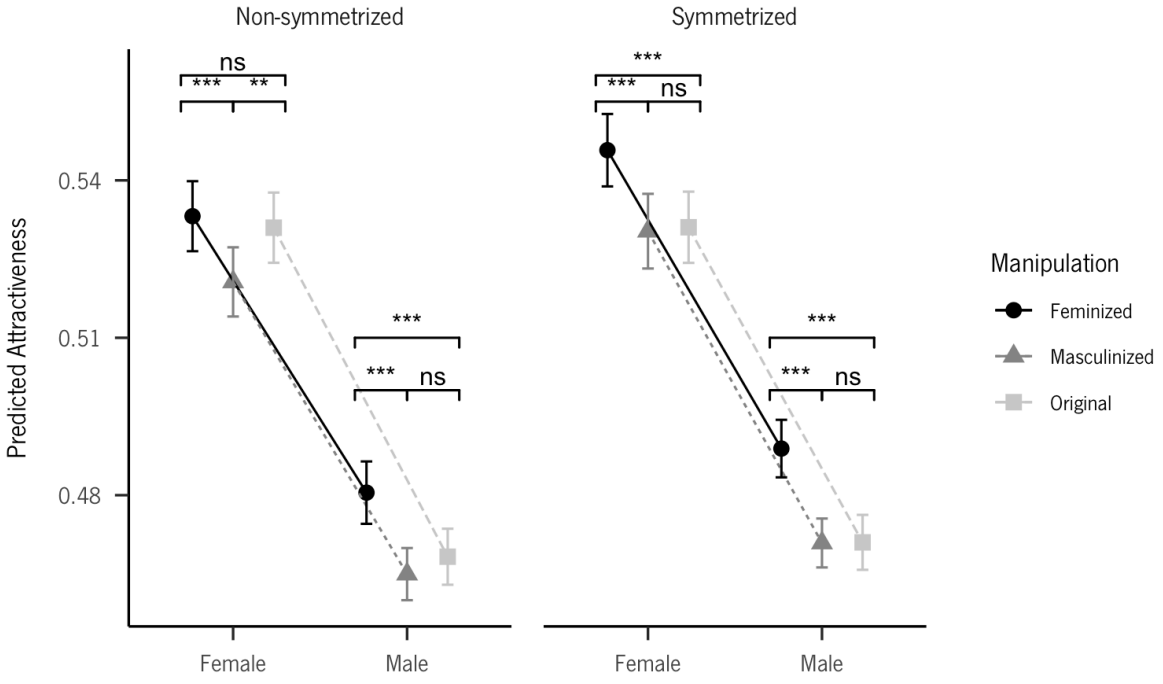
Post-hoc analysis using Bonferroni correction showed that feminized faces were rated as more attractive for both male and female images (H1). In the non-symmetric condition, feminized females were judged as more attractive than masculinized females, $t(490) = 4.41$, $p < .001$, 95% CI [0.01, 0.02], $d = 0.88$, as well as in the symmetric condition, $t(490) = 5.44$, $p < .001$, 95% CI [0.01 0.02], $d = 1.09$. Also, feminized males in the non-symmetric condition were rated as more attractive than masculinized ones, $t(490) = 5.47$, $p < .001$, 95% CI [0.01, 0.02], $d = 1.09$, as well as in the symmetric condition, $t(490) = 6.34$, $p < .001$, 95% CI [0.01 0.03], $d = 1.27$. Additionally, feminized manipulations were perceived as more attractive than the original faces for all conditions, except for females in the non-symmetrized version, $t(490) = 0.77$, $p = 1$, 95% CI [-0.01, 0.01], $d = 0.15$. Similarly, no differences were found between the masculinized versions and the original faces, except for that condition in which masculinized female photos were judged as less attractive than the original ones in the non-symmetrized versions, $t(490) = -3.64$, $p = .007$, 95% CI [-0.02, -0.01], $d = -0.73$.

For the symmetry main effect that was observed (H2), post-hocs revelated that symmetrized versions were only more attractive for feminized female faces, $t(490) = 4.43$, $p < .001$, 95% CI [-0.02, -0.01], $d = 0.89$, and masculinized female faces $t(490) = -3.41$, $p = .02$, 95% CI [-0.02, -0.01], $d = 0.58$, in comparison with the non-symmetrized ones. No differences were observed for males or between original photos.

Finally, supporting the sex main effect, in the non-symmetrized condition, feminized females were perceived as more attractive than feminized males, $t(118) = 6.12$, $p < .001$, 95% CI [0.03, -0.08], $d = 3.71$, with the same occurring for masculinized versions, $t(118) = 6.47$, $p < .001$, 95% CI [0.03, 0.08], $d = 3.92$, and original faces, $t(118) = 7.28$, $p < .001$, 95% CI [0.04, 0.09], $d = 4.42$. In the symmetrized condition, the same pattern was found, with feminized female photos being rated as more attractive than feminized male photos, $t(118) = 6.61$, $p < .001$, 95% CI [0.03, 0.08], $d = 4.01$, as well as masculinized versions, $t(118) = 6.90$, $p < .001$, 95% CI [0.03, -0.09], $d = 4.19$, and original ones, $t(118) = 6.98$, $p < .001$, 95% CI [0.03, 0.09], $d = 4.23$.

Figure 10

The attractiveness ratings for VGG-19 regarding both non-symmetrized (left panel) and symmetrized (right panel) sexually dimorphic manipulations of male and female faces



Note. Bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

4.5. Discussion

The main aim of the present study was to investigate whether beauty prediction algorithms replicate human judgments concerning facial sexually dimorphic traits. We hypothesized that sexually dimorphic versions of male (masculinized) and female (feminized) facial pictures would be rated as more attractive (H1). Also, we expected that symmetrized versions of both male and female facial pictures would be perceived as more attractive (H2). Additionally, we aimed to provide a benchmark for facial attractiveness prediction using multiple databases.

The fine-tuned model was used to predict the attractiveness of symmetrized and non-symmetrized versions of masculinized, feminized, and original frontal facial images with neutral expressions from the FRL-London database. Surprisingly, our results showed that feminized manipulations were rated as more attractive compared to the masculinized versions for both male and female faces. Thus, we partially confirmed our first hypothesis (H1), as we expected a sexual dimorphism main effect, with feminized versions being preferred for females, but not for males. Moreover, despite the observed main effect of

symmetry, post-hoc analyses suggested that symmetry increased facial attractiveness specifically for feminized and masculinized versions of female faces. Thus, the data also partially supported our second hypothesis (H2). Additionally, across all conditions, females were consistently rated as more attractive than males.

We achieved a Pearson correlation of .86 with the fine-tuned VGG-19 on the test set across four databases. Although slightly lower than state-of-the-art results (r = .93; Gan et al., 2023), our approach addresses a key limitation by reducing bias from relying solely on the SCUT-FBP5500 dataset. This offers a valuable benchmark for facial beauty prediction, encouraging future research to explore and improve on these findings.

4.5.1. Theoretical Implications

Firstly, our work contributes to understanding how facial beauty prediction algorithms make decisions. The consistent overall preference for feminine facial traits suggests that beauty prediction algorithms can implicitly learn human attractiveness preferences, like Kagian's et al. (2008) findings. More recently, Tong et al. (2021), using the VGG architecture, showed that DNNs use putative ratios (e.g., golden ratio) as essential attributes for predicting facial attractiveness, akin to human judgments. This convergence between algorithmic and human judgments underscores the complex interplay between facial features, attractiveness perception, and evolutionary pressures. Further investigation into the mechanisms underlying both facial attractiveness prediction and sexual dimorphism is therefore warranted.

Regarding our first hypothesis (H1), and despite our initial assumptions, feminized versions of both male and female faces were rated as more attractive. The preference for femininity in women is well-supported in the existing body of literature (Fraccaro et al., 2010; Kleisner et al., 2024; Marcinkowska et al., 2014; O'Connor et al., 2013; Perret et al., 1998). However, there are mixed findings concerning the effect of sexual dimorphism on male attractiveness. Some research reports a stronger preference for more masculine male faces (Feinberg et al., 2005; Johnston et al., 2001; Little, Jones, et al., 2008; Penton-Voak et al., 1999, 2001; Stower et al., 2020), while other studies suggest a preference for more feminine faces (DeBruine et al., 2010; Little et al., 2001; Marcinkowska et al., 2019; Nakamura & Watanabe, 2020; Penton-Voak et al., 1999; Perret et al., 1998; Rhodes et al., 2003), or report no differences between masculinized and feminized versions of male faces (Cornwell et al., 2004; Kleisner et al., 2024; Swaddle & Riersen, 2002).

A possible explanation for these diverse findings may be associated with the level of attractiveness from both the rater and the photo. For instance, Hu et al. (2018) found that when judging attractive faces, both male and female participants favored masculine male faces over feminine ones. Conversely, in the less attractive condition, they preferred feminine male faces to masculine ones. Furthermore, Welling et al. (2008) found that women's preferences for femininity in men's faces decreased after viewing images of highly attractive men. Since the predicted attractiveness in our results may be considered average, this could explain the lack of preference for masculinity. Moreover, there is an increased preference for masculinity among women who perceive themselves as attractive (Little et al., 2001). Furthermore, women perceived as having relatively low facial attractiveness by others, showed a preference for more "feminine" male faces when selecting partners for long-term relationships compared to short-term relationships (Penton-Voak et al., 2003).

Furthermore, enhancing masculine facial features may increase perceptions of dominance and negative attributes, such as coldness or dishonesty (Perret et al., 1998). These aspects are considered significant by women within the context of relationships and paternal investment (Perret et al., 1998). Subsequent research has unveiled that women prefer less masculine male faces in long-term relationships under specific conditions of environmental harshness, such as resource scarcity or elevated stress levels (Little, Cohen, et al., 2007; Little, Burriss, et al., 2008). These findings align with the notion that men with more favorable genes (higher testosterone levels) invest less in the relationship, as they can afford to choose their mate (for a review, see Penton-Voak & Perret, 2001).

However, it is important to note that this aspect remains ambiguous within the existing body of literature. In a recent study, women exhibited a preference for masculinized faces over feminized ones (Stower et al., 2020). Notably, this preference for masculine male faces was more pronounced when assessing potential co-parenting partners compared to short-term relationships (Stower et al., 2020). Supporting these findings, Bartlome and Lee (2023) demonstrated that facial attractiveness, instead of facial masculinity influenced perceptions of paternal involvement.

Finally, hormonal changes occurring during the menstrual cycle may alter women's preference for sexually dimorphic cues. In women, the preference for masculinity is higher during the late follicular phase of the menstrual cycle (when fertility is high and progesterone level low) (Jones et al., 2008). Similarly, Fink and Neave (2005) found that women tend to prefer masculinity in male faces around ovulation, while they prefer feminized male faces during the rest of the cycle. This likely indicates a balanced trade-off between the attraction to males who appear to ensure reproductive success and males who are perceived as capable and nurturing fathers.

Concerning our second hypothesis (H2), our results showed that the facial beauty prediction algorithm found symmetrized faces more attractive, but only for sexually dimorphic versions of female faces. Symmetry is one of the most researched factors contributing to facial attractiveness (for a review, see Little et al., 2011; Thornhill & Gangestad, 1999). Similar to our findings, machine learning models trained to predict facial attractiveness based on geometric facial features have been found to implicitly learn human psychophysical biases towards symmetric faces (Schölkopf et al., 2007; Sutić et al., 2010). However, it is important to note that the specific characteristics that make symmetric faces more attractive, independent of their symmetry, are not definitively defined.

Since our results showed a preference for symmetric sex-dimorphic traits exclusively in female faces, insights from prior studies (Little, Jones, et al., 2008; Tybur et al., 2022) suggesting an intercorrelation between symmetry and sexual dimorphism may shed light on why symmetrized male faces were not found more attractive than non-symmetrized versions. In a cross-cultural study, perceived sexual dimorphism demonstrated a correlation with symmetry measurements (Little, Jones, et al., 2008). Additionally, research found that women's preferences for symmetry were positively correlated with preferences for masculinity in male faces and that men's preferences for symmetry were positively correlated with preferences for femininity in female faces (Little, Jones, et al., 2008). Furthermore, Scheib et al. (1999) found that facial symmetry was associated with masculine facial cues in males, such as increased lower face length and cheekbone prominence (Penton-Voak & Chen, 2004; Pound et al., 2009). Symmetry could potentially enhance the perception of masculinity or be interpreted by the algorithm as a cue of masculinity in male faces, which might explain why the effect was observed only for female faces.

Despite the critical role of symmetry in the perception of attractiveness, evidence suggests that sexual dimorphic cues may be more influential than symmetry in attractiveness evaluations, which supports our findings. For instance, Mogilski and Welling (2017) found that participants focused more on sexual dimorphic cues than on symmetry when selecting a partner for a romantic relationship. Furthermore, Swaddle and Cuthill (1995) altered symmetry within a face while keeping the mean size of facial features constant, revealing that symmetric faces were perceived as less attractive. Additionally, Zheng et al. (2021) found that symmetry enhances facial attractiveness by increasing perceived normality, suggesting that attractiveness perception may involve additional inferences about a face. Likewise, using a random forest machine learning algorithm to predict facial attractiveness, Jones and Jaeger (2019) found that shape averageness, dimorphism, and skin texture symmetry emerged as valuable features capable of yielding relatively precise predictions. However, it was observed that shape symmetry did not contribute significantly to the predictive accuracy.

Our results revealed that women were perceived as more attractive than men by the facial beauty prediction algorithm. Similarly, neural networks using facial landmarks as input demonstrated a sex bias, wherein female faces were consistently predicted to be more attractive than male faces (Palumbo et al., 2017). Additionally, Mclellan and McKelvie (1993) found that both men and women rated photographs of females as more attractive than males. Moreover, Levy et al. (2008) reported that male raters found beautiful females more attractive than beautiful males, while female raters showed no differences in their attractiveness judgments.

Considering the sex effect observed, it could be argued that the algorithm's general preference for feminization may stem from an inclination towards feminine traits, regardless of the sex of the face being evaluated. However, several studies have highlighted the impressive capability of convolutional neural networks in sex recognition tasks. For example, in a study using internet images, VGG-19 achieved 98.2% accuracy in classifying the face's sex (Nistor et al., 2017). Furthermore, another study using the IMDB-WIKI dataset reported that VGG-19 achieved a sex classification accuracy of 91.1% (Nga et al., 2020).

4.5.2. Limitations/ Further studies

There are some limitations mainly associated with the databases that warrant consideration. Novel research has revealed that beauty prediction algorithms trained using SCUT-FBP5500 images exhibit poor prediction accuracy when assessing faces from other databases (Żejmo et al., 2023). There may be a cultural effect in our study, as the largest database consisted solely of Asian raters, potentially influencing preferences for masculinity in male faces. Research suggests that a preference for more masculine men is more pronounced in countries with higher economic and national health indices (Marcinkowska et al., 2019). To prevent the model from overfitting to the characteristics of the SCUT-FBP5500 dataset, we included additional datasets with standardized frontal facial images.

Furthermore, there is an interrelationship between attractiveness and emotional expression (Garrido & Prada, 2017; Golle et al., 2014; Lindeberg et al., 2019). Human raters consistently perceive attractive faces as more appealing (Garrido & Prada, 2017; Golle et al., 2014), and research indicates that positive emotions are more readily recognized in attractive faces (Golle et al., 2014; Lindeberg et al., 2019). Extensive efforts have been devoted to the development of emotion recognition algorithms (for a review, see Balasubramanian et al., 2019). On one hand, these models have not yet integrated attractiveness ratings; on the other hand, beauty prediction models typically do not account for

emotionality. Future studies should investigate whether algorithms mirror human biases regarding attractiveness in relation to emotions and explore their interaction with sexual dimorphism.

Additionally, integrating multiple databases with varying rating scales for facial beauty prediction can pose challenges, as noted by Żejmo et al. (2023). Lim (2008) addresses the challenge of standardizing Likert scales, noting that the mean may shift depending on the scale's point range. To address this issue, Lim (2008) suggests a rescaling system based on transitional probabilities. However, given that the scales from the selected datasets range from 1-5 to 1-100, we opted for a straightforward normalization to the 0-1 range. Nonetheless, using ordinal attractiveness judgments as scalar intervals presents a rescaling challenge. The interval properties of Likert scales are inherent to the data, influenced by observers' mean responses rather than the labels themselves (Allen & Seaman, 2007). Thus, we advocate for a unified rating system for attractiveness datasets to enhance predictive models.

In this study, VGG-19 was trained using attractiveness ratings from both male and female evaluators who assessed photos of individuals from both the same and opposite sexes. From an evolutionary perspective, the sexual dimorphism hypothesis posits that individuals seek high-quality partners for reproduction. Therefore, the same-sex attractiveness judgments in these datasets may represent a potential limitation. However, as previously discussed, Hu et al. (2018) demonstrated congruent attractiveness preferences among men and women, indicating a preference for masculinity in attractive male faces, whereas feminine traits were preferred in less attractive male faces. Additionally, earlier research, such as that by Simpson and Gangestad (1990), did not find differences between same-sex and opposite-sex attractiveness preferences. Supporting the preference for sexual dimorphism, Li et al. (2020) reported that male participants rated masculinized versions of male faces as more attractive than feminine faces. Moreover, the self-rated sex-typicality appears to moderate this effect. For instance, individuals who perceive themselves as possessing more exaggerated sex-typical traits tend to exhibit stronger preferences for exaggerated sex-typical shape cues in faces of the same sex (Kandrik & DeBruine, 2012). Further studies may explore whether same-sex or opposite-sex ratings could explain the observable effects. Therefore, researchers should consider incorporating this factor when developing future databases of facial attractiveness.

