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Hormonal contraceptives as disruptors of competitive motivation and behavior

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Abstract

This thesis investigated whether hormonal contraceptives disrupt steroid hormone modulation of socially competitive attitudes and behaviors that may be associated with natural hormone fluctuation across the menstrual cycle. Through a systematic literature review and three empirical studies, this research provides novel insights into the relationships between reproductive hormones and female competition. A systematic literature review (Chapter 2) of 46 studies (*N* = 16,290) revealed that hormonal contraceptive users do not exhibit the same menstrual cycle-related fluctuations in self-perceived attractiveness and intrasexual competition observed in naturally cycling women and may show reduced status-oriented competitive motivation. Two longitudinal diary studies (Chapters 3 and 4) with over 9,500 combined daily observations across 22 countries examined fertility effects on competitive orientations and behaviors. The first study found that fertility probability was positively associated with increased self-development competitiveness in naturally cycling women but not hormonal contraceptive users. The second study failed to detect fertility-linked changes in competitive motivation or behavior, but conceptually replicated findings that hormonal contraceptive users report reduced competitive interest compared to non-users. Finally, a pre-registered experimental study (Chapter 5) demonstrated that naturally cycling women in their mid-follicular phase showed greater competitive persistence compared to both mid-luteal phase women and hormonal contraceptive users. This effect was partially mediated by blunted cortisol and progesterone reactivity in hormonal contraceptive users, suggesting a novel endocrine mechanism by which hormonal contraceptives may downregulate competitive behavior. Collectively, these findings indicate that hormonal contraceptives may influence women's competitive psychology and behavior by disrupting evolved hormonal mechanisms, particularly for self-development and achievement-oriented competition. This thesis discusses the implications of these results for women’s psychology, behavior, and public health.

Declaration by Author

I declare that my thesis is my own work and contains no work written or published by another person. The research reported in this thesis was conducted in accordance with the principles for the ethical treatment of human participants, as approved for this research by the University of Melbourne Human Research Ethics Committee. The word count for this thesis is below the maximum allowable length.

L. Arthur-Hulme

Lindsie Arthur-Hulme

Preface

This thesis is presented with publications. It comprises 6 chapters, of which all 4 empirical chapters have been published as peer-reviewed manuscripts. I contributed over 50% of the content within each publication – I was primarily responsible for writing and revising manuscripts, conducting data analyses, and implementing edits in line with feedback from co-authors and peer reviewers. The references for published chapters are provided below, along with the percentage contribution by each author. Although my general introduction and discussion are not published and therefore not subject to journal spelling requirements, American spelling has been used for consistency across all chapters in this thesis. Finally, I use the personal pronoun "I" in my General Introduction (Chapter 1) and General Discussion (Chapter 6), and "we" in all published work (Chapters 2 to 4), referring to my co-authors.

Chapter 2: Published April 2022

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Author	Contribution	Task Contribution
Lindsie Arthur	70%	Conceptualisation; manuscript writing, editing; coding reviewed articles
Kathleen Casto	15%	Conceptualisation; manuscript – reviewing and editing; supervision
Khandis Blake	15%	Conceptualisation; manuscript – reviewing and editing; supervision

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Author	Contribution	Task Contribution
Lindsie Arthur	70%	Conceptualisation; manuscript writing, editing; data collection; data analyses
Khandis Blake	30%	Conceptualisation; manuscript – reviewing and editing; data analyses; supervision

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Author	Contribution	Task Contribution
Lindsie Arthur	80%	Conceptualisation; manuscript writing, editing; data collection; data analyses
Brock Bastian	5%	Manuscript – reviewing and editing; supervision
Khandis Blake	15%	Conceptualisation; manuscript – reviewing and editing; supervision

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Author	Contribution	Task Contribution
Kathleen Casto	35%	Conceptualisation; manuscript writing, editing; data collection; data analyses; funding
Lindsie Arthur	51%	Conceptualisation; manuscript writing, editing; data collection; data analyses
Siobhan Lynch-Wells	4%	Date collection
Khandis Blake	10%	Conceptualisation; manuscript – reviewing and editing; supervision

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This research also would not have been possible without the support of my co-supervisor and committee members. Thank you to Brock for providing writing and statistical support, and for creating a second lab for me to call home. To Luke, Elise, Christina, and Kim, thank you for your constructive feedback and challenging questions during my annual review meetings. These diverse perspectives and expertise have significantly enriched my work. Finally, I would like to thank Kathleen Casto, who provided me with technical and theoretical support throughout my PhD. Although Kathleen is not a formal member of my committee, she has been a core collaborator and an invaluable contributor to my personal development. Words cannot accurately express my gratitude for the countless brainstorming sessions and writing marathons that we embarked on together.

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To my Mum and Dad, thank you for always celebrating the small wins and making me feel like I can do anything. Mum, I know I can be stubborn, but you taught me my worth and gave me the best role model. I have always aspired to be a strong, independent woman like you, and my commitment to

improving women’s health represents the values you instilled in me as a child. Dad, no matter the circumstances, I feel like the apple of your eye and am grateful for your unconditional love and support.

To my unbelievable friends and loved ones, I would not have made it through without your support. Thank you for letting me ramble on about hormones and the challenges of measuring competition in women. Thank you for not getting upset when I missed events or was too tired to be completely present. Thank you for helping me develop my ideas through endless conversations over the phone, across coffee, while walking Maya, or during chats on the dance floor. And finally, to my dear Matthew, I literally couldn’t imagine finishing this thesis without you. I have never experienced a friendship like yours, based on a deep, mutual respect for one another. Thank you for everything, I am truly grateful beyond words.

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Chapter 1: General Introduction

Throughout human history, competition for resources has played a crucial role in the evolution of physical and behavioral attributes (Wilson, 2014). Contemporary human populations rarely compete using direct physical contests (Daly & Wilson, 2001; Eisner, 2003). Even so, winning competitions remains central to success in many domains, including employment, education, and mating (Baumann & Harvey, 2021; Buser et al., 2024; Buss, 2023; Wang et al., 2018). Across multiple disciplines, existing research has examined some characteristics influencing competitive motivation and behavior, such as personality and gender (Gneezy et al., 2003; Niederle & Vesterlund, 2008; Shuai et al., 2023). Other influences, such as natural and synthetic ovarian hormone levels, remain understudied despite significant potential to impact the lives of people with a menstrual cycle.

Throughout this interdisciplinary thesis, I expand what is known about the psychology of competition by investigating the relationship between the menstrual cycle, ovarian hormone concentrations, and competitive motivation and behavior among women[1]. I investigate both natural hormonal variation associated with the menstrual cycle and synthetic hormones found in hormonal contraceptives. Employing sophisticated methodologies and large, cross-cultural samples, I provide partial evidence that ovarian hormones influence competitive motivation and behavior. I also propose a novel '*hormonal contraceptives as disruptors*' framework (Arthur et al., 2022), arguing that hormonal contraceptives likely attenuate cycle-related variation in competitiveness by disrupting underlying hormonal mechanisms. Providing robust support for this framework, I demonstrate across one review and three empirical studies that some competitive attitudes and behaviors vary across the menstrual cycle and

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[1] In this thesis, terms for gender (i.e., woman) and sex (i.e., female) are not interchangeable. The term 'women' is used to refer to humans with ovaries and a menstrual cycle as this is representative of the majority of participants in my research and the broader literature. However, I acknowledge that not all people who menstruate identify as women, and not all women have ovaries. The term 'female' refers to both human and non-human animals. My intention is to be inclusive while accurately describing the biological factors relevant to this research and maintaining clarity between human and animal studies.

that hormonal contraceptives attenuate these effects. By better understanding the effects of HCs on competitive behavior and motivation, people who rely on this critical medicine can be empowered to make informed decisions about the benefits and costs of available birth control options.

The following introduction provides contextual foundations regarding the proposed effects of endogenous and synthetic hormones on competition. I begin by defining what is meant by the term 'competition' in the current thesis, drawing from both evolutionary and social psychological perspectives. I review life history theory as a core theoretical framework regarding the evolution of resource allocation as it relates to competitive outcomes. I then provide an overview of the endocrine system and its effects on the brain, bodily function, and behavior (including competition). This latter section includes detailed mechanistic information about hormone communication that provides important context for later chapters. I then provide an overview of the methods used in menstrual cycle research, including a justification of the methods employed in this thesis. This chapter concludes with an overview of my novel theory, followed by the aims of this thesis, and the goals each chapter sought to address.

Competition

The meaning of 'competition'

The term competition is used in numerous disciplines (e.g., anthropology, management, sport sciences, education, economics, political science; Fülöp, 2004), often with vastly different meanings. The Oxford Dictionary (2023) defines competition as the act of trying to win something that others also want access to. This definition captures a consistent premise of competition, suggesting that it involves striving for a common goal or accessing a limited resource (Andersson, 1994; Clutton-Brock, 2017). However, the Oxford Dictionary also implies that competition is a deliberate and active process. This perspective negates interdisciplinary views which suggest competition can be both indirect and non-conscious (Garcia et al., 2013; Winegard & Geary, 2021). In the current thesis, I use definitions of competition drawn from both biology and psychology, which differ in their scope, research focus, and timeframes.

Biological perspectives on competition

From a biological perspective, competition is a fundamental principle of evolution. Competition occurs when multiple organisms (of the same or different species) require access to resources that influence survival and reproduction (Andersson, 1994; Birch, 1957). When some organisms access fewer resources than others what results is variation in reproductive success, measured as an individual's genetic contribution to future generations (e.g., the number of offspring that survive to reproductive age). Biologists typically distinguish between two main types of competition — *contest* and *scramble* — which both play a crucial role in shaping population dynamics, community structure, and evolutionary trajectories over multiple generations (Nicholson, 1954). Contest competition occurs when resources can be monopolized, leading to clear winners and losers: Successful competitors gain access to a resource while others are excluded entirely (e.g., male elephant seals fighting for control of territory and mates; Le Boeuf, 1974). Scramble competition involves resources that can be divided among competitors, with each individual obtaining a portion based on their ability to acquire it (e.g., foraging and grazing feeding behavior; Parker, 2000). The distinction between contest and scramble competition is useful because it shows that competition can (and often does) occur without competitors meeting (Isbell, 1991; Nicholson, 1954).

Psychological perspectives on competition

In psychology, the meaning of competition has evolved over time (Fülöp, 2009). Early psychological research viewed competition and cooperation as dichotomous, meaning that high levels of one necessarily resulted in lower levels of the other (Fülöp & Orosz, 2015). Competition was also viewed as a unidimensional construct, such that competitiveness was akin to anti-social and uncooperative behavior (Schneider et al., 2010). Modern psychological research views competition as multifaceted because the purpose and target of competition can vary greatly (Fülöp & Orosz, 2015). For instance, competition may aim to produce self-improvement, beating others, or mastering a new skill, while the target of competition could be the self, another person, or another group of people.