Furthermore, sexual orientation may influence preferences for sex-dimorphic face shapes. Research indicates that homosexual men tend to have a stronger preference for masculinity in male faces compared to other demographic groups (Glassenberg et al., 2010). However, there is evidence suggesting that sexual position moderates facial masculinity preferences (Zhang et al., 2018; Zheng, 2021). Individuals' self-labeling as "top" or "bottom", as well as their preferences for their partner's sexual

position, are indicative of their preferences for masculinity. Generally, individuals seeking a "top" as a romantic partner prefer more masculine faces than those seeking "bottoms" (Zhang et al., 2018; Zheng, 2021). Additionally, homosexual women exhibited stronger preferences for masculinity in female faces compared to heterosexual women (Glassenberg et al., 2010). Thus, sexual orientation may be a crucial factor to consider in subsequent models. To account for this, we suggest that authors incorporate sexual orientation when developing databases of facial attractiveness and make this information available to other researchers.

4.5.3. Conclusions

The results of the present study align with previous findings in the psychological literature, which indicate a preference for femininity in both sexes. Moreover, we supported prior findings about a preference for symmetric faces. However, our results reveal an interplay between sexual dimorphism and symmetry, as the preference for symmetric faces was observed only in dimorphic faces, not in the original versions. Furthermore, our results provide a benchmark for developing beauty prediction algorithms using multiple databases. Future research could build on these findings by investigating additional cues of facial attractiveness. Overall, our findings suggest that beauty prediction algorithms can implicitly learn and replicate human biases regarding facial attractiveness.

4.6. References

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CHAPTER 5

Empirical Study 4:

AI and Human Biases:

How Facial Expressions Shape Algorithmic Beauty Judgments

5. AI and Human Biases: How Facial Expressions Shape Algorithmic Beauty Judgments

Fernandes, N., & Arantes, J. (in preparation). AI and Human Biases: How Facial Expressions Shape Algorithmic Beauty Judgments.

All data, analysis code, and research materials are available at:

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Additionally, supplementary materials are presented in Appendix D.

5.1. Abstract

Psychological research shows that happy expressions enhance perceived facial attractiveness, whereas angry expressions diminish it. Although previous research has explored the mechanisms underlying beauty prediction algorithms, none have yet addressed the potential effect of distinct facial expressions on attractiveness. This study investigates how different facial expressions affect algorithmic assessments of attractiveness. We hypothesized that happy facial expressions would be rated as more attractive than angry ones (H1). Also, we expected an interaction effect between sex and facial expression, with happy faces having a stronger impact on perceived attractiveness for females compared to males (H2). Moreover, we expected that happy expressions would increase the attractiveness of masculinized faces for both sexes, but not for feminized ones (H3). Using a transfer learning methodology, we trained the VGG-19 architecture to predict facial attractiveness across multiple facial expression databases. The fine-tuned version achieved a Pearson correlation of .91 on the test set, successfully predicting human attractiveness ratings. Then, it was used to predict the attractiveness of male and female faces with happy, angry, and neutral expressions, including sexually dimorphic versions. Our findings supported the negative impact of angry expressions on perceived attractiveness for both sexes (H1). No evidence was found supporting the interaction between facial expressions and sex (H2). Interestingly, happy expressions increased the attractiveness of masculinized faces for females, but not for males, partially supporting H3. This study provides new insights into the alignment between AI-based facial attractiveness evaluations and human judgments and highlights the nuanced interplay between facial expressions and perceived attractiveness.

Keywords: beauty prediction; facial attractiveness; facial expressions; sexual dimorphism; VGG-19

5.2. Introduction

Beauty, at least for lovers, often seems to be exclusively a projection of personal preferences. However, a closer look at common beauty standards makes us realize that objective cues must exist, as there is a certain level of agreement among observers. In addition, physical appearance plays a critical role in impression formation. The literature suggests the presence of a halo effect, where attractive individuals are perceived to have more socially desirable characteristics, such as happiness and competence in romantic relationships (Dion et al., 1972). Further research has shown that facial impressions influence personality (Sutherland et al., 2015; Todorov et al., 2015) and trustworthiness judgments (Ma et al., 2017; Oosterhof & Todorov, 2008; Xu et al., 2012). This holds particular significance considering the real-life outcomes of first impressions. For example, assessments of trustworthiness based on facial photographs impact decisions in online financial lending (Duarte et al., 2012; Yang, 2014). Additionally, facial attractiveness influences decisions related to hiring and promotions (Gilmore et al., 1986; Hochschild & Borch, 2011; Lutz, 2010).

Because of its significant social implications, the objective representation of facial beauty has attracted scholars from various fields. Psychologists, adopting an evolutionary perspective, have focused on facial attractiveness as a signal of health (for a review, see Little, 2021). Key indicators include symmetric (Fink et al., 2006; Jones et al., 2001; Perret et al., 1999), sexual dimorphic (Fraccaro et al., 2010; Johnston et al., 2001; Penton-Voak et al., 2001; Perret et al., 1998), and happy (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984) faces. Computer scientists have relied on these findings to develop machine-learning models capable of predicting facial attractiveness. These models can analyze multiple variables simultaneously, typically consisting of hand-crated features such as distances between facial landmarks (e.g., symmetry and sexual dimorphic cues), and geometric ratios (e.g., golden ratio) (Schölkopf et al., 2007; Sutić et al., 2010; Zaidel & Cohen, 2005; Zhao et al., 2020).

Recently, deep learning techniques have demonstrated exceptional performance, surpassing traditional methods in various domains, particularly in sound (Jia et al., 2019) and vision (O'Mahony et al., 2020). The primary advantage of employing deep neural networks (DNNs) lies in their ability to process raw data without the need for manually crafted features. For instance, in attractiveness prediction, there is no longer a requirement to create hand-crafted features. These image classification models were initially trained on millions of images, bringing facial attractiveness predictions more aligned with real-world judgments aided by the current availability of computing resources. Facial beauty prediction algorithms commonly employ a transfer-learning methodology, which involves using pre-trained architectures and fine-tuning the model for the specific task (for a review, see Weiss et al., 2016). Fine-

tuning involves adjusting the model's parameters to better suit the new task, typically achieved by training the last layers of the model on the new dataset. Once fine-tuned, the model can effectively predict the attractiveness of new facial images (Gan et al., 2020; Vahdati et al., 2019; Zhai et al., 2020). This approach has gained popularity due to its computational efficiency and performance advancements.

Convolutional Neural Networks (CNNs) are commonly used architectures in the computer vision field (for a review, see Voulodimos et al., 2018). A CNN is typically composed of multiple layers, with a key characteristic being the incorporation of convolutional layers. These layers apply a kernel, a small matrix of weights, to the input grid, enabling the network to adaptively extract spatial hierarchies from raw images (for a detailed explanation, see Albawi et al., 2017). CNNs have been applied to facial attractiveness prediction tasks, demonstrating notable success in achieving high correlations with human judgments of attractiveness (e.g., Bougourzi et al., 2022; Gan et al., 2023; Gao et al., 2018).

However, the use of these models poses some challenges. Given their black-box properties, increasing attention has been directed toward understanding how these models make decisions. This has become critically important for both researchers and legislators. Explainable AI (XAI) methods attempt to address this issue by providing insights into the decision-making processes of deep learning models (for a review, see Abhishek & Kamath, 2022). Typically, these methods involve identifying the most critical regions of interest in an image for the model (Qin et al., 2018; Wang et al., 2020).

Some researchers argue that even with XAI techniques, DNNs should be avoided in high-stakes decision-making (Rudin, 2019, 2022). Aligned with this notion, The European Parliament has recently declared its intention to regulate the use of AI in the EU (European Parliament, 2023). According to this framework, the uninformed use of beauty prediction algorithms poses unacceptable risks, given their potential to contribute to a social scoring system. The directive explicitly defines social scoring as the classification of individuals based on their behavior, socioeconomic status, or personal characteristics (European Parliament, 2023). As previously discussed, physical attractiveness influences impression formation and social interactions. Therefore, understanding how facial beauty prediction algorithms function is crucial for building confidence in their applications, particularly within the field of plastic surgery, where such models could be beneficial (Kanevsky et al., 2016; Štěpánek et al., 2019).

Despite significant advancements in the technical aspects of facial beauty prediction algorithms, less attention has been given to whether these models are replicating human-like psychophysical biases in their judgments. An initial study by Kagian et al. (2008) showed that machine learning algorithms implicitly learned a human's preference for average faces (Alley & Cunningham, 1991; Grammer & Thornhill, 1994; Rhodes et al., 1999). Just as the exploration of the human mind, often considered a

black box, has benefited from cognitive science, this field also has the potential to contribute to Explainable AI (XAI) by crafting experimental paradigms aimed at enhancing the interpretability, fairness, and transparency of AI systems (Srinivasan & Chander, 2020; Taylor & Taylor, 2021). A novel approach proposed by Gan et al. (2023) involves preliminary feature extraction before the transfer learning phase, improving CNNs' ability to predict facial attractiveness. By considering the factors that influence human perception of attractiveness and incorporating this information into the model, its evaluations can be enhanced. For example, facial expressions could provide valuable insights (Golle et al., 2014; Morrison et al., 2013; Penton-Voak & Chang, 2008).

Emotion recognition is a key issue in AI research, using both physical (e.g., facial expression and speech) and physiological (e.g., electroencephalogram, electrocardiogram, galvanic skin response, and eye tracking) signals (for a review, see Khare et al., 2024). Similar to facial beauty prediction, CNN models have demonstrated remarkable effectiveness in emotion recognition using images due to their ability to extract spatio-temporal characteristics (Akhand et al., 2021; Khattak et al., 2022; Li et al., 2017, 2020; Xie & Hu, 2017). For instance, Akhand et al. (2021) achieved accuracy of 96.5% on Karolinska Directed Emotional Faces (KDEF) dataset using a transfer learning methodology. Nonetheless, whether there is an interdependence between facial beauty and the accuracy of emotion recognition in AI predictions remains to be explored.

Literature in cognitive psychology shows that facial attractiveness influences emotion recognition (Lin et al., 2022; Lindeberg et al., 2019; Mertens et al., 2020). Happy facial expressions are recognized faster and more accurately for attractive faces but not for unattractive ones (Lindeberg et al., 2019). This effect has also been observed for microexpressions (40-200ms range) (Lin et al., 2022). Similarly, in a study presenting multiple faces simultaneously, participants were faster and more accurate when evaluating attractive crowds with more happy faces than when judging unattractive crows with more angry expressions (Mertens et al., 2020).

Moreover, it is not just facial attractiveness that moderates emotion recognition; the inverse relationship also holds. Happiness increases facial attractiveness, whereas anger diminishes it compared to neutral facial expressions (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984). Recent research corroborates these findings by manipulating changes in facial expression (e.g., smiling) in AI-generated images (Valuch et al., 2023). Since evidence suggests a positive correlation between perceived health and attractiveness (Lie et al., 2008, 2010; Roberts et al., 2005; Singh et al., 2024), the preference for happy faces is attributed to the positive impact of health on one's sense of happiness (Dfarhud et al., 2014).

Nonetheless, differences between sexes may surface when examining the relationship between emotional expressions and facial attractiveness. For instance, Lindenberg et al.'s (2019) findings showed that the improvement in recognizing happy, attractive faces was more pronounced for female faces than for male faces. Also, happiness ranked as the most appealing emotional expression among females, while it stood among the least attractive for males (Tracy & Beall, 2011). In contrast, pride exhibited a divergent pattern, emerging as the most attractive expression in males and one of the least attractive in females. As previously discussed, women's preference for pride in men could be linked to evaluations of social status and the perceived ability to provide resources. Men's preference for happy women may stem from the perception that happiness indicates good health, which is a crucial factor for reproductive purposes.

However, the association between happy women and angry men might stem from the sexual dimorphism inherent in facial features rather than merely a result of sex stereotypes influencing perception. Sexual dimorphism, a biological phenomenon observed in humans and other animals, refers to noticeable differences in traits between males and females of a given species, such as size, bone structure, or plumage color (Darwin, 1871; Frayer & Wolpoff, 1985). Men with higher testosterone levels exhibit distinct facial features, including pronounced brow ridges, thicker jawlines, and wider faces (Scott et al., 2013). In contrast, femininity in women is associated with higher estrogen levels and is identified by features like smaller jawlines and narrower faces (Little, Jones, et al., 2011). According to Le Gal and Bruce (2002), the facial expression of surprise can feminize a face by enlarging the gap between the eyebrow and the eye, while the expression of anger can masculinize a face by reducing this distance. This was confirmed in an experimental study where manipulated versions of computer-generated avatars, adjusted to reflect the characteristics of average male exemplars, resulted in a heightened perception of anger in their facial expressions (Becker et al., 2007). Furthermore, by controlling for markers of dominance and affiliation in male and female faces, Hess et al. (2004) found a reversal of the stereotype, with women being rated as angrier and men as happier.

Research has shown that angular shapes convey threat, whereas curved shapes do not (Aronoff et al., 1992; Blazhenkova & Kumar, 2018). Aronoff et al. (1992) state that these geometric shapes are present in humans' expressions of anger and happiness, respectively. They proposed that anger is associated with physical threat and the display of social dominance, while happiness is linked to cooperativeness, acceptance, and the formation of alliances. Supporting this, Blazhenkova and Kumar (2018) found that curved shapes were more strongly associated with females, whereas angular shapes were linked to males. These findings align with the notion that human males are more likely to engage in violence and intra-male competition compared to females, driven by differences in parental investment

and sexual selection, as proposed by Trivers (1985). Therefore, happy facial expressions should attenuate the threatening effect of masculine male faces. Recent research supports this claim, showing that women prefer less feminized features in happy male faces compared to neutral or angry expressions (Carrito et al., 2023).

5.2.1. Present work

Despite considerable progress in facial beauty prediction algorithms, there is still a gap in the literature concerning the decision-making processes of these algorithms. This study aims to explore whether beauty prediction algorithms mirror human biases toward facial expressions and sexually dimorphic facial traits. The primary objective is to investigate the impact of facial expressions on algorithmic evaluations. We hypothesize that happy facial expressions will be perceived as more attractive than angry facial expressions (H1). However, we expect an interaction effect between sex and facial expression, with happy faces having a stronger impact on perceived attractiveness for females compared to males (H2). Furthermore, we will explore the potential impact of sexual dimorphism on this phenomenon. We expect that happy expressions will mitigate the threatening effect of masculinity, so both masculinized male and female happy faces will be predicted as more attractive than their angry and neutral versions, comparatively to the differences in the feminized versions (H3).

5.3. Method

5.3.1. Materials

The SCUT-FBP5500 dataset (Liang et al., 2018) is the benchmark for training and evaluating facial beauty prediction algorithms, with state-of-the-art models achieving a Pearson correlation of .93 with human attractiveness judgments (Gan et al., 2023). However, despite the dataset's large size (n = 5500), attractiveness ratings were solely provided by Asian raters, which may limit the generalizability of the beauty prediction algorithms. Furthermore, the high accuracy observed could be due to greater internal consistency in attractiveness judgments within the Asian population (Perret et al., 1998). Therefore, we used four databases with attractiveness ratings for training and evaluating purposes: SCUT-FBP5500 (Liang et al., 2018), Chicago Face Database (CFD; Ma et al., 2015), Face Research Lab London (FRL-London; DeBruine et al., 2017), and FACES (Ebner et al., 2010), for a total of 7217 images.

Additionally, two other databases – Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998) and Amsterdam Dynamic Facial Expressions Set (ADFES; van der Schalk et al., 2011) – were

selected to test the effect of facial expressions made by the fine-tuned VGG-19. Moreover, the sexually dimorphic (masculinized and feminized) versions of images from the KDEF database used in Study 2 (Chapter 3) were employed to investigate potential interactions between facial expressions and sexual dimorphism in the attractiveness predictions made by the VGG-19 model.

In line with standard preprocessing techniques for image data in deep learning applications (He et al., 2016; Simonyan & Zisserman, 2014), pixel values were normalized to a range of [0, 1] by dividing each pixel intensity by 255. This normalization step is crucial for ensuring that the input features are properly scaled, thereby enhancing the training efficiency of machine learning models, especially in neural networks. It also addresses issues such as vanishing or exploding gradients (Hochreiter, 1998; Khan et al., 2018). Attractiveness ratings from all datasets were normalized to be between 0 and 1.

5.3.1.1. SCUT-FBP5500 (Liang et al., 2018). The dataset comprises 5500 frontal face images with diverse characteristics, including sex (male/female), ethnicity (Asian/Caucasian), and various age groups. The dataset is composed of 2000 Asian females, 2000 Asian males, 750 Caucasian females, and 750 Caucasian males. Most of the faces exhibit neutral expressions and are captured against simple backgrounds. Attractiveness ratings were assigned to the faces by 60 Asian raters aged 15 to 60, with ratings ranging from 1 to 5, though no additional information about the raters is provided.

5.3.1.2. Chicago Face Database (CFD; Ma et al., 2015). The dataset consists of 970 facial images featuring neutral, happy, threatening, and fearful expressions. Among the 158 volunteers contributing to the dataset, 37 were Black males, 48 were Black females, 36 were White males, and 37 were White females, all aged between 18 and 40 years. Participants were given specific instructions for each facial expression, resulting in multiple photographs for each scenario (e.g., “Make a closed mouth smile”). A diverse sample of 1,087 raters evaluated the images' attractiveness on a 1–7 Likert scale, with each rater assessing only 15 faces. The raters included 552 females, 308 males, and 227 individuals who chose not to disclose their gender, with an average age of 26.75 years (SD = 10.54). They represented a range of racial backgrounds, including 516 White, 117 Asian, 74 Black, 72 biracial or multiracial, 57 Latino, 18 of other racial backgrounds, and 233 who did not provide racial information.

5.3.1.3. FACES (Ebner et al. in 2010). The dataset is comprised of facial images featuring expressions of neutrality, sadness, disgust, fear, anger, and happiness across diverse age group. The dataset includes 171 individuals, categorized as young (n = 58, age range 19–31), middle-aged (n = 56, age range 39–55), and older adults (n = 57, age range 69–80), resulting in a total of 1026 pictures. Attractiveness evaluations were conducted by 154 raters, all of whom were Caucasian and German. Rater were randomly assigned to either set A or set B, both containing identical pictures of the same subjects

displaying various facial expressions with minor differences such as head inclination angles. For our study, only set A was used. Each image received attractiveness ratings from a minimum of 8 to a maximum of 14 raters per age group by gender, resulting in six attractiveness ratings available in the metadata of the original dataset. The average of these ratings, measured on a scale from 1 to 100, was used in our analysis.

5.3.1.4. Face Research Lab London (FRL-London; DeBruine et al., 2017). The dataset contains 102 frontal facial images with neutral expressions. The sample included 52 males and 50 females (M_{age} = 26.9, SD = 7.07), representing diverse ethnicities: 69 White, 13 Black, and 20 Asian individuals. Attractiveness ratings were collected from 2513 individuals, aged 17 to 90, using a 1 to 7 scale.

5.3.1.5. Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998). KDEF is one of the most used databases for facial expressions. It consists of 70 amateur actors (35 females and 35 males), aged between 20 and 30 years, displaying seven different expressions: fear, anger, disgust, happiness, neutral, sadness, and surprise. Garrido and Prada (2017) provided attractiveness ratings for a subset of 210 images, featuring angry, happy, and neutral expressions. The sample of raters consisted of 155 students from Portuguese universities, 83.20% of whom were female, with an average age of 23.73 years (SD = 7.24). Each participant rated 36 images on a 1-7 Likert scale for facial attractiveness.

5.3.1.6. Amsterdam Dynamic Facial Expressions Set (ADFES; van der Schalk et al., 2011). ADFES consists of dynamic expressions performed by 22 models (10 females, 12 males; 10 Mediterranean, 12 Northern-European) aged 18 to 25. The database also offers still pictures, created from the frontal face videos by freezing the film at the moment of the most intense muscular contraction of the model's expression. For the current study, still images of 22 models displaying neutral, happy, and angry expressions were used, resulting in a total of 66 images for predicting facial attractiveness.

5.3.1.7. Algorithm. Following our results from Study 3 (Chapter 4), we used the VGG-19 algorithm, which is part of a series of very deep convolutional neural networks (VGGNet), including VGG-11, VGG-13, and VGG-16, developed by the Visual Geometry Group Network (VGG) (Simonyan & Zisserman, 2014). Originally, VGGNet was trained on over 1 million images for the purpose of image classification across 1,000 categories. It has also been widely used for facial expression recognition (Meena et al., 2022; Sajjanhar et al., 2018) and facial attractiveness prediction tasks (Anderson et al., 2018; He et al., 2020). The VGG-19 architecture consists of five sets of convolutional layers, followed by a final block containing three fully connected layers. All blocks are interconnected by a 3x3 Max Pooling layer. The initial two blocks have two convolutional layers each, with dimensions of 64x64x64 for the first

block and 128x128x128 for the second block. The subsequent three blocks, namely the third (size 256x256x256), fourth (size 512x512x512), and fifth (size 512x512x512) blocks, consist of four convolutional layers each.

5.3.2. Procedure

The procedure consists of three phases. Phase 1 involved fine-tuning the VGG-19 neural network for predicting facial attractiveness using transfer learning techniques. In Phase 2, a subset of images from the KDEF database was modified to create masculinized and feminized versions, highlighting sexually dimorphic features to study their influence on perceptions of attractiveness. Phase 3 involved evaluating the attractiveness of images with varying facial expressions and sexually dimorphic manipulations using the fine-tuned VGG-19.

In phase 1, we applied transfer learning to the VGG-19 pre-trained weights from the Keras Applications Module: tf.keras.applications (Chollet, 2015). We froze all convolutional layers and the classification problem was changed by a regression one by including a final dense layer. The final three dense fully connected layers were trained for 100 epochs, with patience set to 20 epochs, using Adam optimizer with a learning rate of 0.001 and weight decay of 0.004. Adam is an "algorithm for first-order gradient-based optimization of stochastic objective functions, based on adaptive estimates of lower-order moments" (Kingma & Ba, 2014, p. 1). The training process ended by the 33th epoch, as validation loss ceased to improve from the 13th epoch. A train/validation/test split of 60/20/20 size was used, resulting in 4338/1442/1437 images for the corresponding set. A Pearson's correlation of .89 in the test set was achieved (RMSE = 0.14; MAE = 0.11). Finally, we fine-tuned the model by unfreezing all the model's layers. We set the training for 10 epochs (patience of 5), using Adam optimizer with a learning rate of 0.00001 and weight decay of 0.004, to prevent overfitting (see He et al., 2016 for an explanation on hyperparameters' setting for fine-tuning). The model validation loss did not improve from the 8th epoch. We enhanced performance on the test set, with a Person correlation of .91 (RMSE = 0.13; MAE = 0.09, $p < .001$).

In Phase 2, we generated masculinized and feminized photos for 5 female and 5 male frontal images, each showing different facial expressions (anger, happiness, neutral). The chosen faces were rated as average in terms of attractiveness (Garrido & Prada, 2017). Building upon prior studies (Little et al., 2008; Perret et al., 1999), this was achieved using a 50% linear transformation towards either the female avatar (resulting in a feminized version) or the male avatar (resulting in a masculinized version). The avatars, representing average faces, were formed by averaging 30 male faces (creating the male avatar) and 30 female faces (creating the female avatar). All image manipulations were performed using

computer vision techniques provided by the Psychomorph software (Tiddeman & Perret, 2002) and its web-based version WebMorph (DeBruine, 2018). These sexually dimorphic versions were previously rated in terms of attractiveness in our Study 2 (Chapter 3), allowing us to compare VGG-19 predictions with actual human attractiveness judgments.

In Phase 3, the fine-tuned VGG-19 model was used to predict facial attractiveness for non-manipulated images displaying various facial expressions from the ADFES and KDEF datasets (n = 272), as well as the created sexually dimorphic versions from the KDEF dataset (n = 60). Statistical comparisons were conducted to analyze differences across various facial expressions and sexual dimorphism conditions. Additionally, the algorithm's ratings were correlated with actual human judgments of attractiveness using data from Study 2 (Chapter 3) for the sexually dimorphic versions, and with data from the Portuguese validation of KDEF by Garrido and Prada (2017) for the original KDEF versions. The results are available in Appendix D (Figure D.1, Figure D.2).

5.3.3. Data analysis

The VGG-19 attractiveness judgment was used as the dependent variable in two linear mixed-effects model (LME). The first model consisted of attractiveness ratings from the KDEF and ADFES datasets, with two fixed main effects: facial expression (anger, happiness, and neutral), sex (male/female), and their two-way interaction term. The second model tested whether VGG-19-attractiveness evaluations of the sexually dimorphic versions from the KDEF dataset depended on facial expression and sex. Therefore, attractiveness judgments were entered as the dependent variable, and facial expression (anger, happiness, and neutral), sex (male/ female), sexual dimorphism (masculinized/feminized), and their three-way interaction term were used as fixed effects. The photo's code was included as a random factor with varying intercepts in both models to account for individual differences in attractiveness (for a detailed explanation on LME models, see Pinheiro & Bates, 2000). A post-hoc analysis with Bonferroni adjustment was conducted to account for the significant effects observed. All statistical analyses were carried out using R Statistical Software (v4.3.1; R Core Team, 2023), utilizing the lme4 package (v.1.1.34; Bates et al., 2015) for modeling and ggplot2 (v.3.4.4.9000; Wickham, 2016) for visualization. The data and reproducible code are publicly available at Fernandes (2024).

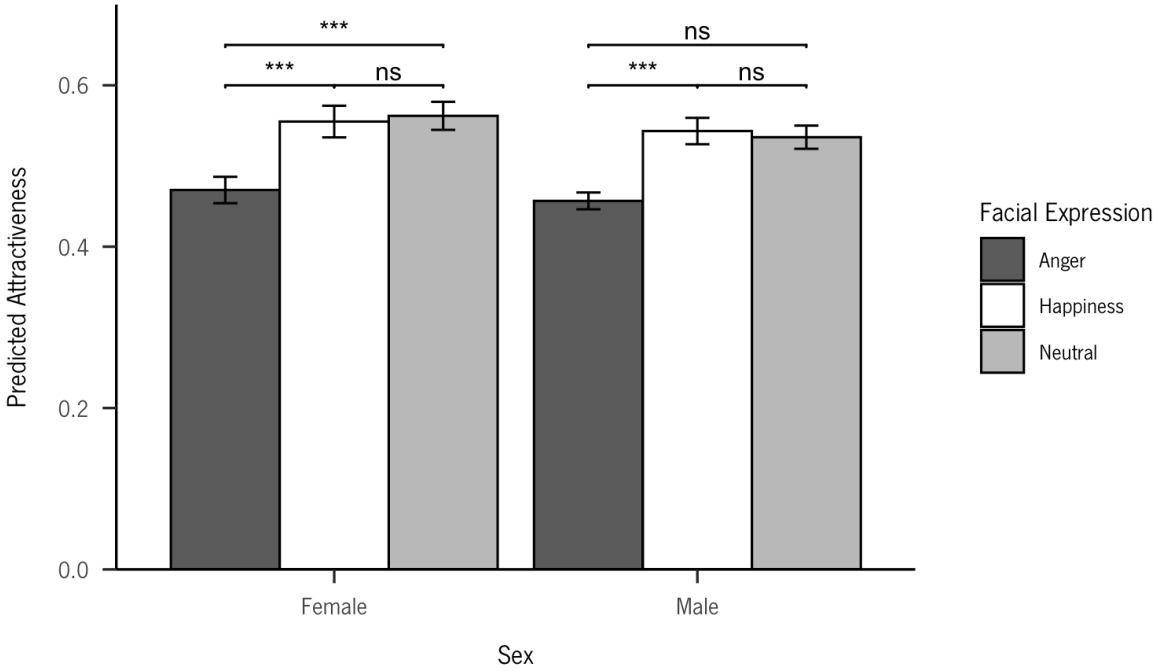
5.4. Results

The first LME (estimated using REML) included the main effects of facial expressions and sex, and their interaction term (Figure 11). The model included the image's code as a random factor. The model's total explained variance, R^2, was 69%, and the part related to the fixed effects alone, marginal R^2, was 13%. The model showed a statistically significant main effect of facial expression, with anger expressions being rated as less attractive than neutral faces, b = -.09(.01), p < .001, 95% CI [-0.12, -0.07], while no differences were observed between happy facial expressions and neutral faces, b = -.01(.01), p = .593, 95% CI [-0.03, 0.02]. No significant differences were observed between male and female faces, b = -.03(.02), p = .236, 95% CI [-0.07, 0.02]. Also, the interaction term between facial expressions and sex was not significant (p > .05).

Post-hoc analysis using Bonferroni correction supported these findings. Anger expressions were rated as less attractive than neutral faces, both for females, t(177) = -6.72, p < .001, 95% CI [1.01, 1.89], d = -1.45, and male faces, t(177) = -6.00, p < .001, 95% CI [0.82, 1.66], d = -1.24. Similarly, angry faces were less attractive than happy facial expressions for both female, t(177) = -6.24, p < .001, 95% CI [-1.77, -0.89], d = -1.33, and male faces, t(490) = -6.58, p < .001, 95% CI [-1.78, -0.93], d = -1.36. In contrast, no differences were observed between happy and neutral expressions, for either female, t(177) = -0.54, p = .854, 95% CI [-0.31, 0.54], d = -0.12, or male faces, t(177) = 0.58, p = .831, 95% CI [-0.53, 0.29], d = 0.12.

Figure 11

Attractiveness ratings by VGG-19 across different facial expressions for both females and males



Note. Bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

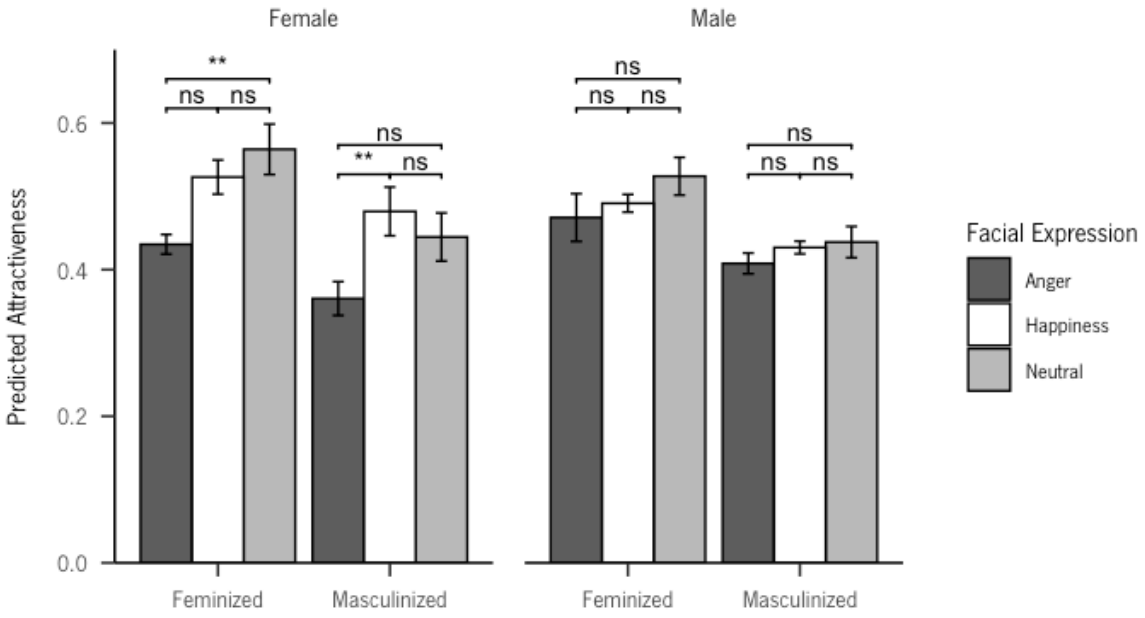
An additional LME (estimated using REML) was composed of the main effects of facial expression, sexual dimorphism, and sex, with their three-way interaction term (Figure 12). The model included the image's code as a random factor. The model's total explained variance, R^2, was 65%, with the portion related to the fixed effects alone (marginal R^2) equal to 50%. The model revealed a statistically significant main effect of facial expression, with anger expressions being rated as less attractive than neutral faces, b = -.13(.03), $p < .001$, 95% CI [-0.19, -0.07], while no significant differences were observed between happy facial expressions and neutral faces, b = -.01(.03), p = .200, 95% CI [-0.10, 0.02]. Additionally, masculinized faces were rated as less attractive than feminized faces, b = -.12(.03), $p < .001$, 95% CI [-0.18, -0.06]. No differences were observed between male and female faces, b = -.04(.03), p = .297, 95% CI [-0.11, 0.03]. Also, the interaction term was not statistically significant ($p > .05$).

Post-hoc analysis using Bonferroni correction revealed that the facial expression effect was mainly explained by differences in female faces. Feminized female angry faces were perceived as less attractive than neutral faces, $t(40)$ = -4.45, p = .002, 95% CI [1.40, 4.22], d = -2.81, and masculinized versions of female angry faces were rated as less attractive than happy faces, $t(40)$ = -4.10, p = .005, 95% CI [-3.97, -1.19], d = -2.58. Moreover, the preference for femininity was explained by differences between female

feminized and masculinized neutral expressions, $t(40) = 4.11$, $p = .005$, 95% CI [1.21, 3.99], $d = 2.60$. No statistical differences ($p > .05$) were observed for any other facial expression between their masculinized and feminized versions or between male and female faces.

Figure 12

Attractiveness ratings by VGG-19 across different facial expressions for both female (left panel) and male (right panel) sexually dimorphic versions



Note. Bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

5.5. Discussion

This research aimed to test whether beauty prediction algorithms implicitly learn human psychological biases concerning facial attractiveness. The primary objective was to investigate the impact of facial expressions on algorithmic evaluations of attractiveness. We hypothesized that happy facial expressions would be perceived as more attractive than angry facial expressions (H1). Also, we expected an interaction effect between sex and facial expression, with happy faces exerting a stronger influence on the perceived attractiveness of female faces compared to male faces (H2). Additionally, we predicted that happy expressions would be rated as more attractive than angry and neutral expressions for the masculinized versions of both male and female faces, in comparison to the observed differences for feminized versions (H3).