Showcasing the diversity of competition research in psychology, entire books are dedicated to reviewing the antecedents, strategies, and outcomes of competition (e.g., Fisher, 2017; Garcia et al., 2013). For instance, some researchers are interested in characteristics that enhance or suppress competition, including features of the competitor (e.g., personality, motivation), environment (e.g., public, private), and target (e.g., gender, previous success, attractiveness; Hanek, 2024; Ku & Adam, 2024; Salvador et al., 2024). Other work investigates the effectiveness of competitive strategies (Fisher & Krems, 2022; Puts et al., 2022; van Kleef & Cheng, 2020) and consequences of winning and losing competitions, including effects on interpersonal relationships, group cohesion, and individual self-esteem (Boos et al., 2015; Gilabert, 2023; Koivula et al., 2002; Russell & Fiske, 2008).

Use of competition research in this thesis

In this thesis I draw from both biological and psychological definitions of competition. From biology, I use animal models to consider how competitive environmental pressures have produced distinct biological and psychological adaptations that enhanced survival and reproductive success (Stearns, 1989). I then argue that contextual factors (e.g., resource scarcity, social norms) have shaped the evolution of human physiology, and that these physiological systems influence behavior in modern human societies. I consider how the female endocrine system may influence competitive motivation and behavior in order to maximize reproductive success. Beyond biology, I also adopt a psychological perspective by investigating differences in competitive motivation and behavior at the individual (within-person) and group (between-person) levels.

These distinct but complementary perspectives enable me to consider distal and proximal motivations for engaging in competition. Distal goals represent long-term aspirations, while proximal goals are short-term, specific objectives that provide immediate motivation and guide behavior in the present (Manderlink & Harackiewicz, 1984). Proximal goals often enable individuals to reach their distal goals by facilitating short- and long-term trade-offs that contribute to some ultimate desirable outcome (Latham & Seijts, 1999). For example, engaging in mating competition in the short-term (the proximal goal) may enhance reproductive success (the distal goal) in the future, despite potentially involving immediate costs. To understand the specific competitive measures used throughout my thesis, the following section reviews distal and proximal motivations driving human competition, with a particular focus on the types of resources women compete for and the strategies used to obtain these resources.

Perceived gender differences in competition

Perceived gender differences in competitiveness have long been a subject of scientific inquiry and societal discourse. The prevailing scientific narrative has often portrayed men as more competitive than women (Gneezy et al., 2003; Niederle & Vesterlund, 2008, 2011). These narratives are reinforced by media and cultural stereotypes portraying men as more assertive and aggressive, while women are viewed as more cooperative and nurturing (Collins, 2011; Santoniccolo et al., 2023). Such perceptions are grounded in historical gender roles, where men's competitiveness was associated with their role as providers and protectors, while women's cooperative behaviors were linked to caregiving and communal responsibilities (Reynolds, 2022).

Contrary to these earlier beliefs, recent scholarship and popular culture suggests a more nuanced approach is required to understand competitive behavior across genders. Recent research shows that people of all genders frequently engage in competitive behaviors when there are clear, meaningful outcomes at stake (Günther et al., 2010; Hanek, 2024; Jetter & Walker, 2015). However, social structures and cultural norms have influenced the domains and objectives of acceptable competition across genders (Pierik, 2022; Zhu & Chang, 2019). For example, patriarchal social structures have channeled men’s competition towards resources that directly enhance status and power, such as high-ranking positions, financial success, and political influence (Farias et al., 2023). In contrast, women's competitive behaviors have often been directed towards outcomes associated with feminine roles, including social status within peer groups, attractiveness, and resources related to child-rearing (Campbell, 2013). Thus, gender differences in competitiveness exist on a spectrum, with considerable overlap between genders and significant individual variation within genders.

The study of women's competitiveness is an important academic endeavor due to the historical underrepresentation and mischaracterization of women in scientific literature. For decades, research on competitive behavior was predominantly focused on male subjects, leading to a skewed understanding of human competitiveness (Casto & Edwards, 2016b; Casto & Mehta, 2019). This gender bias in research not only perpetuated stereotypes about women's supposed lack of competitive drive but also resulted in incomplete theories of human behavior and decision-making (e.g., Niederle & Vesterlund, 2011). Understanding women's competitiveness is crucial for developing more accurate models of human behavior, designing effective policies to promote gender equality, and challenging persistent stereotypes that may hinder women's advancement. In the section that follows, I provide an overview of the kinds of resources that women compete for, why these are valuable to women, and the strategies used to obtain them.

Competition and women: what do women compete for (and how)?

Although humans compete for a vast array of resources, a small number of resources – namely, mates, status, and money – hold particular evolutionary significance as they are crucial for survival and reproductive success. Optimal mate selection offers direct (e.g., protection, parental investment) and indirect (e.g., advantageous genes) benefits to individuals and future offspring (Jones & Ratterman, 2009), while status facilitates access to resources for the individual and their kin (Adler et al., 1994; von Rueden et al., 2011; von Rueden & Jaeggi, 2016; Zhang & Santtila, 2022). Money also acts as a modern proxy for resources, with greater economic resources positively predicting higher quality of life, better health, and higher offspring survival (Huber et al., 2010; Nutakor et al., 2023; van Bodegom et al., 2013; Wang & Geng, 2019).

Depending on the context and goal of competition, women employ a variety of strategies to secure and retain vital resources. For instance, women frequently employ indirect and covert forms of competition, such as social exclusion, gossip, or alliance-building (Krems et al., 2023). These strategies can be highly effective at undermining rivals while maintaining social harmony and avoiding backlash directed at overtly competitive women (Rudman et al., 2012; Rudman & Glick, 2001; Williams & Tiedens, 2016). Alternatively, women can enhance their appearance or engage in self-promotion to appear more desirable and competent. Below I further outline the value of these three resources and some strategies women use to acquire them. Notably, these overviews are brief summaries of the work detailed in Chapters 2-5 and do not reflect the full spectrum of strategies women can use to compete.

Competition for mates

Mating competition manifests in the *selection*, *attraction*, and *guarding* of potential or current romantic partners. Mating competition is necessary for individuals to extend their genetic lineage and drives a range of behaviors related to the acquisition of desirable partners. High quality mates typically possess traits that are likely to contribute to successful reproduction and survival of offspring (Buss & Schmitt, 1993, 2019). For instance, physical health and fitness are important indicators, as they signal an individual's ability to withstand environmental pressures and provide for potential offspring (Byers & Waits, 2006; Gangestad et al., 2007). Other physical characteristics, such as attractiveness, are used as a proxy for good health and genetics (Foo et al., 2017; Lewis et al., 2022; Shackelford & Larsen, 1999), though it remains unclear whether attractiveness is truly associated with better offspring outcomes (Achorn & Rosenthal, 2020).

The benefits of acquiring a high-quality mate extend beyond genetic benefits for future offspring, with quality mates playing a crucial role in the provision of resources and formation of enduring social networks. This is particularly true for women, where ecological and cultural characteristics (e.g., dominance of men in hunting and agricultural food production, patrilineal wealth distributions) have constrained women’s direct access to resources (Prall & Scelza, 2024; Reynolds, 2022). Men with high mate value typically possess greater resources, social influence, and physical capabilities (Fales et al., 2016; Hughes & Gallup Jr., 2003; Marlowe, 2004; Sell et al., 2017), providing protection against various threats, including physical dangers, social conflicts, and economic hardships (Buss & Schmitt, 2019; Krems et al., 2023). These benefits also extend into family units and provide an optimal environment for child-rearing (Geary, 2000).

Self-promotion and *competitor derogation* emerge as two prominent strategies for women's mating competition (Fisher et al., 2009; Schmitt & Buss, 1996). Self-promotion involves women actively highlighting their own desirable attributes to enhance their desirability to potential mates (Schmitt & Buss, 1996). While individual preferences vary greatly, men generally place a higher emphasis on physical attractiveness compared to women (Buss & Schmitt, 2019; Walter et al., 2020; Whyte et al., 2021). Appearance enhancement, which involves improving or modifying physical attributes, is thus frequently identified as a key competitive strategy among women (Arnocky & Vaillancourt, 2017; Cashdan, 1996; Davis & Arnocky, 2022). Self-promotion can also be achieved by highlighting personal skills, achievements, and abilities, or by demonstrating desirable personality traits like kindness and intelligence (Fisher & Krems, 2022; Krems et al., 2023).

In contrast to self-promotion, competitor derogation focuses on diminishing the perceived value of mating rivals (Buss & Schmitt, 1993; Fisher et al., 2009). This strategy may involve criticizing competitors' appearance or behavior, spreading negative information about them, downplaying their achievements, and engaging in social exclusion (Krems et al., 2023). The goal of competitor derogation is to make rivals appear less desirable to potential mates, thereby improving one's own relative standing (Fisher et al., 2009; Schmitt & Buss, 1996). Women may employ self-promotion or competitor derogation strategies simultaneously or independently, depending on the specific context, prevailing cultural norms, and individual preferences.

Competition for status

The desire to acquire and maintain status is considered a fundamental human social motive (Anderson et al., 2015). Competition for status can be found in any setting with hierarchies, such as families, romantic relationships, friendships, workplaces, and intergroup interactions (Fülöp & Orosz, 2015). By establishing clear lines of authority, hierarchies enable efficient decision-making, distribution of resources, and can help maintain stability among diverse communities (Sapolsky, 2004; van Vugt, 2006). For the individual, status seeking is likely motivated by the implicit understanding that high status individuals often possess greater access to resources, mates, and influence (von Rueden et al., 2011). Such resources and influence can translate into tangible benefits, such as improved health, greater educational and career outcomes, and a range of psychological benefits (e.g., improved well-being, reduced mental illness; Adler et al., 1994; Anderson et al., 2012; Finegan et al., 2018; Prall & Scelza, 2024; Zhang & Santtila, 2022).

Some scholars argue that *prestige* and *dominance* represent two distinct but interrelated strategies individuals use to achieve social standing (Cheng et al., 2010, 2013; cf. Anderson et al., 2015). The prestige pathway is founded in the recognition of an individual's expertise, competence, and contributions to the group (Henrich & Gil-White, 2001). Those who acquire status through prestige are viewed positively and are valued for their skills and achievements, leading to voluntary deference from others (Henrich & Gil-White, 2001; Jiménez & Mesoudi, 2019). In contrast, status acquired through dominance is achieved by demonstrating physical strength, aggression, and the capacity to punish or reward others (Cheng & Tracy, 2014). Since dominance is typically imposed through fear or coercion, dominance-based status may also lead to resentment or resistance from low status individuals (Cheng, 2020; Maner, 2017).

Competition for money

Competition for financial resources is fundamental to individual and group dynamics within modern socioeconomic systems. In economic and sociological contexts, money manifests in two primary forms: income and wealth (Bourquin et al., 2024). Income refers to the flow of financial resources an individual or household receives, typically derived from wages, salaries, investments, or government transfers. Wealth, conversely, encompasses the total stock of assets minus liabilities that an individual or household possesses at a given point in time, including tangible (e.g., real estate, personal property) and financial assets (e.g., stocks, bonds, savings). A high degree of wealth can buffer against financial shocks and offer opportunities for long-term investments in education, entrepreneurship, and other wealth-building activities (Keister & Moller, 2000). While interconnected, income and wealth represent distinct aspects of financial resources that can be used to obtain or maximize survival and reproductive opportunities (Buss, 2015; Hill & Buss, 2010).

In modern societies, the acquisition and accumulation of wealth is associated with benefits that extend beyond immediate reproductive and survival goals. For example, initial access to financial resources can influence educational attainment, with higher-income families able to invest more in educational resources, private tutoring, and extracurricular activities that enhance cognitive development and academic performance (Duncan & Murnane, 2011). The ability to afford higher education, particularly at prestigious institutions, often translates into increased social capital and improved career prospects, perpetuating intergenerational cycles of wealth and status (Behrman & Taubman, 1976; Yang & Qiu, 2016). In employment settings, wealth can provide individuals with the means to pursue unpaid internships, relocate for job opportunities, or invest in additional training and certifications, all of which can lead to more lucrative career paths (Morrison, 2022; Swan, 2015; Sykes & Maroto, 2016).

People employ various strategies to acquire income and wealth. In real world settings, many focus on education and skill development to increase their earning potential through high-paying careers. Others concentrate on investing, whether in stocks, real estate, or other assets, to grow their wealth over time. In research settings, financial decision-making is often measured using various economic games that simulate real-world scenarios in controlled environments (Baumert et al., 2014; Thielmann et al., 2021). These games often involve participants making choices about allocating money or resources under different conditions. Researchers analyze participants' choices in these games to gauge risk tolerance, fairness preferences, strategic thinking, and other aspects of financial decision-making. By comparing financial outcomes across different demographics or experimental conditions, researchers can draw insights into how various factors affect financial behavior and decision-making processes (Battigalli & Dufwenberg, 2009; Frydman & Camerer, 2016).

Summary of competition

In the section above I have defined how the term competition is used in this thesis, provided an overview of the resources women traditionally compete for, and previewed some strategies women use to obtain those resources. Above I have presented each resource and associated strategies as distinct categories, though in real world interactions these are deeply interconnected. For example, access to financial resources may enhance mating competition through elevated status. To avoid duplication, Chapters 2-5 provide a more detailed and nuanced analyses of women's competitive motivations and strategies. I now turn to life history theory to provide a theoretical framework connecting principles of evolution to human traits and behaviors. Specifically, I consider how social and ecological pressures may have produced biological systems (namely, the endocrine system) that are unique to humans. The following section also lays the theoretical foundations for why I expect hormones to influence behavior in modern human populations.

Life-History Theory

Core theoretical principles

Originally known as life-history evolution (Nettle & Frankenhuis, 2019), life history theory attempts to explain between-species variation in patterns of growth, development, and reproductive strategies (Stearns, 1989). Life history theory proposes that organisms face trade-offs in allocating key resources – particularly energy and time – to competing needs. Energy and time invested in one area cannot be used for another, leading to non-conscious strategic decisions that shape an organism's life course. Proposed trade-offs are thought to be influenced by environmental factors, including resource availability, predation risk, and environmental predictability (Roff, 2002; Stearns, 1989). Notably, however, life history theory argues that there is not one optimal strategy that maximizes all aspects of fitness simultaneously, but rather a set of trade-offs that are shaped by an organism's evolutionary history and current environment.

Developmental trajectories, reproductive strategies, and parental investment across species can be examined through the life history framework (Roff, 2002). For example, in some species traits that benefit early survival are selected (e.g., precocial species, where young are relatively mature at birth), while in others, traits that are advantageous in later life are selected (e.g., larger size, enhanced fighting ability, greater energy storage for prolonged breeding seasons; Stearns, 1989). Similarly, organisms must decide whether to allocate energy toward acquiring new mates or caring for existing offspring, producing many versus few offspring, or investing in current versus future reproductive efforts (Fromhage et al., 2007; Trivers, 1972; Wade, 1979). This last point is particularly evident in females and long-lived species, where individuals might reduce current reproductive output to ensure survival and breeding opportunities in the future (Archie et al., 2014; Griesser et al., 2017). Although higher parental investment typically reduces offspring mortality (Morris, 1985, 1987), reproductive and parental investment vary considerably across different ecologies (Kokko & Jennions, 2008; McGinley et al., 1987).

Foundational life history research used mathematical modelling to argue that clusters of traits were common across species, and that these clusters were influenced by the competitiveness of the environment (MacArthur & Wilson, 1967; Pianka, 1970). For example, species which produce many offspring also tend to mature quickly, develop early independence, and exhibit less parental investment (known as the *r*-strategy). The r-strategy is thought to be more successful in environments that are unpredictable, where the ability to reproduce quickly and in large numbers is advantageous because it maximizes the chances that at least some offspring will survive. In contrast, species who invest heavily in each reproductive effort are also more likely to be long-lived and relatively larger than other animals (known as the *K*-strategy). The K-strategy is thought to benefit organisms in highly competitive environments, where resources are limited but stable. Here, it is advantageous to invest heavily in fewer offspring but enhance their survival and competitive abilities (Pianka, 1970).

Over time, the simplicity of the *r/K* framework led to its decline as it failed to account for the complexity of species variation and models of selection were not well supported by empirical data (Nettle & Frankenhuis, 2020). Ecologists began moving away from generalized system-level models and started tailoring models to specific organisms and traits (Sear, 2020). However, recent biological research, including studies on humans and other species, suggests that some physiological traits and behaviors cluster together (Dammhahn et al., 2018; Réale et al., 2010). This work provides renewed support for the idea that specific characteristics may have evolved together, including physiological traits (e.g., metabolic rate) and behaviors (e.g., aggression, sociability, and risk-taking).

Life history theory in psychological research

Despite emerging from the same empirical concepts, the meaning and use of ‘life history theory’ varies between biological and psychological disciplines (Nettle & Frankenhuis, 2019, 2020; Sear, 2020). For instance, Nettle & Frankenhuis (2019) report that when psychology began utilizing life history theory to understand psychological constructs, foundational biology research was cited equally in publications from both disciplines. However, post-2010, psychological life-history research has become increasingly distinct from its biological roots and has become almost singularly focused on individual differences in developmental speed (i.e., the fast-slow continuum; Kaplan & Gangestad, 2015; Oli, 2004). Given that this thesis is situated within the field of psychological sciences, I briefly outline differences between the two literatures and explain how life history theory is applied to the current thesis.

A key difference between biological and psychological life history researchers is whether they investigate how different environments can lead to variation *between*- or *within*-species, respectively. Biologists believe that ecosystem variation produces between-*species* variation, leading to complex configurations of life history traits and characteristics across species (Stearns, 1989). Psychologists in this field view life history theory as a framework explaining individual differences among humans, and researchers examine how variation in the environment (particularly during development) produces between-*person* differences (Del Giudice, 2020; Nettle & Frankenhuis, 2019). In addition to maturation and reproductive trade-offs, this psychological research examines whether early life experiences alter psychosocial outcomes, including risk taking, pro-sociality, delay discounting, and religiosity (Ellis et al., 2009).

Although I am interested in psychological outcomes, this thesis does not adopt a psychological life history perspective. There are numerous issues with the psychological life history perspective, not least that life history was never conceived as a within-species theory of behavior (Sear, 2020). Life history theory was originally developed to explain how species adapt to their environment through evolution (Stearns, 1989). This is fundamentally different to how psychologists use the theory to explain developmental plasticity, or individual adaptation to the environment (Zietsch & Sidari, 2020). Although covariation may be observed between developmental environments and behavior related to reproduction in humans, these observations do not reflect genetic covariance in growth, reproduction, and lifespan outcomes, as would be predicted by life history theory (Dinh & Gangestad, 2024; Zietsch & Sidari, 2020). Further, empirical support for the psychological perspective is limited, with inter-individual trait covariation failing to satisfy theoretical principles of life history theory, such as gene-trait associations or the alignment of traits along a fast-slow continuum in humans (Copping et al., 2014; Richardson et al., 2017).

Consistent with the biological perspective, I am interested in species level adaptation and the underlying physiological mechanisms; namely, proposed trade-offs between periods of high and low competitiveness that may be mediated by the endocrine system and change across the menstrual cycle. Therefore, in this thesis, naturally cycling participants are observed as a homogenous sample so that it is possible to observe trade-offs in large, cross-cultural samples. Hormonal contraceptive users are then included as a comparison group to test assumptions about the impact of disrupting these evolved hormonal mechanisms. In the following section I review the functional significance of the endocrine system and outline why hormonal messaging is expected to influence competitive motivation and behavior.

Hormonal communication and function

Structure and function of the endocrine system

The endocrine system is a complex network of glands and organs that produce, store, and secrete hormones (Neal, 2016). Hormones are biochemical messengers that regulate physiological processes and help maintain homeostasis (Hiller-Sturmhöfel & Bartke, 1998). There are many types of hormones produced within the endocrine glands, including the hypothalamus, pituitary and adrenal glands, and gonads (ovaries and testes). The endocrine glands release hormones directly into the bloodstream, allowing them to travel to target tissues and organs throughout the body. Hormonal messages are then received by binding to receptors on target cells, triggering a cascade of cellular events that lead to the desired physiological response (Hiller-Sturmhöfel & Bartke, 1998).

The main function of hormones cannot be easily distilled because hormones facilitate a broad spectrum of biological activities within each hormone axis. For example, hormones regulate growth and development via signaling pathways that influence gene expression and cellular activity (Marino et al., 2006; Rasier et al., 2006). Hormones are also crucial in maintaining homeostasis by modulating metabolic processes, fluid balance, and cardiovascular function (Clerico et al., 2006; Murphy & Bloom, 2006). In reproductive processes, they control the maturation and function of reproductive organs, the production of gametes, and continuation of healthy gestation (Rosner et al., 2024; Weinbauer & Nieschlag, 1996). In order to regulate these specific functions, the hypothalamus and pituitary glands use feedback mechanisms to communicate with peripheral endocrine glands – such as the adrenal glands (HPA-axis), thyroid (HPT-axis), and gonads (HPG-axis) – that release hormones in a coordinated and concurrent manner.