The fine-tuned VGG-19, which achieved a Person's correlation of .91 on the test set, was used to predict the facial attractiveness of male and female faces exhibiting happy, angry, and neutral expressions. Moreover, the model evaluated the attractiveness of sexually dimorphic versions of male and female faces, each displaying different facial expressions (happy, angry, and neutral). Our results supported the negative effect of angry expressions on facial attractiveness (H1), with angry female and male faces rated as less attractive than happy and neutral faces. No evidence was found for an interaction between facial expressions and sex (H2). Furthermore, for the sexual dimorphic versions, our results showed that masculinized happy faces were rated more attractive than angry ones, but this effect was exclusive to the female faces. No statistical differences were observed between happy and neutral faces. However, our results followed the predicted direction, as masculinized female faces with happy expressions were rated as more attractive than their neutral counterparts. We partially confirmed our third hypothesis (H3), as we expected that happiness would mitigate the threatening effect of masculinization for both sexes.

5.5.1. Theoretical Implications

Our results align with previous studies on human judgments of attractiveness (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984; Valuch et al., 2023), with VGG-19 rating happy and neutral expressions as more attractive than angry expressions. Research suggests that angry faces activate avoidance mechanisms, whereas happy faces are associated with approach behavioral responses (Seidel et al., 2010). The same study found that the activation of the behavioral avoidance system was enhanced for angry male faces (Seidel et al., 2010). Further research supports these findings, with perceived resting negative emotion in neutral faces being a stronger predictor of attractiveness for women and a stronger predictor of threat for men (Hester, 2019). Despite the heightened threat perception associated with angry expressions in male faces, behavioral data suggest that angry expressions also reduce the rewarding value of female faces. For example, male participants tend to invest more effort in prolonging their viewing time of happy and neutral attractive female faces, whereas they tend to look away more quickly from attractive angry faces (Jaensch et al., 2014).

Similar to previous studies (Morrison et al., 2013; Mueser et al., 1984), we did not observe differences between happy and neutral facial expressions. Therefore, our findings emphasized the negative impact of anger on attractiveness perception, instead of supporting the hypothesis that happiness increases physical attractiveness compared to neutral expressions (Garrido & Prada, 2017; Reis et al., 1990; Valuch et al., 2023). Social stereotypes suggest that anger displays are more acceptable

for men, while smiling is considered requisite for women, reflecting perceptions of men as more dominant and women as more affiliative (Hess et al., 2005; Mehu et al., 2008). For instance, women's smiling faces influenced men's judgments of attractiveness, generosity, competitiveness, health, agreeableness, extraversion, and neuroticism (Mehu et al., 2008). In contrast, men's smiling faces only influenced women's judgments of health, and to a lesser extent, openness to experience (Mehu et al., 2008). Similarly, research has found that smiling male faces were seen as more suitable for long-term relationships (e.g., high ratings of trustworthiness), neutral faces were preferred for short-term relationships (e.g., high ratings of masculinity) (Okubo et al., 2015).

For instance, Golle et al. (2014) found that perceived attractiveness is strongly influenced by smile intensity. Additionally, the contrast between "genuine" Duchenne smiles, characterized by the contraction of both the zygomatic major and orbicularis oculi muscles (Ekman, 1989), and posed smiles may contribute to this effect. Surakka and Hietanen (1998) found that viewing faces with Duchenne smiles evoked greater feelings of pleasure and empathy compared to non-Duchenne smiles and neutral expressions. The sexual dimorphic versions suggest that happiness may reduce the potential threat of masculinized female faces, as happy facial expressions were judged more attractive than angry faces, while no differences were observed between neutral and angry expressions for masculinized female faces. This supports that the aversive reactions to masculinity are lessened when accompanied by a smiling expression (Carrito et al., 2023). In contrast to Carrito et al. (2023), this effect was only observed for female faces. Since the masculinization process enlarges female faces, this may result in larger smiles and perceived happiness, leading to more favorable attractiveness judgments. This aligns with previous studies showing that, regardless of sex, larger facial movements during smiling are influenced by facial size (Sforza et al., 2010). Compared to females, males exhibit overall larger facial dimensions, significantly greater total width across all visible maxillary teeth, and a wider smile (Grover et al., 2015; Horn et al., 2021).

The main effect of femininity is supported across studies, evident in both male (Carrito et al., 2016; Perret et al., 1998; Rhodes et al., 2000) and female faces (Fraccaro et al., 2010, Perrett et al., 1998). While preferences for feminine women are consistently documented in the literature, contradictory findings emerge when it comes to male faces. On one hand, the immunocompetence hypothesis suggests that masculinity, as a marker of higher testosterone levels, leads to the perception of masculine men as healthier (Penton-Voak & Chen, 2004; Thornhill & Gangestad, 2006) and more dominant (Neave et al., 2003; Thornhill & Gangestad, 2006), making them more attractive to potential mates (Johnston et al.,

2001; Penton-Voak et al., 2001). On the other hand, some studies suggest a preference for feminine male faces (Carrito et al., 2016; Perret et al., 1998; Rhodes et al., 2000).

These contrasting findings can be explained by the idea that males with higher quality traits (i.e., elevated testosterone levels) may invest less in relationships due to their broader range of mating options (Ekrami et al., 2021; Holzleitner & Perrett, 2017). Research indicates a cyclical preference for masculinity linked to women's menstrual cycle, suggesting that when seeking parental investment (such as in the non-fertile phase), facial shapes associated with relatively lower testosterone levels are favored (for a review, see Penton-Voak & Perret, 2001). Conversely, Penton-Voak and Perret (2001) report that relatively more masculine faces are preferred when the probability of conception is high (fertile phase of the cycle). Similarly, preferences for vocal masculinity are more pronounced in short-term partners compared to long-term ones (Little, Connely et al., 2011; Vukovic et al., 2011). However, our results reveal that preferences for feminine faces were specific to neutral expressions. This suggests a possible interaction between the algorithm's perceived masculinity and facial expression, influencing attractiveness judgments (Carrito et al., 2023).

5.5.2. Limitations/ Further studies

There are certain limitations, primarily related to the databases used in this study, that require consideration. The available databases included mean attractiveness ratings from both same-sex and opposite-sex raters. From an evolutionary perspective, the sexual dimorphism hypothesis suggests that individuals aim to select high-quality partners for reproduction. Hence, the inclusion of same-sex attractiveness evaluations in these datasets might be viewed as a potential constraint. Although previous research has not found differences in sexual dimorphic preferences when evaluating same-sex or opposite-sex individuals (Hu et al., 2018; Simpson & Gangestad, 1990), we believe that further studies should investigate whether the sex, gender, and sexual orientation of the rater affect the interaction between facial expressions and sexual dimorphism. Therefore, researchers should consider incorporating this factor when developing future databases of facial attractiveness.

Recent research has shown that the degree of head turn (Ho & Newell, 2020) or tilt (Marshall et al., 2020) can also influence human attractiveness judgments. Ho and Newell (2020) discovered that happy facial expressions became more attractive when accompanied by a head turn towards the observer, whereas this effect was not observed for angry expressions. Moreover, tilting the face upward increases perceptions of masculinity, physical dominance, and social dominance, while decreasing perceptions of femininity and physical attractiveness (Marshall et al., 2020). However, in their second experiment,

Marshall et al. (2020) showed that these effects vary depending on the angle at which the face is presented and its movement, including the direction and location in space. For example, advancements have been made in beauty prediction through video analysis, such as predicting the winner of Miss Universe based on their stride down the catwalk during the evening gown competition (Carvajal et al., 2016). Therefore, further research should replicate our results across different head turn and tilt angles, while integrating movement into algorithmic assessments.

Moreover, additional studies should explore whether human biases persist in multimodal attractiveness prediction. Despite most attractiveness prediction research focusing on computer vision techniques, some researchers have expanded the scope of attractiveness prediction beyond visual cues, exploring the domain of vocal features. Obuchi (2021) showed that vocal attractiveness could be predicted by mapping acoustic features using machine-learning techniques. Similarly, Nguyen et al. (2013) proposed a Dual-supervised Feature-Attribute-Task (LDFAT) capable of extracting features from multiple modalities (visual and auditory) for attractiveness prediction.

Psychological research also provides important insights into sexual dimorphic vocal cues. Like facial features, sexual dimorphism modulates vocal traits in men and women. Testosterone levels negatively correlate with voice pitch, meaning that higher levels of testosterone are associated with lower voice pitch (Aung & Puts, 2020; Evans et al., 2008). These lower-pitched voices are often perceived as more attractive (Feinberg et al., 2006; Jones et al., 2010; O'Connor et al., 2012; Re et al., 2012; Vukovic et al., 2010). Conversely, men tend to prefer women with higher-pitched voices, which are linked with higher estrogen levels (Abitbol et al., 1999; Feinberg et al., 2005, 2008; Re et al., 2012). Interestingly, cross-modality effects may occur. Hill et al. (2013) found that women might prefer men with less masculine faces if they have more masculine voices, and vice versa. Additionally, evidence suggests an association between vocal attractiveness and emotional judgment (Xu et al., 2013). Hence, future research should investigate the potential interaction between facial expressions and sexual dimorphism in algorithmic attractiveness prediction across different sensory modalities.

Furthermore, the present work should be extended to a wider range of emotions. Although most research focuses on the influence of happiness and anger on approach and avoidance behaviors, other emotional states, such as sadness and disgust, may elicit more complex behavioral responses (Seidel et al., 2010). For instance, disgusted faces were judged as the least attractive compared to neutral, happy, sad, angry, and fearful expressions (Ebner et al., 2018). Also, facial expressions could interact with sex. In males, pride was rated as the most attractive expression, whereas it was one of the least attractive in females (Tracy & Beall, 2011). The interaction between head orientation and facial expressions may also

be relevant. Preferences for front views of faces over three-quarter views, for example, were observed when judging the attractiveness of happy, but not disgusted expressions (Main et al., 2010). Different types of happy expressions, including open and closed smiles, may also convey different social messages. For example, an open smile might convey contempt or fear instead of happiness (Helwig et al., 2017; Rychlowska et al., 2017). Moreover, females tend to be perceived as more attractive and intelligent when displaying a closed smile, whereas broader smiles may enhance social attractiveness in men, though not necessarily intelligence (Mehu et al., 2008; Otta et al., 1994).

Our findings raise intriguing questions about whether vison-based approaches replicate human biases across different domains and to what extent these biases influence perceptions of attractiveness. For instance, there have been advancements in the field of automatic personality perception, which involves predicting an individual's personality based on their image (Jacques Junior et al., 2022; Moubayed et al., 2014). However, little is known about the influence of facial expressions and attractiveness on these algorithms' evaluations. Psychological research shows that facial expressions are associated with specific personality traits. For example, facial expressions of contempt and smiling tend to be associated with more affiliative personality traits (Arya et al., 2006). Similarly, Otta et al. (1994) showed that smiling expressions evoke more positive perceptions, such as sympathy, kindness, and optimism, whereas head tilting leads to negative evaluations. Additionally, the "beauty is good" stereotype leads to more favorable personality attributions toward attractive men, such as higher ratings of social and intellectual competence (Eagly et al., 1991; Lorenzo et al., 2010). Therefore, further studies may explore whether incorporating facial expression recognition and attractiveness prediction into an early stage of automatic personality perception may prevent algorithmic biases favoring attractive individuals in areas such as hiring decisions (Baert & Decuypere, 2014; Talamas et al., 2016; Trichas et al., 2017) or political elections (Hart et al., 2011; Palmer & Peterson, 2016; Stockemer & Praino, 2015).

5.5.3. Conclusions

The results of the present study are consistent with previous findings in the psychological literature, which indicate a reduced preference for angry expressions in both sexes. However, no differences were found between happy and neutral expressions. Regarding the interaction between facial expressions and sexual dimorphism, we found that happy expressions enhanced the attractiveness of masculinized female faces compared to masculinized angry faces. This suggests that any aversive response to masculinity may be mitigated by the presence of a smiling expression. Future research could

expand on these findings by exploring other sensory modalities. Overall, our results suggest that, like human judgments, algorithmic predictions of facial attractiveness may be influenced by emotional cues.

5.6. References

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CHAPTER 6

General Discussion

The present doctoral thesis aimed to provide a more comprehensive perspective on the cognitive mechanisms underlying attractiveness perception, particularly in relation to time perception. Additionally, it sought to explore whether evolutionary preferences for attractiveness are observed and potentially perpetrated by AI models. TIhis dissertation included four studies: the first two (Chapters 2 and 3) examined the influence of the menstrual cycle and emotional expressions on time perception of attractive stimuli, while the last two studies (Chapters 4 and 5) focused on algorithmic evaluations of sexually dimorphic and emotional faces.

This final chapter contextualizes the findings described and debated in the previous chapters from a broader perspective. We begin by summarizing our main findings, followed by a reflection on the strengths and limitations of the studies conducted. Next, we offer suggestions for future research and conclude with a discussion about the broader implications of our work.

6.1. Summary of the Main Findings

Our first study (i.e., Study 1) sought to understand whether the previously reported attractiveness effect on time perception would be modulated by the phase of the females' menstrual cycle. In this study, female participants attended the experiment in two phases of their menstrual cycle: menses and ovulation. In each phase, participants performed an oddball task using a time reproduction paradigm, similar to that implemented by Arantes et al. (2013). The experiment consisted of three blocks: visual attractiveness, visual dimorphic, and auditory dimorphic.

In Study 1, we found that masculinized male voices were overestimated in duration compared to feminized voices during the ovulation phase but not during the menstruation phase of the cycle. Our findings partially support the cycle's shift ovulatory hypothesis (Gangestad & Thornhill, 2008; Gildersleeve et al., 2014; Jones et al., 2008), as the effect was only found for the auditory modality (Pisanski et al., 2014; Puts, 2005, 2006). Since this cycle-related shift was not observed in the visual modality, it could be reasoned that women's enhanced speech perception during ovulation might explain this difference (e.g., Anderson et al., 2020; Guimaraes et al., 2006; Sao & Jan, 2016). Furthermore, we replicated previous findings regarding the time dilation effect of viewing attractive stimuli (Arantes et al., 2013; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021), although no differences were found for the sexually dimorphic stimuli versions. Thus, Study 1 contributes to the literature by examining the effect of the menstrual cycle on time perception and by extending prior evidence of time dilation effects for attractive stimuli to other sensory modalities, specifically auditory stimuli. What remains to be explained

is why sexual dimorphism in male faces did not influence females' time estimates, similar to what was observed with attractive faces and sexually dimorphic voices.

One potential explanation for the lack of significant findings could be the heterogeneity of facial expressions displayed by the stimuli in the first study. In the attractiveness manipulation, male faces displayed emotional expressions (Arantes et al., 2013), whereas in the sexual dimorphism condition, only neutral faces were presented. To address this issue and eliminate any potential influence of facial expressions, we decided to proceed with a second study (i.e., Study 2) to address and explore the potential role played by facial expressions on our previous results. This study investigated the interaction between facial expressions and attractiveness on time perception. Importantly, this time, we had both male and female participants performing a similar oddball task to that of our first experiment. However, in this study, and in contrast to the procedure of Study 1, participants were assigned to one of these conditions: attractiveness or sexual dimorphism. This methodological change was implemented because presenting both conditions would have increased the duration of the time perception task by over 30% compared to our first experiment and previous studies (Arantes et al., 2021; Tian et al., 2019; Zhou et al., 2021), potentially leading to participant fatigue. Additionally, separating the two conditions allowed us to assess the photographs at the end of the experiment without overwhelming the participants, ensuring more focused and reliable evaluations. In the attractiveness condition, they were presented with attractive and unattractive opposite-sex faces. In the sexual dimorphic condition, similar sexually dimorphic manipulations were performed as in Study 1, resulting in masculinized or feminized versions of opposite-sex faces. In each condition, the presented photo had different facial expressions: anger, happiness, and neutrality.

Again, no differences were found for the time perception task in Study 2. Therefore, our results do not support previous findings on the effect of attractiveness (Arantes et al., 2013, 2021; Ogden, 2013; Sano et al., 2022; Tian et al., 2019; Zhou et al., 2021), emotionality (Droit-Volet et al. 2004; Droit-Volet & Meck 2007; Gil et al. 2007; Kliegl et al., 2015) or their interaction on time perception (Tomas & Španić, 2016). Concerning the participants' assessments of the arousal and attractiveness of the photos, our findings support previous studies suggesting that angry faces elicit higher arousal (Angrilli et al., 1997; Yin et al., 2021) while happy faces are viewed as more attractive (Golle et al., 2014; Garrido & Prada, 2017).