The coordination of each hormonal axis relies heavily on positive and negative feedback mechanisms that maintain tight control over total hormone levels in the body. Although positive feedback mechanisms do exist, the most prevalent mechanism is the negative feedback loop (Melmed et al., 2015). When hormone levels reach a certain threshold, the hypothalamus and pituitary glands reduce or cease their hormone production, thus inhibiting further production of that hormone sequence. The delicate balance between positive and negative feedback ensures that physiological processes remain within the narrow limits that support optimal human function. Disruption of these feedback loops, through physiological malfunction (e.g., hyperthyroidism, diabetes) or synthetic hormone use (e.g., hormone replacement therapy, steroid use), can result in dysregulation of the endocrine system and associated physiology (Wass & Stewart, 2011).

Crucially, single hormones (or hormone axes) can affect multiple physiological systems (Duarte-Guterman et al., 2014; Gonçalves & De Felice, 2021). Communication across endocrine axes is thought to reflect single hormone interactions with multiple receptor subtypes distributed around the brain and body. For example, estrogen affects multiple physiological systems because it can interact with different types of receptors, specifically ERα and ERβ (Ng et al., 2014). These receptors are distributed in various tissues, such as the gonads, mammary glands, bone, and prostate, and they play distinct roles depending on their location. When estrogen binds to these receptors, it can activate different signaling pathways and recruit various co-regulator proteins, leading to a wide range of biological responses (Ng et al., 2014). The interdependent nature of hormone signaling therefore means that disruption to one part of the system can lead to unintended disruption in other systems.

The purpose of providing such a detailed overview of the functional structure of the endocrine system is to provide strong mechanistic support for why I expect hormonal contraceptives to influence processes beyond the reproductive system. Although hormonal contraceptives were largely developed to prevent pregnancy and other cycle-related effects (e.g., painful or heavy periods; Grandi et al., 2019; Uhm & Perriera, 2014), the synthetic hormones administered in hormonal contraceptives inevitably interact with other hormone axes and physiological systems. For example, research has shown that combined oral contraceptives are associated with changes to the HPA- and HPT-axes (Garcia & Rech, 2015; Hertel et al., 2017; Roche et al., 2013). The diverse collection of side effects potentially caused by hormonal contraceptives (e.g., cardiovascular risk, headaches, and weight gain; Cooper & Patel, 2024) is further evidence that synthetic hormones influence functions outside of the reproductive axis. It is for this reason that artificially altering sophisticated hormone communication systems can lead to the disruption of seemingly unrelated processes.

The menstrual cycle and hormonal contraceptives

The menstrual cycle

The menstrual cycle is a cyclic, hormone-driven process which regulates reproductive function and fertility. The human menstrual cycle typically occurs every 28 days, though cycles lasting between 21-35 day are common (Thiyagarajan et al., 2023). The menstrual cycle also consists of two primary phases: the follicular and the luteal phases (Owen, 1975). The follicular phase begins on the first day of menstruation and lasts approximately 14 days. This phase ends with ovulation, when a dominant follicle ruptures and releases an egg into a fallopian tube. The luteal phase, also lasting approximately 14 days, begins after ovulation. The ruptured follicle transforms into the corpus luteum, which produces estradiol and progesterone until the tissue breaks down and is reabsorbed into the body. Progesterone causes the uterine lining to thicken in preparation for potential implantation. If pregnancy does not occur, levels of estradiol and progesterone decline rapidly, triggering menstruation and the start of a new cycle (Hampson, 2020).

A series of positive and negative feedback loops govern hormone levels across the cycle. In the lead-up to ovulation, a negative feedback loop operates within the HPG-axis to regulate hormone levels (Barbieri, 2014). The hypothalamus secretes gonadotropin-releasing hormone (GnRH), which stimulates the pituitary gland to release follicle-stimulating hormone (FSH) and luteinizing hormone (LH). FSH promotes the growth of ovarian follicles, and these follicles produce estrogen. As estrogen levels rise, they initially exert negative feedback on the hypothalamus and pituitary gland, consequently reducing the release of GnRH and FSH to prevent the overstimulation of follicular development (Barbieri, 2014). Immediately preceding ovulation, high levels of estrogen switch to a positive feedback mechanism, leading to a brief surge in LH. This LH surge triggers ovulation, releasing the mature egg from the ovary. After ovulation, the corpus luteum secretes progesterone, which exerts negative feedback on the hypothalamus and pituitary to lower LH and FSH levels, stabilizing the cycle until the next phase (Owen, 1975).

Hormonal contraceptives

Among reproductive aged women, hormonal contraceptives are one of the most commonly used prescription medications (United Nations, 2019). Designed to prevent pregnancy by altering natural hormone levels, hormonal contraceptives introduce synthetic hormones into the body, such as progestins (synthetic progesterone) and sometimes estradiol. These synthetic versions of naturally occurring estradiol and progesterone artificially create a negative feedback loop in the HPG-axis, suppressing the body's endogenous hormone production signals (Melo & Creinin, 2016). Hormonal contraceptives also thicken cervical mucus and thin the uterine lining, thus reducing sperm mobility and the chances of implantation (Brache et al., 1985; Dinehart et al., 2020; Lewis et al., 2010).

Hormonal contraceptives can vary in several ways, including the type of hormones used, the dosage, and the method of administration (Hampson, 2023). Some hormonal contraceptives contain progestins only (progestin-only contraceptives), while others combine progestins with synthetic estrogen (combined contraceptives). The dosage and hormonal concentrations also differ across products, leading to variation in the efficacy and side effects associated with difference hormonal contraceptives (Genazzani et al., 2023). Methods of delivery also vary, with options including oral pills, transdermal patches, injections, vaginal rings, intrauterine devices (IUDs), and implants (Genazzani et al., 2023).

These variations can influence how often a contraceptive needs to be administered, with some requiring daily use (e.g., oral pills), while others can last for months or years (e.g., injections, implants, IUDs).

Influence of hormones on psychology and behavior

Behavioral endocrinology is the study of how hormones influence behavior, providing insight into the relationship between physiological processes and observed actions (Nelson, 2010). Before modern science discovered specific functioning of the endocrine system, people had an inherent understanding that behavior could be tied to physical structures (Soares et al., 2010). Among farmers and agricultural communities, castration (i.e., removal of male testes to suppress testosterone production) has been used for over 9,000 years to minimize sexual and aggressive behavior in domestic animals (Hess et al., 2024; Vendramini et al., 2020). As science has developed more sophisticated research methodologies, the relationship between hormones and specific outcomes has improved markedly. For example, removing the ovaries of rats leads to alterations in memory, reduced exploratory behavior, and increased anxious behavior (de Chaves et al., 2009; Djiogue et al., 2018; Frick et al., 2018).

One of the fundamental principles of behavioral endocrinology is that hormones do not cause behavior directly; instead, they modulate the likelihood of specific behaviors occurring in response to particular environmental or social cues (Oliveira, 2009; Roney, 2016, 2023). Hormones influence behavior through *organizational* and *activational* effects. Organizational effects refer to the long-term influence of hormones during critical periods of development, such as prenatal or pubertal stages (Romeo, 2003; Schulz et al., 2009). Organizational effects shape the structure and function of the brain, predisposing individuals to certain cognitive patterns and behaviors (Berenbaum & Beltz, 2011). Activational effects are transient and occur when circulating hormones act on the brain to trigger or modulate specific behaviors (Buchanan et al., 1992). Through organizational and activational effects, hormones can affect behavior by altering brain function, influencing the activity of neurotransmitters, or changing the sensitivity of neurons to stimuli (Arnold, 2009; McCarthy et al., 2009; Schulz et al., 2009).

Another core premise of behavioral endocrinology is the recognition of a bidirectional relationship between hormones and behavior (Nelson, 2010; Roney, 2016). Hormone reactivity refers to the way in which hormone levels change in response to specific stimuli or experiences. For example, cortisol often increases in response to acute and chronic stressors (Kiecolt-Glaser et al., 2020; Kirschbaum et al., 1993), leading to variation in cognitive processes (e.g., attention, memory; Ellenbogen et al., 2002; Vedhara et al., 2000) and behavioral outcomes (e.g., affiliative behaviors, social withdrawal; Doane & Adam, 2010; Nitschke et al., 2020; von Dawans et al., 2021). The magnitude and duration of the hormonal response can also vary depending on the individual's psychological state, past experiences, and genetic predispositions (Bunea et al., 2017; Ouellet-Morin et al., 2008; Zorn et al., 2017). Understanding the bidirectional nature of hormonal effects is crucial because it demonstrates how the same hormone can have different effects depending on the social, physiological, and psychological context in which it is activated (Heinrichs et al., 2003; Toufexis et al., 2014).

The final core premise of behavioral endocrinology is the study of adaptive, hormone-mediated trade-offs. In response to changing environmental demands, hormones coordinate shifts in behavior, physiology, and energy allocation (Roney, 2016, 2018). In line with life history theory, hormonal systems theoretically facilitate trade-offs between competing priorities, such as growth, reproduction, and survival, ensuring that resources are directed toward the most critical needs at any given time (Stearns, 1989). For example, in contexts where mating opportunities are high, hormones may promote behaviors that enhance social competition or reproduction, while in times of stress or scarcity, they may prioritize energy conservation and survival strategies (van Anders et al., 2011; Wingfield et al., 1990). This ability to dynamically adjust physiological and behavioral responses emphasizes the role of hormones in optimizing fitness across different environmental conditions.

Effects of hormones on competitive motivation and behavior

Early research investigating the relationship between hormones and competitive behavior focused on testosterone effects in males. The challenge hypothesis posits that testosterone levels rise in male animals in responses to social challenges, particularly during breeding seasons or territorial disputes (Wingfield, 2017; Wingfield et al., 1990). Instead of remaining constantly elevated, testosterone reactivity is considered an adaptive mechanism allowing males to modulate competitive behavior according to the context, thus minimizing the costs while maximizing reproductive success (Archer, 2006). Complementing this, the dual hormone hypothesis proposes that the effects of testosterone on social behavior, particularly status-seeking and dominance, are moderated by cortisol levels (Mehta & Josephs, 2010). This hypothesis suggests that testosterone's influence on status-related behaviors is strongest when cortisol levels are low, and weaker when cortisol levels are high (Mehta & Josephs, 2010; Mehta & Prasad, 2015).

Compared to research in men, the role of testosterone in female competitive behavior has only recently received empirical attention. The challenge hypothesis is supported by studies of non-human females (Rosvall et al., 2020), though the evidence is less consistent among women (Archer, 2006). In support of the dual hormone hypothesis, research indicates that women also experience competition-induced changes in testosterone, an effect which may be moderated by cortisol levels (Casto et al., 2022; Casto & Edwards, 2016b, 2016a). Due to strong socialization pressures (e.g., backlash experienced by competitive women; Rudman & Glick, 2001; Williams & Tiedens, 2016), testosterone effects may be attenuated for women due to the over reliance on androcentric experimental designs (Casto & Prasad, 2017). Further, women are largely underrepresented in competition research compared to men, thus leaving the true extent of testosterone effects largely unknown (Gray et al., 2020).