Additionally, feminized female faces were rated as more attractive than their masculinized counterparts (Fraccaro et al., 2010; Kleisner et al., 2024; Marcinkowska et al., 2014; O'Connor et al., 2013; Perret et al., 1998). Nonetheless, no differences were found between feminized and masculinized

male faces. Although this null result does not support evolutionary predictions of a stronger preference for more masculine male faces (Johnston et al., 2001; Little, Jones, et al., 2008; Penton-Voak et al., 1999, 2001; Stower et al., 2020), it may be explained by findings from other studies that suggest a preference for more feminine male faces (DeBruine et al., 2010; Little et al., 2001; Marcinkowska et al., 2019; Nakamura & Watanabe, 2020; Penton-Voak et al., 1999; Perret et al., 1998; Rhodes et al., 2003). This null result could also reflect an absence of preference for facial masculinity rather than a clear preference for femininity (Cornwell et al., 2004; Kleisner et al., 2024; Swaddle & Riersen, 2002).

Building on the findings from Study 2, which showed a preference for femininity exclusively in female faces, Study 3 explored whether beauty prediction algorithms replicate human biases towards sexually dimorphic facial traits. So, we used a transfer learning methodology to train six deep convolution neural networks initially developed for image classification problems and are typically adapted for facial beauty prediction (e.g., Saeed & Abdulazeez, 2021; Zhai et al., 2020). Then, the top-performing model, VGG-19 (Simonyan & Zisserman, 2014), predicted the attractiveness of previously masculinized and feminized faces. Results from Study 3 suggested that feminized versions were rated as more attractive than masculinized versions of both female (Fraccaro et al., 2010; Kleisner et al., 2024; Marcinkowska et al., 2014; O'Connor et al., 2013; Perret et al., 1998) and male faces (DeBruine et al., 2010; Little et al., 2001; Marcinkowska et al., 2019; Nakamura & Watanabe, 2020; Penton-Voak et al., 1999; Perret et al., 1998; Rhodes et al., 2003).

Following the attractiveness evaluations of the sexually dimorphic photos in Study 2, and the results obtained from Study 3, we examined, in Study 4, the impact of facial expressions on algorithmic evaluations and the potential influence of sexual dimorphism in this effect. Therefore, VGG-19 predicted the attractiveness of male and female faces displaying angry, neutral, and happy expressions. Moreover, the algorithm performed attractiveness evaluations of the sexually dimorphic versions presented in Study 3.

Results from Study 4 suggest that, for the original faces, happy and neutral expressions are perceived as more attractive than anger expressions (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984; Valuch et al., 2023). No differences were observed between happy and neutral expressions (Morrison et al., 2013; Mueser et al., 1984). Concerning the interaction between facial expressions and sexual dimorphism, we found that happy expressions increased the attractiveness of masculinized female faces compared to masculinized angry faces, thus supporting the idea that aversive behavior towards masculinity is lessened when followed by a smiling expression (Carrito et al., 2023).

This effect also finds support in our Study 3, where we observed that happy female faces received higher attractiveness ratings than neutral expressions for masculinized faces, but not for feminized ones.

6.2. Time Perception

Regarding the main findings on time perception, Study 1 conducted in this thesis replicated previous results, demonstrating an overestimation effect for attractive photos, suggesting an increased pacemaker rate when participants viewed attractive stimuli (Arantes et al., 2013; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021). Thus, the results of Study 1 align with arousal-based models of the internal clock, such as the scalar expectancy theory (SET; Gibbon et al., 1984). Furthermore, we found that the menstrual cycle moderates the effect of attractiveness on time perception in the auditory modality. Masculinized male voices were perceived for longer durations than their feminized counterparts during the fertile phase, but not during the menstruation phase. Our findings align with previous research showing an increased preference for masculine male voices during the fertile phase (Pisanski et al., 2014; Puts, 2005, 2006). However, what remains unexplained is why the menstrual cycle effect did not extend to the visual attractiveness condition, especially as some research even refutes a cycle shift favoring masculinity and instead suggests an increase in overall sexual desire during ovulation (Jones, Hahn, Fisher, Wang, Kandrik, Han et al., 2018; Jünger et al., 2018; Roney & Simmons, 2016). A possible explanation is that women's heightened speech perception during ovulation (Anderson et al., 2020; Guimaraes et al., 2006; Sao & Jain, 2016) may have contributed to the cycle's specific influence on the auditory modality. It is also possible that the attractive images were so arousing that they accelerated the internal clock, independent of the menstrual cycle phase. In this case, the effect on time perception would be driven more by heightened arousal levels associated with attractiveness rather than specific hormonal fluctuations linked to different phases of the cycle.

Additionally, we did not find evidence of an effect of sexually dimorphic faces on time perception. A possible reason could be associated with a potential trade-off women face between choosing men with masculine voices over masculine faces, and vice-versa Hill et al. (2013). Our design did not examine cross-modal effects, relying instead on independent blocks per stimulus type, therefore, we lack evidence to support this explanation. However, the effect was observed in the visual attractiveness condition, where stimuli varied in emotional expressions, and not in the sexual dimorphism condition, which used only neutral expressions. Therefore, we conducted Study 2 to explore whether emotionality could account for these findings. Contrary to our initial expectations, Study 2 did not reveal an interaction between facial expressions and attractiveness on time perception. Our null results, despite using opposite-sex faces,

differ from previous findings that reported an overestimation of same-sex angry faces compared to neutral ones, but only for attractive faces (Tomas & Španić, 2016). Furthermore, we did not replicate previous findings regarding the overestimation of attractive faces (Arantes et al., 2013, 2021; Tian et al., 2019; Zhou et al., 2021) or emotional facial expressions (Droit-Volet et al., 2004; Droit-Volet & Meck, 2007; Gil et al., 2007; Kliegl et al., 2015). It is important to note that Study 2 utilized different facial stimuli compared to Study 1. In Study 2, faces varying in attractiveness were selected from a previously validated database (KDEF; Goeven et al., 2008) for the Portuguese population (Garrido & Prada, 2017), featuring facial photos taken in highly controlled settings. In contrast, Study 1 employed stimuli from prior research (Arantes et al., 2013), which included highly attractive facial and torso images. Therefore, a possible explanation for the lack of results in Study 2 might be the fact that the stimuli's facial attractiveness may not have been high enough to elicit the physiological arousal (Nakamura & Kawabata, 2014; Maner et al., 2003) required to accelerate the internal clock (Arantes et al., 2013; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021).

6.3. Attractiveness Evaluations

6.3.1 Sexual dimorphism

Attractiveness ratings from all our studies showed a preference for femininity in women, from both human (Study 2) and algorithmic (Study 3 and 4) evaluations, supporting prior findings in the literature (Fraccaro et al., 2010; Kleisner et al., 2024; Marcinkowska et al., 2014; O'Connor et al., 2013; Perret et al., 1998). This is explained, from an evolutionary standpoint, as an indicator of reproductive qualities (Fink & Penton-Voak, 2002; Foo, Nakagawa, et al., 2017). For male faces, on the other hand, no differences in attractiveness preferences were observed between masculinized and feminized versions for the human raters (Study 2), while VGG-19 rated feminized male faces as more attractive than their masculinized counterparts (Study 3 and 4). This inconsistency is commonly observed in the literature, with some studies suggesting a preference for feminine male faces (DeBruine et al., 2010; Little et al., 2001; Marcinkowska et al., 2019; Nakamura & Watanabe, 2020; Penton-Voak et al., 1999; Perret et al., 1998; Rhodes et al., 2003), while others report a preference for masculine faces (Johnston et al., 2001; Little, Jones, et al., 2008; Penton-Voak et al., 1999, 2001; Stower et al., 2020). Additionally, some studies have reported no significant differences between masculine and feminine male faces (Cornwell et al., 2004; Kleisner et al., 2024; Swaddle & Riersen, 2002).

These divergent findings are often attributed to methodological differences, such as sexual dimorphic manipulations, i.e., face shape or skin color manipulation (Carrito et al., 2016; Said and

Todorov, 2011), and the initial level of masculinity (Ekrami et al., 2021) or the attractiveness of the face (Hu et al., 2018). Additionally, individual differences, such as menstrual cycle stage (Penton-Voak et al., 1999), age at menarche (Niu & Zheng, 2020), rater's personality (Johnston et al., 2001; Stower et al., 2020), and self-attractiveness (Docherty et al. 2020; Kandrik & DeBruine 2012; Little et al. 2001; Marcinkowska et al., 2021) might also explain these divergent findings. Given that the same image manipulation techniques were consistently applied across all four studies in this thesis, we attribute the lack of observed differences in Study 2 to individual factors rather than differences in facial manipulations. Moreover, a possible explanation for VGG-19's preference for femininity may be related to ethnic differences between our human raters and the raters from the databases used to train the model. Specifically, the majority of raters from the largest database used for model training were Asian, whereas the majority of our human sample consisted of Caucasian individuals. This might be of great interest as research suggests that preferences for masculinity may be evolutionary novel and restricted to “Western” perceptions (Scott et al., 2014). For instance, Scott et al. (2014) conducted a study across 12 different cultures and found that both men and women in large urban societies and areas with lower disease rates showed a stronger preference for sexually dimorphic faces. These results suggest that preferences for masculine features are linked to specific environmental factors (for a review, see Pisanski & Feinberg, 2013). Specifically, female Chinese subjects revealed either a preference for masculinized (Zhejiang providence) or neutral (Shanghai municipality) male faces (Scott et al., 2014). Moreover, Wu et al. (2022), using a speed-dating methodology revealed that Asian American females showed a preference for masculinity. Also, we included additional databases with raters from different social and cultural backgrounds. Therefore, ethnicity alone should not account for the VGG-19’s preferences for feminine men.

Interestingly, the preference for feminine men does not support the immunocompetence hypothesis (Penton-Voak & Chen, 2004; Thornhill & Gangestad, 2006) or the intrasexual competitiveness theory (Puts, 2010; Scott, 2012). Instead, our findings mirror the potential trade-off women face between choosing less masculine but more agreeable, investing long-term partners and men with a more masculine appearance, which may signal good physical condition (Folstad & Karter, 1992) but also less socially desirable traits, such as coldness or dishonesty (Perret et al., 1998). Furthermore, women seem to prefer less masculine male faces for long-term relationships than for short-term relationships (Conway et al., 2010; Holzleitner & Perrett, 2017; Little et al., 2007).

No major conclusions should be drawn from our findings regarding the relationship context, as this was not explored in the present dissertation. However, this raises the question of whether beauty is

an objective concept or rather perceived subjectively based on the rater's motivations. If the latter is true, should beauty prediction algorithms be trained using a more holistic approach? Overall, our findings show that deep learning algorithms for predicting facial beauty can effectively capture the psychophysical biases that influence human perceptions of facial attractiveness (Kagian et al., 2008).

6.3.2. Facial expressions

We observed that angry faces were perceived as the least attractive (compared to happy and neutral faces), both from human (Study 2) and algorithmic (Study 4) evaluations. These results are supported by prior findings in the literature (Garrido & Prada, 2017; Morrison et al., 2013; Mueser et al., 1984; Reis et al., 1990; Valuch et al., 2023). However, contrary to previous studies supporting the hypothesis that happiness enhances physical attractiveness compared to neutral expressions (Garrido & Prada, 2017; Valuch et al., 2023; Reis et al., 1990), we did not find significant differences between happy and neutral facial expressions in the algorithmic evaluations. This is clear in the correlation plot between the VGG-19 predictions and human ratings from Garrido and Prada's (2017) study using a Portuguese sample (Figure D.1 of Appendix D). The Portuguese sample rated the happy faces as the most attractive, while most VGG-19 attractiveness predictions fell below the correlation line for these faces. This discrepancy is particularly pronounced for female faces, which may explain why the correlation for female faces only approached significance, whereas a significant correlation was found for male faces. In human judgments of attractiveness, the differences observed were limited to certain conditions, such as the attractive female condition, consistent with research suggesting that the effect of happiness on female faces is more pronounced for attractive faces (Jaensch et al., 2014). Our findings align with prior studies showing no differences between happy and neutral expressions (Mueser et al., 1984; Morrison et al., 2013) and contrast with the notion that happiness increases attractiveness as it signals good health (Dfarhud et al., 2014; Lie et al., 2008, 2010; Roberts et al., 2005; Singh et al., 2024). Together, these findings suggest that facial beauty prediction algorithms may reflect the same avoidance mechanism toward angry expressions as humans do (Jaensch et al., 2014; Seidel et al., 2010).

6.3.3. Interaction between sexual dimorphism and facial expressions

Our findings suggest that for the masculinized versions of both male and female faces, happy expressions were perceived as more attractive than neutral ones by the human raters (Study 2). For the VGG-19's attractiveness evaluations, differences only emerged for female faces, with feminized angry faces being perceived as less attractive than neutral faces, while masculinized angry faces were rated as

less attractive than happy faces. The correlation between VGG-19 predictions and human ratings from our Study 2 (Figure D.2 of Appendix D) was significant for female faces, while no association was observed for male faces. One possible explanation for this discrepancy is that the attractiveness ratings in Study 2 were highly right-skewed, as illustrated in Appendix B (Figure B.4).

Furthermore, the lack of differences in the algorithmic evaluations of male faces may be explained by social stereotypes that consider expressions of anger more acceptable for men. At the same time, smiling is seen as a social requirement for women, reflecting the perception of men as more dominant and women as more affiliative (Hess et al., 2005; Mehu et al., 2008). Furthermore, we extend prior findings suggesting that, not only for male faces (Carrito et al., 2023), but also for female faces, the avoidance response to masculinity is reduced by a smiling expression. Our findings seem to support the idea that masculine facial features may be associated with higher perceptions of negative traits, such as coldness or dishonesty (Perrett et al., 1998; Oosterhof & Todorov, 2008), and that happy expressions diminish this negative effect (Hess et al., 2009; Thierry et al., 2021).

6.4. Limitations and Suggestions for Future Research

We will provide a comprehensive overview of the factors that may have contributed to the difficulties in replicating prior findings, highlighting potential influences and limitations within the current research. Additionally, we will identify key areas where future studies could enhance our understanding and build upon these findings, ultimately advancing the field.

6.4.1. Time perception

In our human-based experiments, a temporal reproduction task was implemented, with durations ranging from 0.133 s to 2.1 s, similar to that from Arantes et al. (2013). However, literature suggests that temporal reproduction tasks may have less power compared to other time perception tasks, as evidenced in a recent meta-analysis from Cui et al. (2023). For instance, research found an overestimation of angry faces when using the temporal bisection task, but not when using the temporal reproduction (Gil & Droit-Volet, 2011; Malva et al., 2023). Cui et al. (2023) propose that this discrepancy occurs because, in temporal reproduction, the physiological arousal diminishes over time, lessening its influence on the perception of duration.

Nevertheless, this explanation is contested by previous temporal reproduction studies, in which it was observed an overestimation effect for longer durations (i.e., greater than 2 seconds; Angrilli et al., 1997; Noulhiane et al., 2007; Tian et al., 2013; Tse et al. 2004; Zhou et al., 2021). Indeed, studies

typically report a larger overestimation as the duration increases, with this effect being multiplicative (e.g., Burle & Casini, 2001). However, it must also be said that longer durations may induce chronometric counting (Wearden, 1991). For example, Noulhiane et al. (2007) observed that emotion only affected the perception of time for durations of up to 4 seconds. We used durations of up to approximately 2 seconds to prevent participants from counting, anticipating an overestimation of around 120% for time intervals between 0.5 and 2 seconds (Arantes et al., 2013; Seigfred & Ulrich, 2010). Since the present thesis was the first to examine the effects of the menstrual cycle and sexual dimorphism on time perception, and to extend these investigations to the auditory modality, further research should consider using various time perception tasks with a broader range of durations. This will help determine whether the absence of differences in our studies is due to the limitations of our methodology in detecting these effects.

Furthermore, although we have used ovulation tests to detect LH surges, one could use quantitative hormonal measures, such as daily saliva samples for estradiol, progesterone, and testosterone (Roney & Simmons, 2013; Shirazi et al., 2018; Stern et al., 2021). Moreover, further studies could collect hormonal samples from the models in the photographs, as objective hormonal indicators of sexual dimorphism (Jones, Hahn, Fisher, Wang, Kandrik, Lao, et al., 2018; Kandrik et al., 2017; Peters et al., 2008;). Additionally, different sexual dimorphic manipulations should be explored, such as skin color manipulation. Evidence suggests that masculinity in male faces (i.e., darker, redder, and yellower tones) is considered attractive regarding reflectance properties, while femininity is preferred in shape properties (Carrito et al., 2016; Said and Todorov, 2011).

Concerning the effect of the relationship context on women's preference for masculinity, with a common preference for more masculine men in short-term compared to long-term relationships (Little, Burriss et al., 2008, Little et al., 2007; Penton-Voak et al., 2003; Penton-Voak & Perret, 2001; Puts, 2005), further research should take into account what type of relationship participants are searching for. Another alternative could be to manipulate the relationship context by explicitly stating that potential partners will be presented for either short-term or long-term relationships. However, when designing these experiments, additional factors should be considered. As previously discussed, there are individual factors such as age at menarche (Niu & Zheng, 2020), rater's personality (Johnston et al., 2001; Stower et al., 2020), and attractiveness level (Burris et al., 2011; Docherty et al. 2020; Kandrik & DeBruine 2012; Little et al. 2001; Marcinkowska et al., 2021) that should be explored in future time perception studies. Furthermore, an important variable to consider when exploring the relationship context is the attractiveness level of the male in the presented photos, as it may be perceived as a stronger cue for parental investment in long-term relationships than sexual dimorphism (Bartlome & Lee, 2023).