Beyond testosterone, estradiol has also been implicated in competitive motivation and behavior. The ovulatory competition hypothesis suggests that during ovulation, a woman's drive for positional advantage increases when the potential benefits, such as fertilization, are greater compared to other phases of the cycle (Durante et al., 2014; Nikiforidis et al., 2017). Evidence supporting this theory comes from research showing that women in their fertile phase, compared to non-fertile phases, report higher levels of intrasexual competitiveness, assertiveness, and engagement in mate attraction strategies, such as increased grooming behaviors and a stronger preference for wearing provocative clothing (Batres et al., 2018; Durante et al., 2008; Piccoli et al., 2013; Saad & Stenstrom, 2012).

Other researchers suggest an adaptive trade-off between periods of high and low reproductive motivation, regulated by varying levels of estradiol and progesterone. The motivational shift hypothesis argues that women experience cycle shifts in motivational priorities, moving between reproductive needs during ovulation and other survival needs (e.g., feeding) during the remainder the cycle (Roney & Simmons, 2017). Multiple well-powered studies support the claim that fertility may be linked to an increase in female sexual motivation (Jünger, Kordsmeyer, et al., 2018; Jünger, Motta-Mena, et al., 2018; Stern et al., 2019). Note that although this theory does not make specific predictions about competitive behavior, the relationship between reproductive motivation and competition for mates suggests that research related to this theory may be relevant for research investigating endocrine mediated outcomes related to mating competition.

As support and opposition for these (and other) theories linking ovarian hormones to competitive outcomes are compared and contrasted in great detail in Chapters 2 to 5, I will not spend time reviewing strengths and weaknesses of each theory here. However, to demonstrate the need for the current thesis, it is important to understand two important limitations in this literature. First, although competition research in women continues to grow, the evidence linking ovarian hormones to competitive motivation and behavior remains inconsistent, thus highlighting the need for further high-quality research (Jones et al., 2019; Nikiforidis et al., 2017). Second, research investigating effects of progesterone on competition are extremely limited and thus present an opportunity for initial investigation.

Studying menstrual cycle effects on competition

As described above, research is mixed regarding proposed effects of ovarian hormones on competition. Several reviews in the field suggest that these mixed results are the result of poor research methods and analyses (e.g., Arthur et al., 2022; Gangestad et al., 2019; Jones et al., 2019; Stern et al., 2019). It is therefore important to outline some methods commonly used in the menstrual cycle literature, before I briefly describe the methodological approaches used in this thesis.

Counting methods

One common approach to studying cycle phase effects is the use of self-reported menstrual cycle data to estimate a participant's current cycle day or phase: these methods are called *counting methods*. Studies using these methods require participants to provide details about their cycle, including their most recent menstruation onset date and average cycle length (Blake et al., 2016). Counting methods are popular due to their relatively straightforward implementation and cost-effectiveness, allowing researchers to gather large samples without the need for costly and invasive hormone testing procedures (Arslan et al., 2023). Within the counting methods, researchers must decide between the use of forwards or backwards counting methods, and the use of discrete or continuous phase estimates.

Using counting methods, researchers can adopt forward or backward counting approaches, or a combination of both (Gangestad et al., 2016). The *forward counting method* involves counting forward from the participant's most recent menstrual period onset to estimate subsequent cycle phases. The *backwards counting method* counts backwards from the next menstrual onset, which can be inferred (calculated using the last menstruation and average cycle length) or real (based on actual information about when the participant's next menstruation began). Backwards counting is argued to provide more accurate estimates of fertility because the length of the luteal phase is usually less variable compared to the follicular phase (Baird et al., 1995; Blake et al., 2016; Gildersleeve et al., 2013). In some instances, forward counting may be used to schedule testing sessions, while backwards counting (when available) is used retrospectively to confirm participants cycle phase following participation in a survey or lab study.

Early research investigating menstrual cycle effects typically utilized discrete cycle phase windows to estimate participant fertility (e.g., Penton-Voak et al., 1999; Penton-Voak & Perrett, 2000). For example, the fertile phase may be defined as days 12 to 14, with participants in this window considered fertile, while participants outside of this window may be considered non-fertile or grouped into a different phase. Critically, discrete windows are subject to extensive researcher degrees of freedom (Wood & Carden, 2014), with classifications of the fertile phase varying extensively across studies, including ranges of 3 to 15 days (Harris et al., 2013). Further, this method assumes a rigid, predictable pattern of ovulation and does not easily account for variability in cycle length or ovulation timing across individuals (Gangestad et al., 2016). One strength of discrete cycle phase estimates is that they can be applied to other phases of the cycle (e.g., mid-follicular, premenstrual), though similar estimation limitations apply.

As an alternative to discrete windows, researchers interested in fertility effects can use fertility probability estimates, offering a continuous approach to assessing fertility across the menstrual cycle (Arslan et al., 2021). By matching estimated conception and confirmed menstrual onset dates in a sample of mothers who had recently conceived, Stirnemann et al. (2013) created a continuous measure of fertility probability. Rather than pinpointing a fixed window, this method assigns a probability estimate to each day of the cycle. Proponents of this method argue that continuous estimates are better able to account for individual variation in cycle length and timing of ovulation, providing a more flexible and nuanced estimate of fertility (Arslan et al., 2023; Gangestad et al., 2016). Unlike discrete windows, continuous estimates cannot be applied to other cycle phases and are thus limited to fertility research.

In recent years, the use of continuous fertility estimates have been applied to longitudinal diary designs, tracking outcomes across the full menstrual cycle. In these repeated-measures studies, participants provide daily self-report data about their mood, motivations, and other psychological outcomes (e.g., Arslan et al., 2021; Schleifenbaum et al., 2021). Menstrual cycle data is also collected throughout the cycle, creating a highly reliable measure of menstrual onset dates and cycle length. Longitudinal diary designs present an opportunity for methodologically rigorous tests of cycle phase effects because they utilize the continuous measure of fertility probability (which outperforms discrete measures for both forward and backwards counting methods; Gangestad et al., 2016) in a within-subject setting. The diary design therefore allows researchers to compare high and low fertility days for each participant, reducing the influence of participant level differences.

Direct hormone testing

Another method used to investigate cycle phase effects on behavior involves the direct measurement of hormone concentrations, including estradiol, progesterone, and LH. In psychological research, hormones are typically measured through blood, saliva, or urine assays (Taylor et al., 2015). Single hormone samples can be used to predict outcomes as a standalone measure (e.g., cortisol predicting stress), or to confirm the cycle phase of participants (Becker et al., 2023; Schultheiss & Stanton, 2009). For example, because LH spikes in the 24 hours prior to ovulation, LH tests are used to confirm that participants are in the ovulatory phase (Blake et al., 2016). Similarly, high progesterone concentrations suggest that a participant is in the luteal phase because progesterone should be quiescent during other phases of the cycle (Thiyagarajan et al., 2023). Critically, intra-individual variability in hormone levels means that single measurements may be influenced by circadian (i.e., daily) and pulsatile hormone variation (Bäckström et al., 1982; Taylor et al., 2015).

Hormonal assays can also be used to determine hormone reactivity across multiple timepoints in a single session. Hormonal reactivity refers to changes in hormone levels in response to external stimuli (Neal, 2016). To test theories of reactivity, researchers typically measure baseline hormone levels before taking subsequent samples following exposure to a competitive task, stressor, or some other relevant stimulus (Becker et al., 2023). By comparing pre- and post-task hormone levels, researchers can assess how much a hormone rises or falls in response to the event. Some limitations of direct hormone measurement include high associated costs, necessary access to specialized equipment, and constrained recruitment due to on-site testing requirements. Despite these limitations, because endocrine signaling is expected to facilitate adaptive responses by either up- or down-regulating hormone levels, some hypothesis testing requires researchers to conduct repeated and direct measurement of hormone concentrations (Schultheiss & Stanton, 2009).

Methodological approaches used in this thesis

The current thesis used mixed, interdisciplinary approaches to studying the effects of hormones on competition. In Chapters 3 and 4, I used longitudinal diary designs. Although hormone testing may provide a more precise assessment of menstrual cycle phase compared to self-reports (Schultheiss et al., 2012; Schultheiss & Stanton, 2009; cf. Arslan et al., 2023), the online diary study platform I employed allowed me to collect data across 22 countries. A cross-cultural sample was important for this research because, according to life history theory, adaptive trade-offs should exist at the species level. Therefore, my research methods required a participant sample which is culturally and geographically diverse. The most robust self-report design currently available is the longitudinal diary design, allowing me to track participants competitive motivation (Chapter 3) and behavior (Chapter 4) across the full menstrual cycle. Fertility probability estimates were calculated for all participants, regardless of whether they were naturally cycling or using hormonal contraceptives. Comparing fertility effects between groups allowed me to determine if fertility effects were specific to naturally cycling participants or whether they were detectable in hormonal contraceptive users, thus suggesting that effects were not due to underlying hormonal physiology between groups.

In addition to self-report designs, I also used a lab-based quasi-experimental design in Chapter 5. This study involved physical and cognitively challenging competitive tasks, conducted in-person at research laboratories in Melbourne and Florida, USA. By measuring progesterone and cortisol before and after the tasks, this study allowed me to test hormonal mechanisms thought to underly variation in competitiveness between cycle phases and for hormonal contraceptive users. Chapter 5 presents a novel investigation of the effects of progesterone and cortisol reactivity, thus extending our understanding of hormone change in response to competition. Testing hormonal reactivity is not possible using online studies and thus warranted the high resources required for this work. Chapter 5 also allowed me to provide a mechanistic explanation for why hormonal contraceptives are thought to influence competitiveness among users.

Theoretical contribution, aims and overview of studies

The purpose of my General Introduction (*Chapter 1*) was to provide the reader with a detailed review of key concepts (including theoretical, mechanistic, and methodological) that were foundational to this thesis but were not detailed in my academic publications. A second purpose was to provide sufficient background information to understand why disrupting natural hormone variation may lead to differences in competitiveness between naturally cycling participants and hormonal contraceptive users. I now provide a brief outline of this theory below.