Additionally, it would be important to explore whether the attractiveness levels of faces would be a factor causing inconsistency in sexual dimorphism preference, thus leading to our null results. In the time perception experiments, we used photos of individuals rated as having average attractiveness for the sexually dimorphic transformations. However, research found that both male and female participants preferred masculine male faces over androgynous male ones when rated as highly attractive, but mixed results for low-attractiveness faces (Yang et al., 2015). In female faces, both males and females preferred feminine faces over androgynous ones when rated as highly attractive, but no clear preferences emerged for faces of lower attractiveness (Yang et al., 2015). Also, the initial level of facial masculinity may influence the preference for masculinity in male faces, with females showing a higher preference for masculinity for initial low and average masculine faces (Ekrami et al., 2021).

Moreover, we used a within-subjects design in Study 1, where the different conditions were presented in distinct blocks, and a between-subjects design in Study 2, to examine the influence of sexually dimorphic and attractive photos on time perception. Future research may explore presenting attractive and sexual dimorphic same-sex and opposite-sex photos within the same block. For example, Little and Mannion (2006), using a within-subject design, found that women's exposure to attractive same-sex images led to lower self-rated attractiveness and reduced preference for male facial masculinity, while exposure to unattractive images increased self-rated attractiveness and heightened preference for masculinity. By using this method, researchers could also unify previous findings about time perception of same-sex (Ogden, 2013; Tomas & Španić, 2016) and opposite-sex (Arantes et al., 2013; Tian et al., 2019; Zhou et al., 2021) photos, to understand whether an interaction would emerge.

Additionally, physiological measures of cognitive load, such as eye tracking and electrocardiogram devices (Haapalainen et al., 2010), could offer valuable insights into previous findings that report either an attentional influence (Ogden, 2013; Sano et al., 2022) or arousal effects (Zhou et al., 2021) on time perception. Indeed, Zhou et al. (2021) found that arousal only mediated the temporal effect for female faces rated as highly attractive. Therefore, incorporating physiological data and using faces with a broader range of attractiveness levels may help explain the lack of significant findings in Study 2 regarding the effects of attractiveness or emotionality on time perception.

We studied time perception of sexually dimorphic faces and voices using independent stimuli (Study 1). Future research should investigate the cross-modal effects on time perception by presenting videos that combine sexually dimorphic facial, body, and vocal cues (Hughes et al., 2004; O'Connor et al., 2012, 2013). Moreover, this approach could be extended to other sensory modalities. For example, Williams and Apicella (2024) demonstrate an agreement in attractiveness judgments across visual,

auditory, and olfactory modalities. Research also suggests that the odor of men with more masculine skin color is considered attractive (Carrito et al., 2017). Building on previous research on multimodal mate preferences (Roth et al., 2021) and time perception (Arantes et al., 2021) in a speed-dating paradigm, future studies could investigate the impact of cross-modal sexual dimorphism on time perception in real-life situations.

6.4.2. Attractiveness prediction

Remarkable advances in facial beauty prediction have been achieved using deep learning models (for a review, see Saeed et al., 2021). However, there is still a lack of understanding regarding how these models make their decisions, which is essential not only for regulating their potential use in commercial and clinical applications but also for improving their predictive capabilities. In light of this, we identified several limitations throughout our studies that warrant further discussion.

The methodology proposed for Study 3 and Study 4, which focuses on the beauty prediction of static facial images, could be extended to include multimodal dynamic predictions. Prior research suggests that incorporating dynamic features improves the prediction of facial attractiveness compared to relying solely on static features (Kalayci et al., 2014). Additionally, audio-visual cues have been shown to enhance inferences of attractiveness and personality when compared to using a single modality alone (Çeliktutan & Gunes, 2017). Building on these findings, future research could explore the influence of sexually dimorphic features in multimodal attractiveness prediction algorithms. Furthermore, considering recent advancements in multimodal emotion recognition (for a review, see Gu et al., 2021), it would be valuable to investigate how emotionality interacts with sexual dimorphism in shaping algorithmic perceptions of attractiveness.

Additionally, significant advancements have been made in the application of machine learning to olfaction (for a review, see Lötsch et al., 2019), with research suggesting that authentication based on human body odor is feasible (Yang & Lee, 2018). While these models are highly relevant for decoding olfactory processes, it is critically important to understand how these algorithms make decisions from both biological and psychological perspectives (Barwich & Lloyd, 2022). Therefore, further data collection (Groot et al., 2020), combined with an interdisciplinary approach (Ferdenzi et al., 2020), is essential for further development of machine learning in olfaction. Specifically, future studies could investigate whether machine learning models can predict attractiveness based on olfactory cues, and how factors such as sexual dimorphism and emotionality influence these judgments.

In the studies conducted in this thesis, we observed preferences among heterosexual or bissexual individuals. However, the literature suggests that sexual orientation may play a potential role in shaping preferences for sexual dimorphism. For instance, research suggests that homosexual men tend to have a stronger preference for masculinity in male faces, while homosexual women exhibit a stronger preference for masculinity in female faces (Glassenberg et al., 2010). Therefore, future research should explore the moderating impact of sexual dimorphism on time perception with respect to sexual orientation. Moreover, it would be valuable to examine whether algorithmic preferences for sexual dimorphism vary based on sexual orientation. To address this, studies should provide information about the sexual orientation of participants when validating databases used for attractiveness assessments. Second, explore whether controlling for potential confounds (e.g., hairstyle) would influence our findings. This is commonly addressed through the use of masking techniques (e.g., DeBruine et al., 2010; Foo, Simmons, et al. 2017; Peters et al., 2009). Nevertheless, prior research suggests that applying a mask to remove hair led to a general preference for femininity (DeBruine et al., 2010). Lastly, it would be valuable to test whether additional state-of-the-art facial beauty prediction algorithms replicate our results and whether our findings could enhance these models' predictive accuracy, for instance by extracting sexually dimorphic features in the preprocessing phase (Gan et al., 2023).

6.5. Conclusion

This doctoral thesis contributes to the understanding of cognitive processes underlying the perception of attractiveness, with a specific focus on time perception. Additionally, it offers insights into how facial beauty prediction algorithms evaluate attractiveness. While previous research on time perception and attractiveness has primarily focused on the influence of attractive faces, this thesis extends that knowledge by manipulating attractiveness through sexual dimorphism, incorporating auditory stimuli, and examining the role of the menstrual cycle and emotionality in shaping the effect of attractiveness on time perception. We found evidence suggesting a moderator effect of the menstrual cycle on the time perception of sexually dimorphic cues, but only for the auditory modality. Furthermore, our findings support previous research on the overestimation of attractive faces (Arantes et al., 2013, 2021; Tian et al., 2019; Tomas & Španić, 2016; Zhou et al., 2021). However, we did not find any influence of sexually dimorphic visual cues on time estimation. Therefore, our findings emphasize the need to account for different sensory modalities when examining the cognitive mechanisms underlying attractiveness perception.

Furthermore, we showed that facial beauty prediction algorithms replicate human-like psychophysical biases in their judgments. Accordingly, our results suggest that the VGG-19 model perceives both male and female feminine faces as more attractive. Also, VGG-19 predictions align with our results from human raters and previous findings in the literature, showing lower attractiveness ratings for angry expressions, which indicates an aversive response to negative emotions. Regarding the interaction between sexual dimorphism and facial expressions, our findings suggest that happy expressions mitigate the negative impact of masculinity on attractiveness.

The present findings have several practical implications across social, professional, and clinical contexts. For example, in social interactions, awareness of overestimating time may indicate attraction toward another person. This insight could be used by social dating platforms and speed dating agencies to help identify optimal matches. Additionally, advertising companies might leverage these findings by incorporating beauty prediction and time perception judgments to enhance consumers' perceived viewing time of ads. With the rise of AI-assisted recruitment processes (Kong et al., 2021), our findings could also aid in designing explainable AI systems for video interviews (Escalante et al., 2017). Attractiveness, sexual dimorphism, and facial expressions have been shown to influence job interview outcomes (Ruben et al., 2015; Watkins & Johnston, 2000) by affecting perceptions of trustworthiness (Hu et al., 2018; Thierry et al., 2021) and competence (Dion et al., 1972; Jackson et al., 1995). Moreover, facial beauty prediction algorithms have clinical relevance, particularly in plastic surgery (Kanevsky et al., 2016; Štěpánek et al., 2019a, 2019b).

Finally, we believe that our work makes a modest but important contribution to the literature. This research fills a gap by examining the influence of sexual dimorphism on time perception, its interaction with facial expressions, and the moderating role of the menstrual cycle. Additionally, we advanced the field of explainable AI by investigating whether the VGG-19 model, commonly used for facial beauty prediction, is affected by sexual dimorphic and emotional cues when evaluating attractiveness. Future studies could explore whether our null findings regarding the influence of sexual dimorphism and facial expressions on time perception are due to the type of task or stimuli used in this research. Furthermore, future research should investigate whether AI attractiveness judgments of sexual dimorphic and emotional cues are consistent when different manipulations of sexual dimorphism or alternative algorithms are used, and whether these findings can be extended to additional emotional expressions and other sensory modalities. In this dissertation, we aimed to explore the relationship between attractiveness and time perception while also shedding light on how AI systems assess attractiveness. In doing so, we have provided a more comprehensive understanding of the mechanisms underlying the

influence of attractiveness on time perception and the role of sexual dimorphism and facial expressions in shaping attractiveness judgments, both from a human and AI-powered perspective.

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APPENDIXES

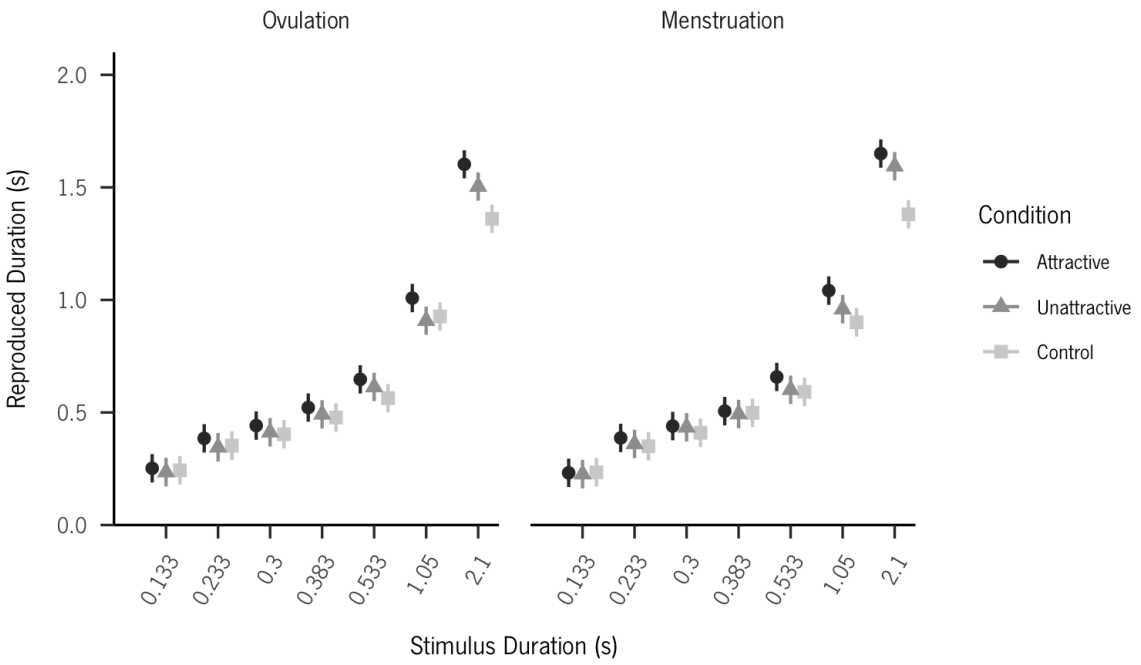
Appendix A: Supplementary Material of Study 1

Table A.1 *Table showing socio-demographic variables. Results are shown in absolute and relative (%) frequencies.*

Personal characteristics	Level	n (%)
Nationality	Portuguese	40 (83.3)
	Brazilian	7 (14.6)
	Spanish	1 (2.1)
Relationship Status	Single	30 (62.5)
	Relationship	18 (37.5)
Socioeconomic status	Low	1 (2.1)
	Medium-Low	9 (18.75)
	Medium	22 (45.8)
	Medium-High	7 (14.6)
	High	1 (2.1)
	Non-disclosure	8 (16.7)
Employment status	Employed	2 (4.2)
	Student	43 (89.6)
	Working student	3 (6.3)

Figure A.1

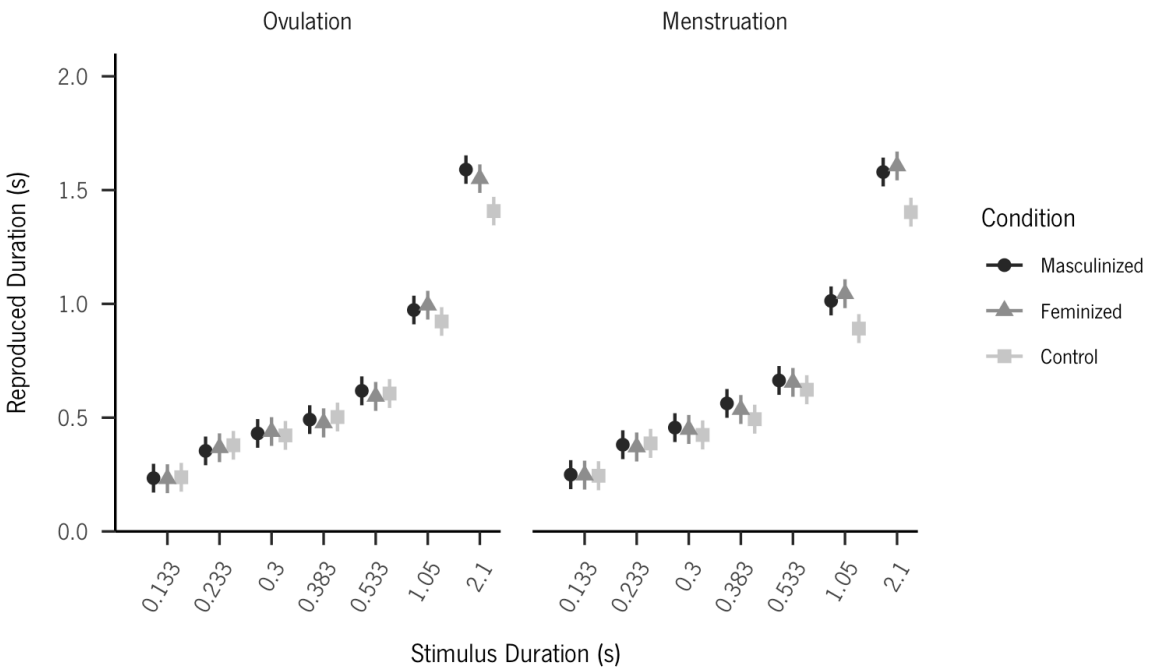
Reproduced durations for the visual attractiveness block across all conditions, for both the ovulation phase (left grid) and menstruation phase (right grid)



Note. Error bars indicate one SE.

Figure A.2

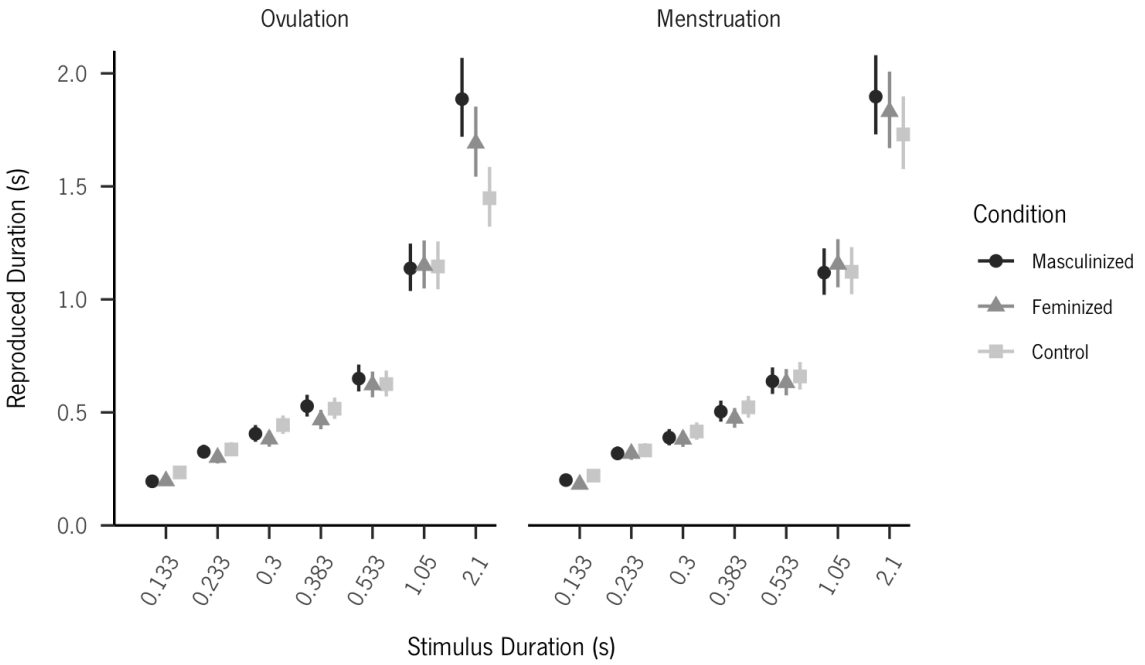
Reproduced durations for the visual dimorphic block across all conditions, for both the ovulation phase (left grid) and menstruation phase (right grid)



Note. Error bars indicate one SE.