Hormonal contraceptives as disruptors of competitive motivation and behavior

Hormonal contraceptives function by exploiting negative feedback loops within the HPG- axis. The key difference between hormonal contraceptive users and non-users is not total hormone levels but the disruption of the natural cyclical pattern of ovarian hormones and associated reproductive events. Assuming that ovarian hormones are associated with variation in competitive motivation and behavior, then disrupting these patterns with synthetic hormones should also disrupt non-reproductive hormone regulated systems, including those associated with competition. Therefore, I propose that hormonal contraceptives disrupt steroid hormone modulation of socially competitive attitudes and behaviors that are associated with natural hormone fluctuation across the menstrual cycle. To test this theoretical framework, my PhD aimed to:

1. Review and synthesize existing research regarding the effect of ovarian hormones and hormonal contraceptives on competition for key resources, including mates, status and money.
2. Use methodologically robust methods to determine whether naturally cycling women experience variation in competitiveness across the menstrual cycle. This step is necessary because without robust research testing for cycle phase effects on competition in naturally cycling participants, testing for disruptive effects of hormonal contraceptives is essentially moot.

3. To establish the effect of hormonal contraceptive use of competitive outcomes.

Aim 1 is primarily addressed in *Chapter 2* and updated in proceeding literature reviews as new research became available. Aims 2 and 3 are addressed in *Chapters 3, 4 and 5*. My General Discussion (*Chapter 6*) closes with an overview of the findings and considers important practical and theoretical contributions of this research. A brief overview of each chapter is provided below.

Chapter 2: Theoretical Framework and Literature Review

Chapter 2 establishes, in more detail, the theoretical framework for why hormonal contraceptives may disrupt the hormone systems expected to affect socially competitive attitudes and behaviors. Chapter 2 should be considered an extension of my general introduction because it provides rich details of proposed hormone mediated competition that are only briefly reviewed here. This chapter also includes a synthesis of 46 studies ($N = 16{,}290$ participants) testing the effect of hormonal contraceptives on competition for reproductive, social, and financial resources. I outline why competition for each resource category holds evolutionary significance and therefore may be influenced by disruption to evolved hormone signaling. I then synthesize research regarding the effect of hormonal contraceptives on each resource category. This chapter concludes with a discussion of implications and provides a set of best practice recommendations for future studies. Particular emphasis is placed on the need for more robust methodologies that have the potential to enhance our understanding of the interplay between hormonal contraceptives and competitive outcomes.

Chapter 3: Daily Diary Study 1

Chapter 3 aimed to investigate the relationship between fertility and four competitive orientations in naturally cycling women and hormonal contraceptive users. This study utilized the longitudinal diary method, collecting over 3,900 observations from people in 21 countries, to explore how fertility probability impacts four types of self-reported competitive motivations: self-developmental competition, hyper competitiveness, competition avoidance, and lack of interest in competition. Using robust methodological design and analyses, this research sought to address limitations in existing research design in attempt to provide a clearer understanding of whether hormonal variations influence female competitiveness.

Chapter 4: Daily Diary Study 2

Chapter 4 aimed to replicate and extend findings from Chapter 3, using a different sample and additional self-report behavioral measures. The attempted replication aimed to explore the influence of fertility probability and hormonal contraceptive use on self-reported competitive behaviors in naturally cycling women and hormonal contraceptive users. Using a longitudinal online diary approach with over 5,600 daily observations from 302 participants, the study sought to examine whether self-reported competitive motivation increased mid-cycle and how hormonal contraceptive use affected these patterns. Due to a partial replication, Chapter 4 focuses on explaining why replicating menstrual research is difficult and emphasizes the importance of context in hormone-mediated research.

Chapter 5: Lab-based quasi-experimental design

Chapter 5 explores the impact of menstrual cycle phases on women's competitive behavior, focusing on the mid-follicular and mid-luteal phase, in addition to hormonal contraceptive users. Moving away from fertility as the primary predictor, this study sought to determine whether naturally cycling women exhibit higher levels of competitiveness during the mid-follicular phase compared to the mid-luteal phase, or compared to women using hormonal contraceptives. Conducted in a controlled laboratory setting, this research involved detailed observations and measurements of competitive behaviors. This study also included hormonal assays of cortisol and progesterone. Baseline hormone measures and hormonal reactivity were assessed to test the underlying hormonal mechanisms thought to influence competitive outcomes.

Chapter 6: General Discussion

When I commenced my PhD in 2020, the majority of research provided support for the idea that some hormones (e.g., estradiol, testosterone) were positively correlated with higher competitiveness.

However, more recent research suggests that the link between hormones and competition is more tenuous than previously thought. As the reader progresses through each chapter, it is possible to see how my thinking about these topics has been revised and updated with new research. In the General Discussion of my thesis, I summarize key findings from each study, reflect on the current state of the literature, and consider how my research fits within this broader context. Chapter 6 also includes an overview of the practical and theoretical implications of this thesis.

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Chapter 2: Hormonal contraceptives as disruptors of competitive behavior: Theoretical framing and review

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Abstract

Emerging evidence suggests that hormonal contraceptives (HCs) impact psychological outcomes through alterations in neurophysiology. In this review, we first introduce a theoretical framework for HCs as disruptors of steroid hormone modulation of socially competitive attitudes and behaviors. Then, we comprehensively examine prior research comparing HC users and non-users in outcomes related to competition for reproductive, social, and financial resources. Synthesis of 46 studies (n = 16,290) led to several key conclusions: HC users do not show the same menstrual cycle-related fluctuations in self-perceived attractiveness and some intrasexual competition seen in naturally cycling women and, further, may show relatively reduced status- or achievement-oriented competitive motivation. However, there a lack of consistent or compelling evidence that HC users and non-users differ in competitive behavior or attitudes for mates or financial resources. These conclusions are tentative given the notable methodological limitations of the studies reviewed. Implications and recommendations for future research are discussed.

Introduction

Hormonal contraceptives (HCs), designed to prevent pregnancy, are one of the most widely used prescription medications among reproductive age women[2] (United Nations, 2019). Although the specific type, formula, and resulting mechanism of action varies, common to all HCs is endocrine disruption due to the introduction of synthetic ovarian hormones into the bloodstream. Despite the prevalence of HC use worldwide and numerous positive impacts on women's reproductive autonomy, emerging evidence suggests that there may be negative effects of HCs on psychological functioning including altered and potentially maladaptive emotion processing (Lewis et al., 2019; Pahnke et al., 2019; Pletzer & Kerschbaum, 2014). Compared with naturally-cycling[3] (NC) women, HC users may exhibit significant alterations in neurophysiology, affecting both structure and function in numerous areas of the brain associated with cognition and emotion (Sharma et al., 2020; for review, Brønnick et al., 2020; Porcu et al., 2019). Behavioral researchers have also begun to uncover differences in adaptive social behaviors between HC users and NC women. Much of this research has focused on a set of outcomes under the broad category of competitiveness and competition, which are important for women's personal and career-oriented social advancement.

The aims of this review are twofold: 1) to introduce a theoretical framework for understanding HC effects on competitive behavior and 2) to comprehensively examine prior research on the effect of HCs on social-behavioral outcomes related to competition. Not only is competing important for social advancement, but competing for access to limited resources is a fact of life: it is exhibited by all organisms in all ecosystems and drives both evolution and reproductive success (Casto & Mehta, 2019;

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[2] Not all people who use HCs identify as a woman. We use women/woman throughout this manuscript to indicate human persons with a preponderance of female biology that leads to associated menstrual and hormonal cycling.

[3] We use the term "naturally cycling" only to indicate that these individuals are not currently on any form of hormonal contraception. There is likely wide inter-individual variability among NC women in characteristics of the menstrual cycle such as length and regularity, a fact that is not well-accounted for in this area of research.

Cheng et al., 2010; Clutton-Brock & Huchard, 2013; Stockley & Bro-Jørgensen, 2011). Individuals who out-compete their rivals are more likely to survive and successfully produce offspring who will then carry their genes into the next generation. It is only by competing—and competing successfully—that individuals can survive, reproduce, and flourish. Despite the importance of competitive behavior, it can be particularly difficult to properly evoke and measure in the laboratory. Attempts to do so often lack ecologically validity and are male-biased (Casto & Prasad, 2017; Williams & Tiedens, 2016).

Guided by the adaptive significance of competition and the constraints of the extant literature, we focus on research that has tested HC effects on two main categories of competitive behavior: competition for reproductive partners (mate selection, attraction, and retention) and competition for social and financial resources (money and social status). We begin with the theoretical framing for hormonal correlates of competitive behavior followed by a brief overview of how HCs affect hormone levels and patterns of exposure. We then review all available prior studies examining HC effects on competitive behavior separately for the two resource categories. We conclude by synthesizing the prior research, identifying methodological strengths and weaknesses, and highlighting avenues for future directions.

Theoretical background: Hormones and life history tradeoffs

Hormones are chemical signals that have both long- and short-term effects on a broad range of social behaviors. Serving as proximal mechanisms that coordinate total-body and brain systems, hormones activate perceptual and behavioral responses to environmental demands (Adkins-Regan, 2005; Nelson & Kriegsfeld, 2016; Roney, 2016). A life-history account of the endocrine system recognizes that hormones mediate the allocation of limited energetic resources towards particular behavioral endpoints depending on environmental constraints and pressures (Adkins-Regan, 2005; Del Guidice et al., 2016; Roney & Gettler, 2015; Stearns, 1992). Shaped through natural selection, hormonal mechanisms optimize the fitness of an organism through genetically-programmed coordination of developmental transitions (e.g., puberty and the onset of the menstrual cycle) and in flexibly coordinating adaptive responding to the environment (e.g., presence of a potential mate or competitor; Gangestad & Grebe, 2017; Roney, 2016). Steroid hormones such as testosterone, estradiol, and progesterone are physiologically necessary for reproduction to occur, but also drive behavioral investment trade-offs between reproduction and survival priorities. We summarize the hormonal effects on trade-offs in Table 1 and review them in detail below.

Testosterone, mate-seeking, competition, and reproductive success

Testosterone is produced in relatively higher quantity in males than females and is a primary end product of the hypothalamic-pituitary-gonadal (HPG) axis. According to a life-history framework, higher testosterone levels promote mating effort and mate competition at the cost of survival needs (e.g., reduced food motivation, fat storage, immune function, and increased risk of injury; Roney, 2016). Adding to this, a predominant well-supported theory within this framework (the challenge hypothesis; Wingfield et al., 1990; Wingfield et al., 2019) proposes that basal levels of testosterone should increase to a higher set-point during times when mating resources are available (e.g., breeding season in birds), increase further in the presence of a potential mate or territorial challenge, and decrease following successful reproduction. Functionally, increased testosterone promotes dominant and aggressive behavior, mate-seeking, mate attraction displays, and status signaling (i.e., reproductive success) while decreased testosterone aids in parental care of offspring.

The challenge hypothesis has been extended to include a broader set of predictions about testosterone responsivity in the context of human social competition, i.e., contests for status (Archer, 2006; Mazur & Booth, 1998). In this literature, testosterone is thought to predict individual differences in status-seeking and motivation for social power, prestige, and dominance which emerges as an enhanced behavioral tendency towards choosing to compete, adopting leadership roles, social-approach, need for control, and reactive aggression (Carré & Archer, 2018; Casto & Mehta, 2019; Geniole et al., 2020; Knight et al., 2020; Terburg & van Honk, 2013).

The original and extended version of the challenge hypothesis is well-supported in human males (Archer, 2006; Roney & Gettler, 2015). Although there is support for the challenge hypothesis among non-human females (Rosvall et al., 2020), predictions are less well-supported in human females (Archer, 2006; but see Casto & Edwards, 2016; Hahn et al., 2016; van Anders & Goldey, 2010). However, women are subject to heightened socialization pressures which could mask effects in male-biased experimental designs and importantly, women are largely understudied compared to men in this context, leaving the true effects unknown (Casto & Prasad, 2017; Gray et al., 2020).

In accounting for a “masculinity bias” within this literature, van Anders and colleagues (2011; 2013) proposed the *steroid/peptide theory of social bonds* (S/P model) which removes sexuality and mating from the testosterone-mediated behavioral tradeoff matrix. Instead, this theory frames high testosterone as promoting competition more broadly defined as resource acquisition or defense and low testosterone as promoting nurturance defined as warm, loving, and supportive care. Importantly, in the S/P model framework, competition and parental care are not considered opposing behaviors; high testosterone increases competitive behaviors within the context of parenting, such as infant defense, status-oriented play, and authoritarian discipline. Future research is needed to expand and support this model.

Estradiol and progesterone, patterned regulators of mate-seeking, competition, and reproductive success

Also regulated by the HPG axis, estradiol and progesterone are produced in higher quantity by females compared to males, but only according to cyclical patterns (i.e., peaking only at certain points in the menstrual cycle) and intervening physiological events (e.g., pregnancy). Because estradiol and progesterone are tightly coupled with, and in fact drive, the physiological changes necessary for fertility and reproduction in females (for review of menstrual cycle physiology, see Hampson, 2020), these ovarian hormones are also thought to promote behaviors relevant to mate acquisition, pregnancy maintenance, and offspring care (Atkins-Regan, 2005; Bridges, 2015; Roney, 2016; Gangestad & Grebe, 2017). Accordingly, the menstrual cycle can be viewed as a pattern of hormonal mediation of adaptive behavioral strategies to facilitate underlying reproductive biology (the *motivational priority hypothesis*; Roney, 2015; 2018). Consistent with this view, peak estradiol at mid-cycle in the late follicular phase (which is necessary for ovulation) is implicated in the upregulation of sexual motivation, altered preferences for cues of fitness in potential mates, perceived attractiveness and confidence, and intrasexual competitiveness: states and behaviors advantageous for reproductive success (Arslan et al., 2018; Blake et al., 2017; Cobey & Hahn, 2017; Haselton & Gangestad, 2006; Jones et al., 2019; Marcinkowska, 2021; Schleifenbaum et al., 2021; Shirazi et al., 2019 – although not all of this research has been well-replicated). Specific to competition behavior within this literature, the *ovulatory competition hypothesis* (Durante et al., 2014; Nikiforidis et al., 2017) proposes that high estradiol associated with fertility amplifies women’s intrasexual competition for mates.

Compared to the mid-cycle estradiol peak, a broader peak of progesterone (combined with a smaller peak of estradiol) occurs approximately one week following ovulation in the mid-luteal phase and is necessary for facilitating implantation of a fertilized egg. Although research in this area is particularly mixed, higher progesterone is associated with reduced sexual motivation, increased sensitivity to social cues, and prosocial behavior signaling affiliation motivation (Burkart et al., 2014; Lobmaier et al., 2019; Maner & Miller, 2014; Roney & Simmons, 2016; Sellitto & Kalenscher, 2022). Within the framework of hormones as mediators of life-history tradeoffs, high progesterone has been associated with reduced competitive behavior but also decreased investment in one’s own social and financial advancement (Eisenbruch & Roney, 2016; Pearson & Schipper, 2013; for review, Welling & Burris, 2019). At least one study has also found that the shift from estradiol to progesterone dominance is characterized by shifting priorities for mating versus survival resources (Roney & Simmons, 2017). The implication of this finding is consistent with the notion that hormones mediate life history tradeoffs, as increased motivation towards certain priorities reduces the motivation toward others.

In summary, naturally occurring steroid hormones promote adaptive behavior that is sensitive to environmental context and reproductive-stage internal and external cues. The evolved mechanisms that regulate hormone production enhance the fitness of the organism, especially its effectiveness at balancing competing demands for reproduction and survival. Competition for mates and reproductively relevant resources are behaviors that should be regulated by these mechanisms. It is for this reason that we propose that by disrupting naturally occurring hormonal patterns, HCs have the potential to thwart endocrine-mediated behavioral expressions of competitive behavior.

HCs as hormone level and pattern disruptors

Composed of synthetic ovarian hormones, HCs general mechanism of action takes advantage of negative feedback loops in the HPG axis. Synthetic forms of estradiol and progesterone (the synthetic form of which is generally called a “progestin”) suppress ovulation by inhibiting new production signals initiated in the brain (Baird & Glasier, 1993; Frye, 2006; Rivera et al., 1999). Although the specific mechanism varies by HC type (e.g., daily oral pill versus periodic injection) and hormone formula (e.g., chemical composition) as reviewed elsewhere (Hampson, 2020; Melo & Creinin, 2016), HCs significantly deplete endogenous levels of steroid hormones relevant to adaptive behavior (for review, Porcu et al., 2019; see Table 1). However, because HC use involves the introduction of synthetic ovarian hormones to the bloodstream, the primary difference between users and non-users is not necessarily the absolute quantity of ovarian hormones (synthetic or endogenous), but the suppression of the typical cyclical pattern and underlying coordinated reproductive events.

Although a topic of ongoing research, there is little overall current understanding about whether endogenous and synthetic forms of ovarian hormones operate similarly in other, non-direct reproductive axes, brain and body hormone regulatory networks (Giatti et al., 2016; Jayaraman & Pike, 2014; Porcu et al., 2012). Testosterone, estradiol, and progesterone are neuroactive in that they have far-reaching effects on neural activity as well as brain network structure and function (Beltz & Moser, 2020; Porcu et al., 2019; Rupprecht, 2003). Estradiol, progesterone, and their metabolites play a critical role in modulation of receptor action and neural circuit activity involved in processes such as memory, emotion, and reward and are essential for brain health (neurotrophic and neuroprotective), and dysregulation of these networks is implicated in various mental illnesses (Galea et al., 2017; Herrera & Mather, 2015; Sharma et al., 2021). Although there is some evidence, for example, that some progestins do not mimic progesterone's ability to metabolize into anxiolytic-acting allopregnanolone, other research suggests progestin might actually have neuroprotective effects following long-term exposure (Giatti et al., 2016; Pluchino et al., 2006; Porcu et al., 2012).

Although somewhat typical total exposure to estradiol and progesterone-like hormones is still possible with HCs, the majority of HCs dramatically downregulate testosterone (e.g., Louw-du Toit et al., 2017; Pletzer et al., 2015; Sitruk-Ware & Nath, 2013; Zimmerman et al., 2014). Like estradiol and progesterone, testosterone also has wide-spread effects in the brain. It is a potent neuromodulator of brain areas involved in motivation, reward, attention, memory, spatial cognition, and emotion processing, with explicit relation to competitive and status-motivated behavior (Celec et al., 2015; Radke et al., 2015; Vermeer et al., 2016; Volman et al., 2011; Votinov et al., 2020). In summary, HCs alter typical steroid hormone levels and patterns of fluctuation. These same hormones are implicated in not only brain function, but also in a range of adaptive behaviors of particular relevance to competition.

Table 1

Hormonal Contraceptives as disruptors of Hormonal Mediation of Evolutionary Adaptive Behavior (life-history tradeoffs), a proposed framework.

Hormone (when at relatively high level)	Hormone-mediated behavioral investment trade-offs	How HCs affect endogenous basal hormone levels*	How HCs affect menstrual cycle pattern of exposure	Overall potential HC use adaptive impact (non-reproductive)†

High Testosterone (T)	↑ mate-seeking**; sexual motivation; competitive (status -oriented) behavior ↓care-based social affiliation, bonding and nurturance	↓ Basal T levels are substantially reduced Oral contraceptive pill use decreases serum total and free testosterone by an average of 31% and 61%, respectively[1]	T levels do not systematically fluctuate across the menstrual cycle (debated) – thus, no significant pattern to disrupt. Possible seasonality effect of T, an effect that is flattened in HC users[2]	<u>Costs of HC use:</u> Reduced competitive, status-seeking behavior; altered ability of season or life-history stage to influence behavior <u>Benefits of HC use:</u> Greater social empathy and relationship maintenance
High Estradiol (E)	↑ sexual motivation; self-perceived attractiveness and confidence; intrasexual competitiveness ↓ investment in other resources, such as food seeking/intake	↓ May*** reduce overall endogenous basal E levels ↑ Exogenous basal E levels are heightened overall (if formula contains synthetic E)	Mid cycle peak in endogenous E may still occur for some formulas, but is likely lower in amplitude. Broad mid-luteal peak in E is eliminated or reduced	<u>Costs of HC use:</u> Flattened “peaks” of highest sexual and competitive motivation <u>Benefits of HC use:</u> Reduced intrasexual competition and aggression, and reduced associated risks to safety
High Progesterone (P)	↑ Sensitivity to social cues (emotion detection in others); prosocial-affiliative behavior; food seeking/intake ↓ sexual motivation; competitive (status-oriented) behavior; physically risky behavior	↓ Endogenous basal P levels are significantly reduced overall ↑ Synthetic basal P levels are significantly elevated overall (in total exposure)	Fairly steady-state (with small daily peaks and troughs) heightened synthetic P for three weeks or more.	<u>Costs of HC use:</u> Reduced competitive behavior; heightened social vigilance; risk-avoidance that prevents taking opportunities <u>Benefits of HC use:</u> Greater social empathy and relationship maintenance; reduced physically risky or energetically expensive behavior

Notes 1. *Refers to the most common hormonal contraceptive forms, but the effect on specific endogenous hormone levels may depend on the type of synthetic hormone formula.

**Primarily in the context of sexual maturity and life stages marked by a lack of committed relationships or children. There is debate about the extent to which this applies to females.

***How estradiol levels are affected by common HCs is not fully understood; although some studies show reduced blood levels (for review, Porcu et al., 2019), other studies show only the luteal peak is suppressed (Taylor et al, 2020). In saliva, some studies have shown no differences between HC users and NC women (Sharma et al., 2020).