Figure A.3

Reproduced durations for the auditory dimorphic block across all conditions, for both the ovulation phase (left grid) and menstruation phase (right grid)

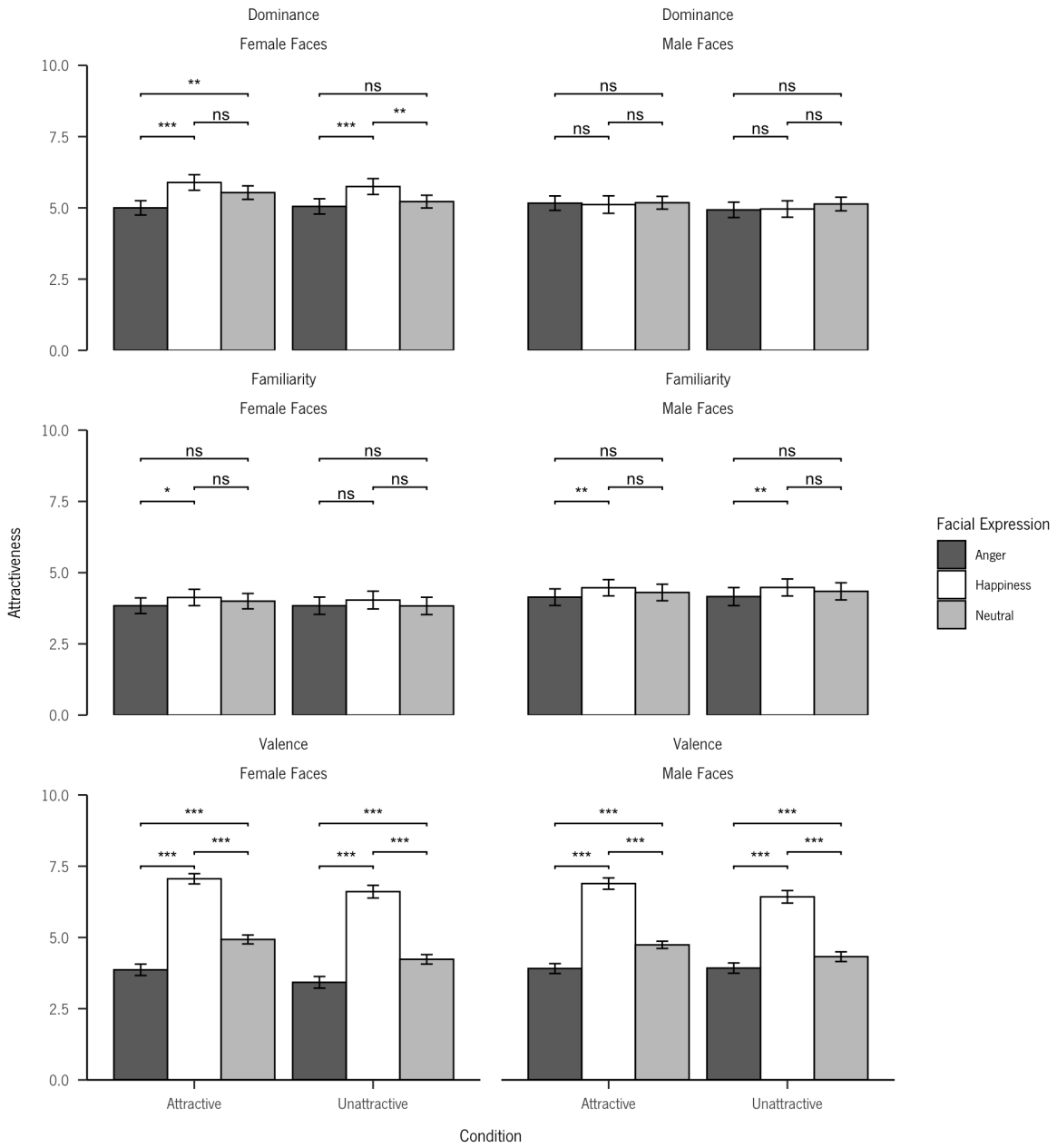


Note. Error bars indicate one SE.

Appendix B: Supplementary Material of Study 2

Figure B.1

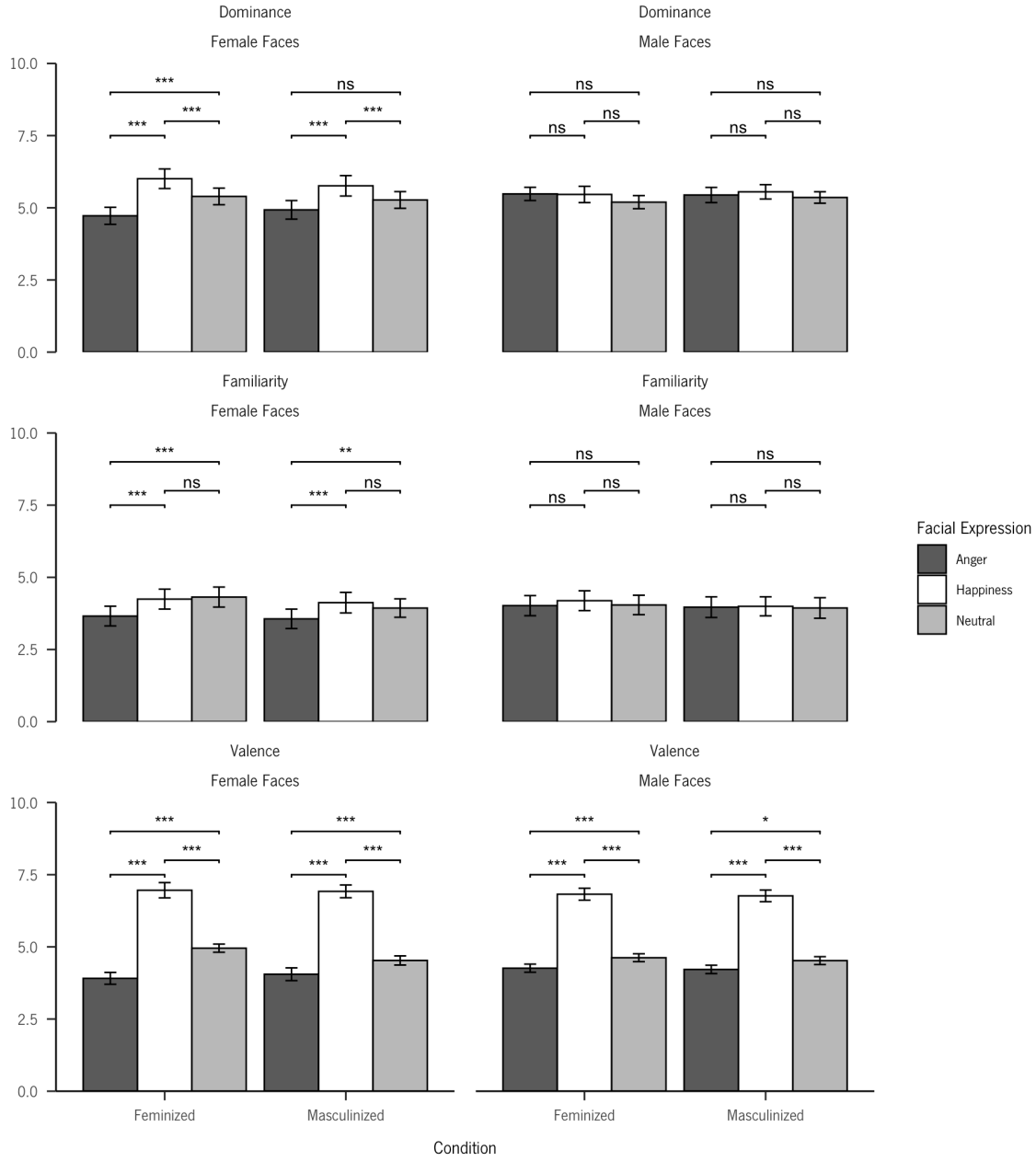
Average dominance, familiarity, and valence evaluations of the attractiveness group across all conditions



Note. Error bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

Figure B.2

Average dominance, familiarity, and valence evaluations of the sexual dimorphic group across all conditions



Note. Error bars indicate one SE; * $p < .05$, ** $p < .01$, *** $p < .001$, ns = non-significant ($p \geq .05$).

Figure B.3

Distribution of the attractiveness ratings of the attractiveness group

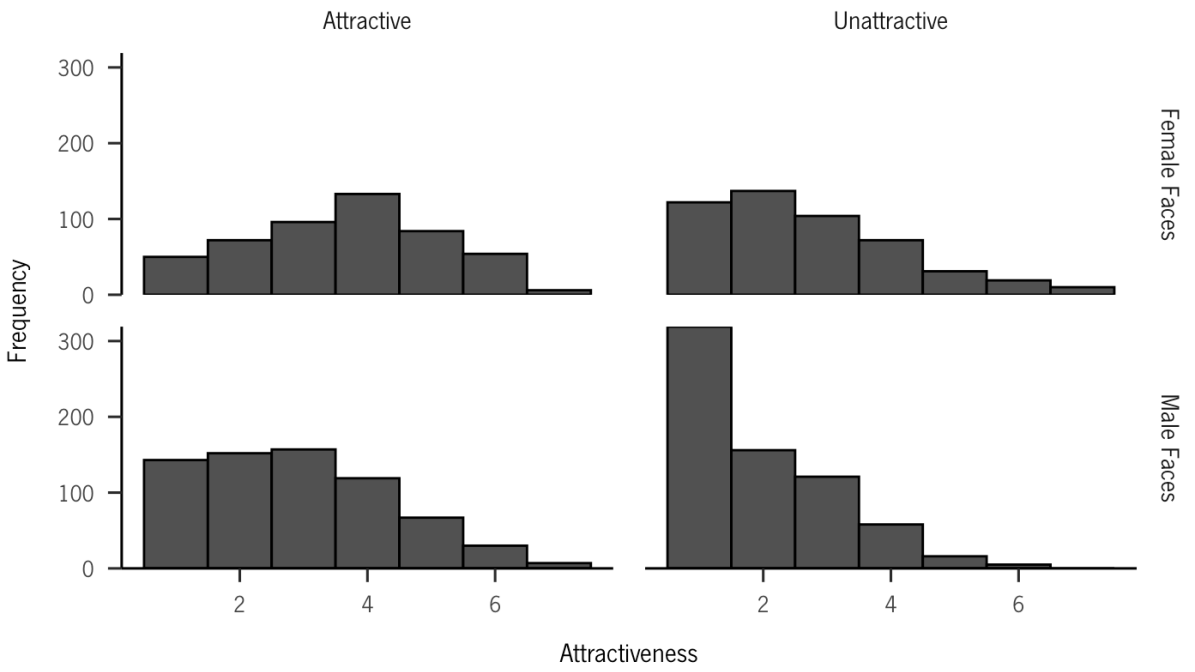


Figure B.4

Distribution of the attractiveness ratings of the sexually dimorphic group

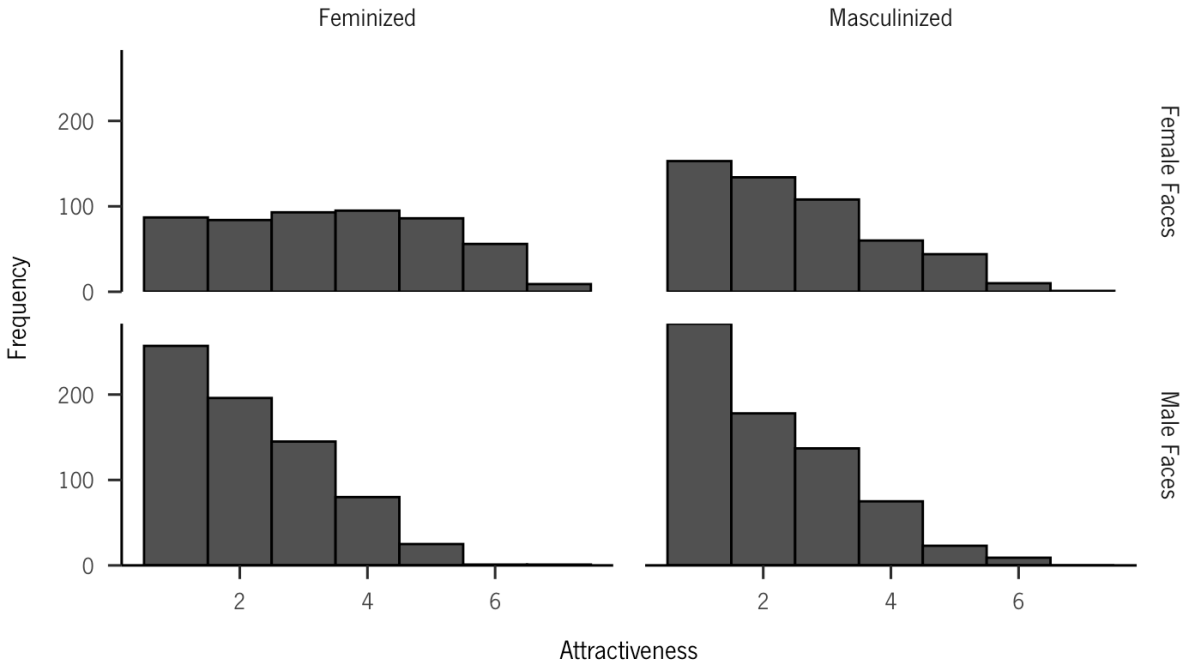


Figure B.5

Distribution of the arousal ratings of the attractiveness group

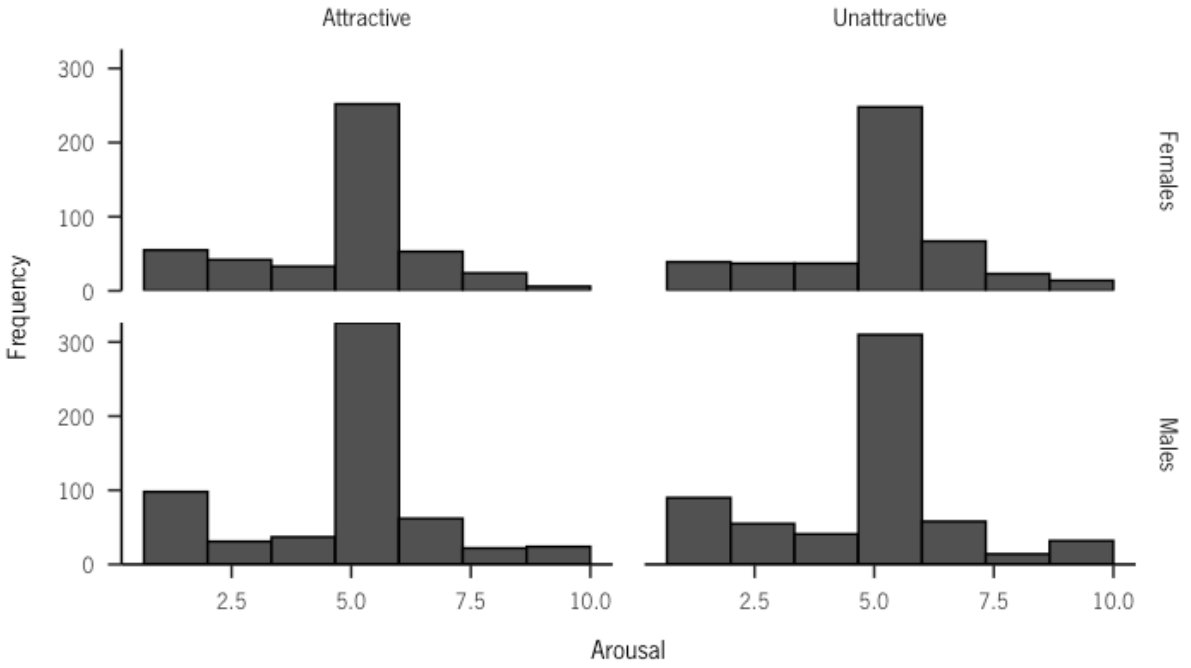


Figure B.6

Distribution of the arousal ratings of the sexually dimorphic group

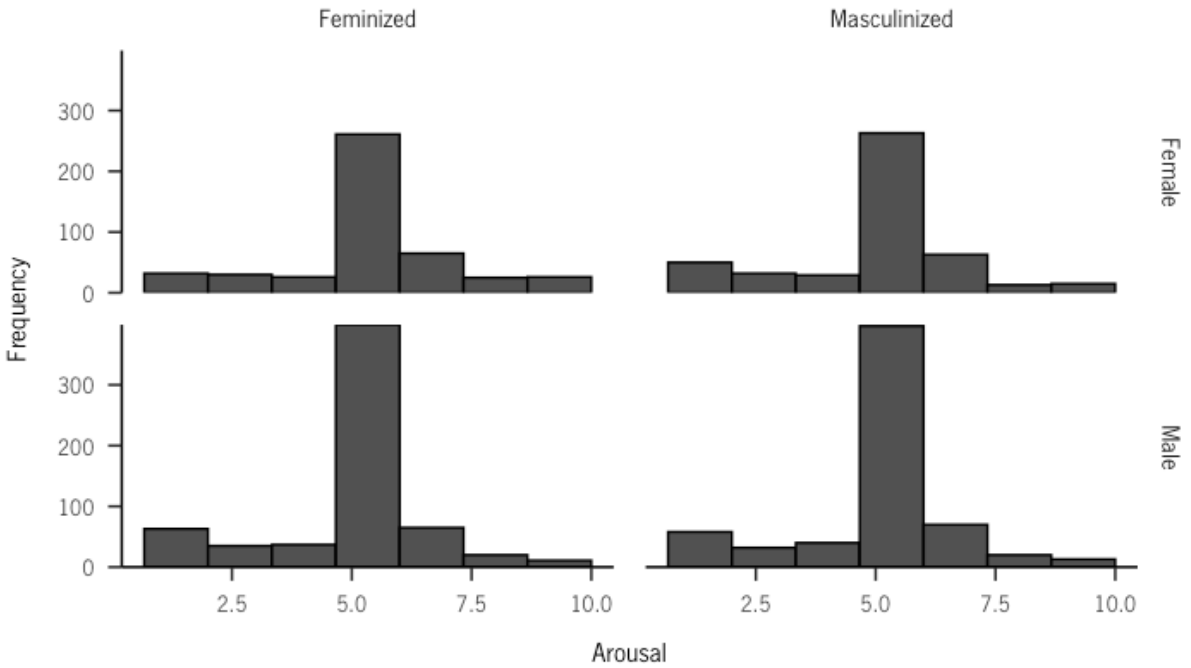
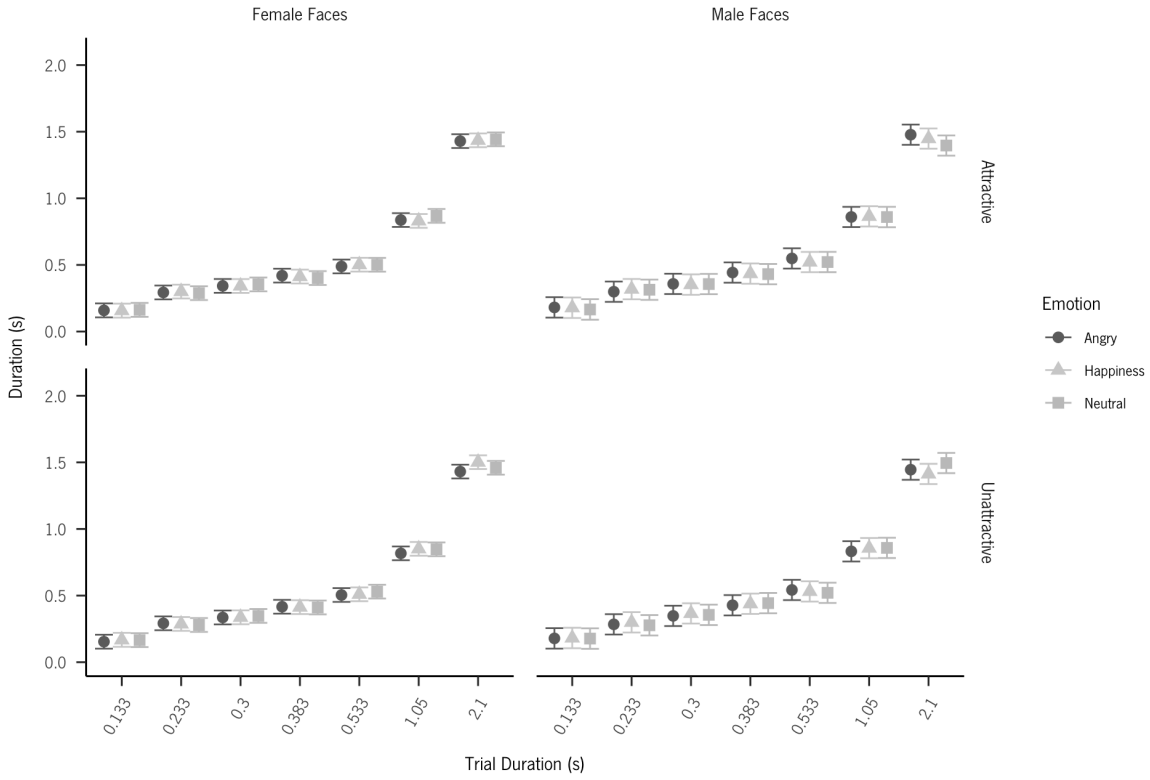


Figure B.7

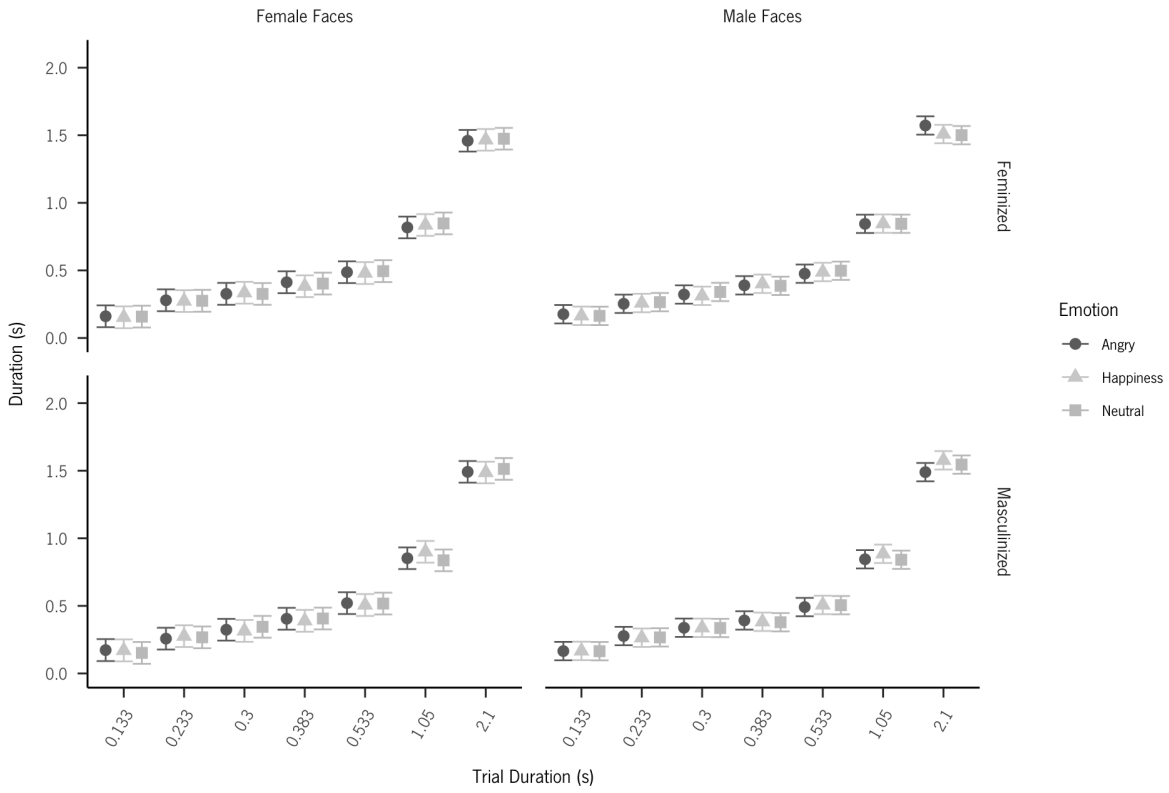
Reproduced durations for the attractiveness block across all conditions, for both female faces (left grid) and male faces (right grid)



Note. Error bars indicate one SE.

Figure B.8

Reproduced durations for the sexually dimorphic block across all conditions, for both female faces (left grid) and male faces (right grid)



Note. Error bars indicate one SE.

Appendix C: Supplementary Material of Study 3

Table C.1

Evaluation metrics for the different models on the test set

Models	***r***	***MAE***	***RMSE***
InceptionResNetV2	.75	0.08	0.099
MobileNetV2	.69	0.09	0.117
EfficientNetV2B0	.38	0.11	0.131
ResNet50	.64	0.08	0.104
Xception	.63	0.09	0.120
VGG-19	.76	0.07	0.094

Note. *r* = Pearson's correlation coefficient; *MAE* = Mean Absolute Error; *RMSE* = Root Mean Squared Error.

Appendix D: Supplementary Material of Study 4

Figure D.1

Correlation between Garrido & Prada (2017) attractiveness validation of KDEF and VGG-19's predictions

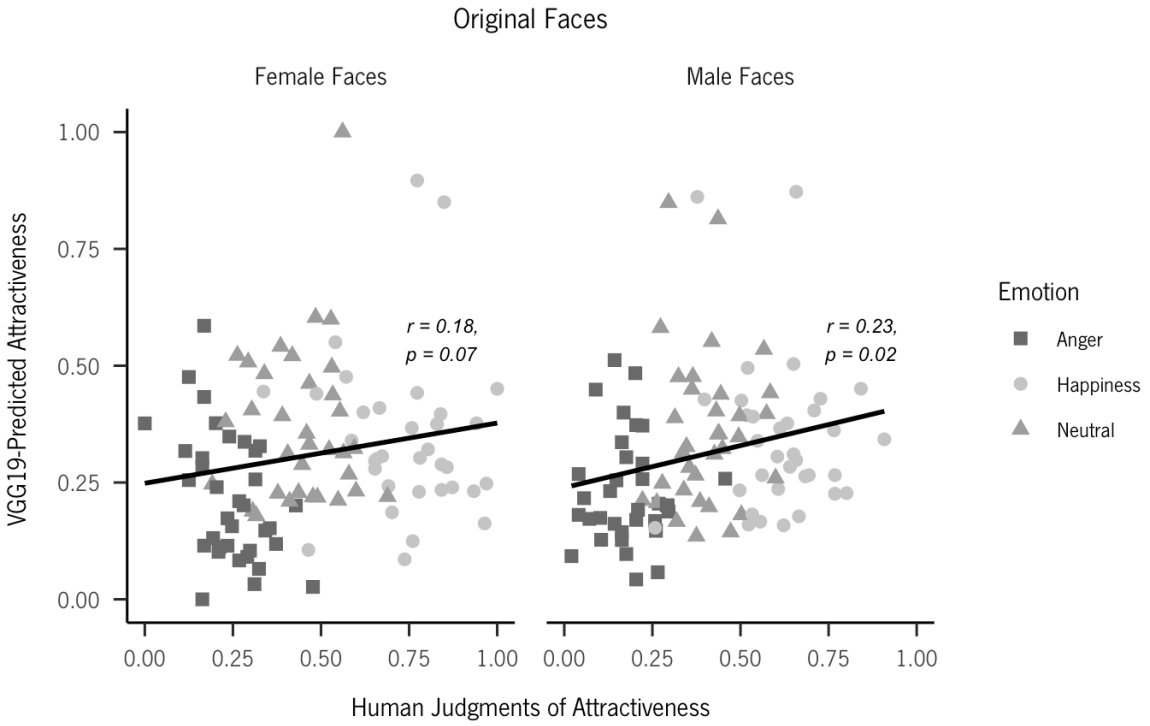
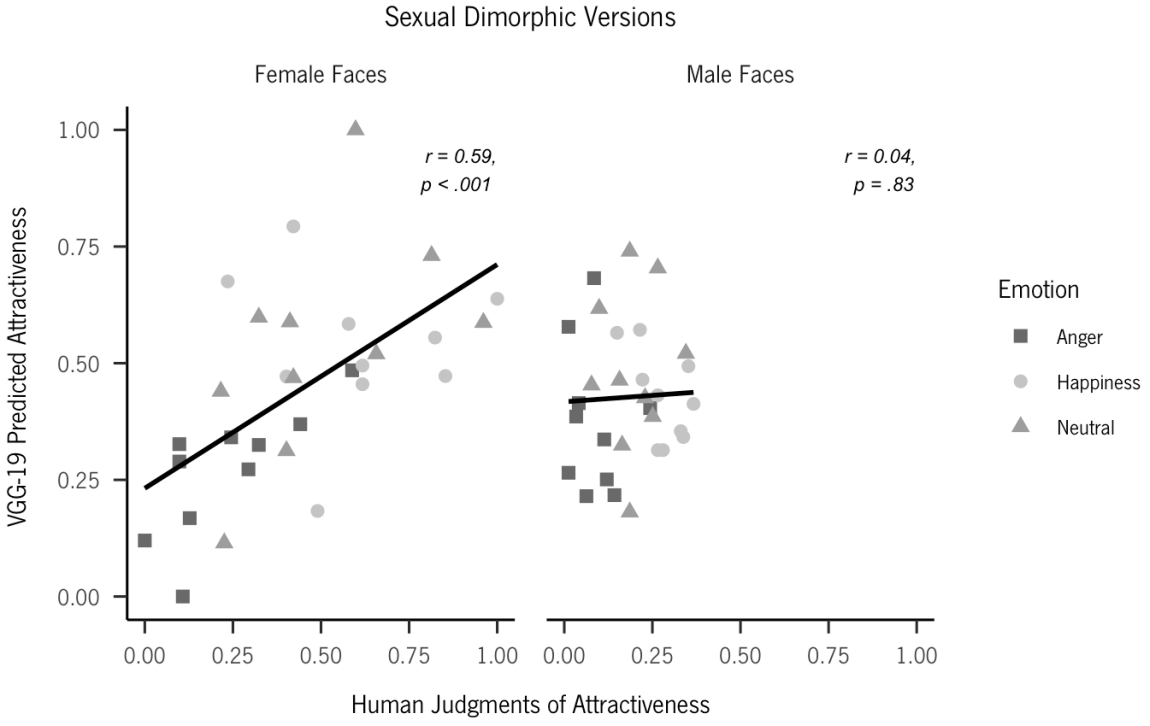


Figure D.2

Correlation between attractiveness ratings from Study 2 and VGG-19's predictions



Appendix E: Study 1 Ethical Approval

The Ethics Committee for Human and Social Sciences of the University of Minho (CEICSH 056/2021) has granted approval for Study 1, using human subjects, presented in Chapter 2 of the current dissertation, as demonstrated below:



Universidade do Minho

Conselho de Ética

Comissão de Ética para a Investigação em Ciências Sociais e Humanas

Identificação do documento: CEICSH 056/2021

Relatores: Emanuel Pedro Viana Barbas Albuquerque e Marlene Alexandra Veloso Matos

Título do projeto: *O efeito do ciclo menstrual na perceção temporal*

Equipa de Investigação: Nuno Fernandes (IR), Investigador Assistente, Escola de Psicologia, Universidade do Minho; Joana Arantes, Investigadora Auxiliar, Escola de Psicologia, Universidade do Minho

PARECER

A Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) analisou o processo relativo ao projeto de investigação acima identificado, intitulado *O efeito do ciclo menstrual na perceção temporal.*

Os documentos apresentados revelam que o projeto obedece aos requisitos exigidos para as boas práticas na investigação com humanos, em conformidade com as normas nacionais e internacionais que regulam a investigação em Ciências Sociais e Humanas.

Face ao exposto, a Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) nada tem a opor à realização do projeto nos termos apresentados no Formulário de Identificação e Caracterização do Projeto, que se anexa, emitindo o seu parecer favorável, que foi aprovado por unanimidade pelos seus membros.

Braga, 12 de outubro de 2021.

O Presidente da CEICSH

(Acílio Estanqueiro Rocha)

Anexo: Formulário de identificação e caracterização do projeto

Appendix F: Study 2 Ethical Approval

The Ethics Committee for Human and Social Sciences of the University of Minho (CEICSH 055/2022) has granted approval for Study 2, using human subjects, presented in Chapter 3 of the current dissertation, as demonstrated below:



Universidade do Minho

Conselho de Ética

Comissão de Ética para a Investigação em Ciências Sociais e Humanas

Identificação do documento: CEICSH 055/2022

Relatores: Emanuel Pedro Viana Barbas Albuquerque e Marlene Alexandra Veloso Matos

Título do projeto: *O efeito de expressões faciais e atratividade na perceção temporal*

Equipa de Investigação: Nuno Fernandes (IR), Doutoramento Psicologia Básica, Escola de Psicologia, Universidade do Minho; Joana Arantes (orientadora), Escola de Psicologia, Universidade do Minho

PARECER

A Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) analisou o processo relativo ao projeto de investigação acima identificado, intitulado *O efeito de expressões faciais e atratividade na perceção temporal*. Os documentos apresentados revelam que o projeto obedece aos requisitos exigidos para as boas práticas na investigação com humanos, em conformidade com as normas nacionais e internacionais que regulam a investigação em Ciências Sociais e Humanas.

Face ao exposto, a Comissão de Ética para a Investigação em Ciências Sociais e Humanas (CEICSH) nada tem a opor à realização do projeto nos termos apresentados no Formulário de Identificação e Caracterização do Projeto, que se anexa, emitindo o seu parecer favorável, que foi aprovado por unanimidade pelos seus membros.

Braga, 17 de maio de 2022.

O Presidente da CEICSH



(Acílio Estanqueiro Rocha)

Anexo: Formulário de identificação e caracterização do projeto