Notes 2. † The focus of this column is on “non-reproductive” behaviors. However, it is important to mention that there is a separate, albeit controversial, literature on the relationship between HCs and sexual functioning (including libido), which could influence social and competitive behavior particularly in reference to mate attraction and retention. Meta-analytic reports and reviews have drawn mixed conclusions – e.g., equal proportion of users reporting negative, positive, and neutral effects of sexual motivation and functioning – (e.g., Boozalis et al., 2016; Casado-Espada et al., 2019; Casey et al., 2017; Guo et al., 2021) suggesting that effects depend on other individual differences and the specific hormone formula.

[1] Zimmerman et al., 2014; [2] Stanton et al., 2011

Overview of Methods

The research reviewed on the topic of HCs and competition were identified using online databases, forward citation searches and author knowledge of research. We conducted online searches in PsycInfo and Web of Science databases and a manual search for relevant studies. Data were systematically extracted by two independent researchers. Full search details are available in the supplementary materials or on the Open Science Framework (https://osf.io/s3jf8/). Descriptive characteristics of the reviewed studies are included in Figure 1. A slight majority of the prior research focused on competition for mating resources compared to competition for financial and status resources. A greater majority of studies only tested *oral* contraceptive use as the method of HCs; thus, the conclusions of this review are mostly limited to implications to this form of HC. Finally, a vast majority of prior studies used a between-subjects design, only testing group differences between self-selected HC users and NC women.

In each section we provide a brief theoretical background, summary table and a synthesis of how HCs might disrupt behavior related to competition for reproductive partners and competition for financial and social resources. Throughout this manuscript we use language that could imply causality (e.g., effects) to describe patterns regarding HCs and competitive outcomes. However, the majority of studies reviewed (n = 45) are quasi-experimental or correlational and therefore causal relationships are not known. Where possible, we extracted standardized effect sizes directly from the original publications or manually calculated them using descriptive statistics extracted from the original publication. In studies with multiple model specifications and robustness checks, we report only the first test of HCs and the relevant competitive outcome. In some instances (33% of key findings), effect sizes are missing due to indirect statistical comparisons or insufficient data for an effect size to be estimated.

The studies reviewed relied on a daunting variety of tasks and ways of operationalizing what we broadly organize under the umbrella of competitive behavior, often employing indirect, unvalidated, and imperfect laboratory or survey-based-response proxies. Where possible, we acknowledge the issue of conceptual ambiguity and operationalization, as well as discuss considerations for generalizability within each section. Due to similarity in the methodological concerns across each thematic area of literature, we also discuss these overall considerations and resulting recommendations collectively at the end.

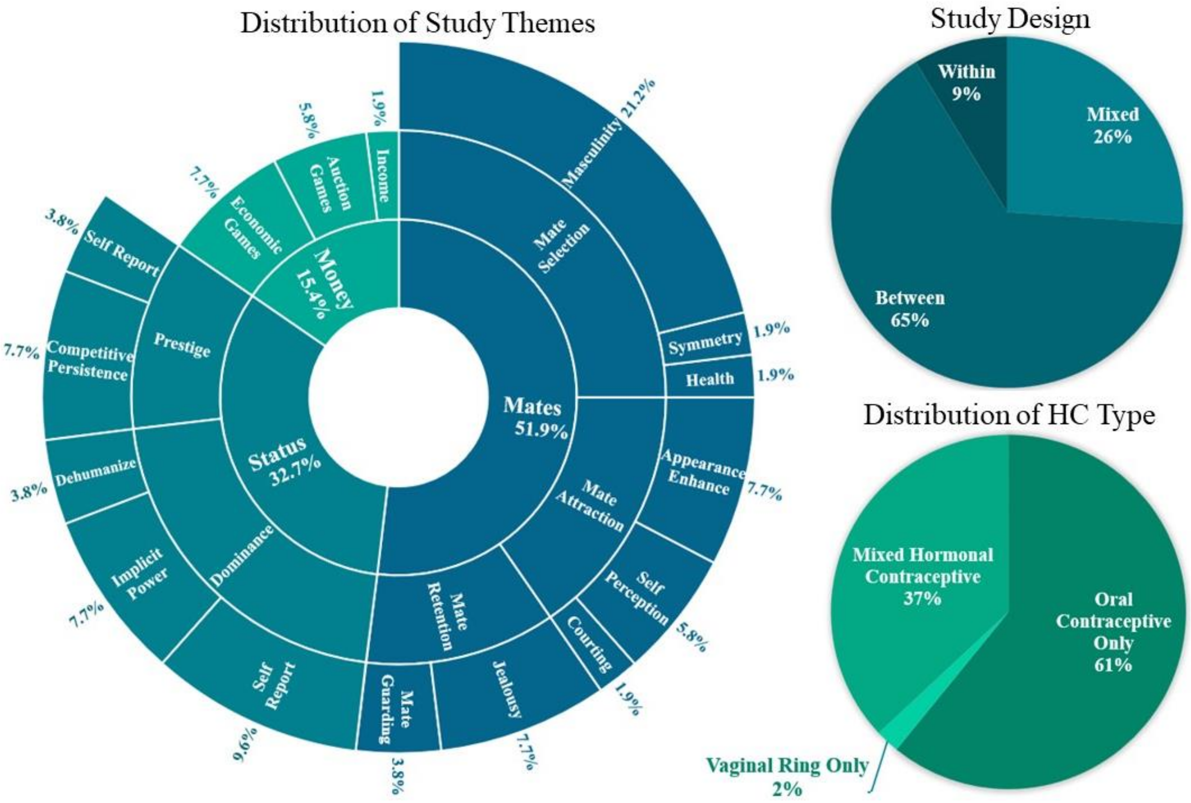


Fig. 1. Descriptive characteristics of reviewed studies. Sunburst chart (left) indicates the proportion of studies included in each section of the review. The inner circle represents broad section categories, middle circle includes sub-themes and outer circle represents specific outcome measures. Pie charts indicate the proportion of studies with different HC types (top right) and study design (bottom right).

Competition for Mating Resources

Prior theory on the endocrine-related mating psychology of women is premised on the notion that hormonal shifts associated with the menstrual cycle impact women's competition for high-quality mates (Cobey & Hahn, 2017; Welling & Burris, 2018). These behaviors are believed to be associated with hormones due to the pubertal onset of patterned ovarian hormone changes and associated increases in sexual behavior, fertility, and secondary sexual characteristics (Balzer et al., 2019; Berenbaum & Beltz, 2011; Forbes & Dahl, 2010; Sisk, 2016). As reviewed above, estradiol mediated fertility is connected with a motivational shift towards attracting or retaining mates, engaging in sex, and intrasexual competition. These motives are primarily implicit: like many hormone-behavior relationships, ovarian hormones alter the probability of behavior through complex, non-conscious neural mechanisms that are subject to environmental constraints (Bernstein et al., 1983; Etgen et al., 1999; e.g., Köllner et al., 2018; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007; Terberg et al., 2012).

Particularly for modern times, evolved mating behaviors have the potential to promote broader indirect benefits for women by helping them achieve social status and financial resources (Blake, 2022; Blake & Brooks, 2019). Thus, mate competition may serve as the basis for, or at least indirectly benefit, individual success in competition more broadly, both financial and social. But there are also costs – the tradeoff being that investing in mate competition can harm social bonds and even physical health and safety (Buunk et al., 2019; Krems et al., 2016, 2021; Vaillancort, 2013). For this reason, many researchers have argued that especially intense mating competition should be limited to the time when benefits outweigh the costs, i.e., the fertile window (the days leading up and during ovulation, tightly coupled with peak estradiol).

In line with predictions from Table 1, HC use could reduce or alter naturally cycling patterns in mating competition, potentially attenuating the moments of greatest sexual and competitive motivation (for review of HCs effects on sexual behavior, see Cobey & Hahn, 2017). Predominant areas of research within the mate competition literature that have tested HC use effects has focused on three subcategories of behaviors: mate selection, attraction, and retention (see Alvergne & Lumma, 2010; Welling, 2013). A review and synthesis of empirical research on each of these areas is detailed below.

Mate Preference

Among non-human animals, female mate selection is driven by a preference for characteristics in males that increase the likelihood of survival and reproduction (for review, Anderson, 1994). This preference may be driven by a desire for direct benefits (e.g., food provided by a partner) and indirect benefits (e.g., genetic materials passed to a female's offspring). Human mate selection follows a similar logic, with both men and women expressing a preference for physically attractive mates and those that possess physical indicators of good health (for review, Gangestad & Thornhill, 2008; Scheib et al., 1999; Whyte et al., 2019). Of course, non-aesthetic factors are also important for human mate selection. Individual traits that signal the capacity for paternal investment (e.g., education, intelligence, trust) are of particular importance for women compared to men (Whyte et al., 2016; 2018; 2019). In any case, mate preferences are the first step in driving competitive behavior: by stratifying characteristics of potential mates based on their value for underlying resource and reproductive needs, preferences identify the targets for competition. Subsequent behaviors of mate attraction and retention are more directly related to social competition with other females for the limited resource of a high-valued mate.

One theory guiding mate selection research in humans is the *ovulatory shift hypothesis*, which argues that women's mate preferences favor masculinity when they are fertile and pro-sociality when they are not fertile (Gangestad & Thornhill, 1998; 2008; Gildersleeve et al., 2014). According to this theory, the mid-cycle fertile window (high estradiol) should be associated with a preference for mates who display relatively higher genetic fitness, but preferences should shift toward characteristics supportive of parenting offspring at other points in the menstrual cycle. Further, when selecting a mate for a long-term relationship, women should place more value in non-physical characteristics, such as whether a mate can provide resources to support her and her offspring. In contrast, the decision calculus for selecting a short-term mate should place less emphasis on resource provision and more emphasis on mates with desirable genes.

Research on the ovulatory shift hypothesis is mixed, with evidence both in support and in conflict with key claims. Demonstrating support for the theory, a meta-analysis by Gildersleeve and colleagues (2014) found that fertility predicted a small but significant preference for cues to genetic quality when women were choosing mates for a short-term partner (Hedge's $g = 0.21$), but not a long-term partner ($g =$

0.06). In contrast, a meta-analysis of similar research papers found that the effect of cycle shifts on mating preferences were only observed in published studies (suggesting a high risk of publication bias), and those that use less precise measures of fertility (Wood et al., 2014). In two critical commentaries, concerns were also raised regarding hidden experimenter degrees of freedom and validity issues with cycle phase estimation (Harris et al., 2014; Wood and Carden, 2014).

Even more recent well-powered non-replications of the ovulatory shift hypothesis (e.g., Arslan et al., 2018; Jünger et al., 2018a) has led to fierce debate in the field (e.g., Gangestad et al., 2019; Jones et al., 2019; Stern et al., 2019). The emergence of new theories (e.g., motivational shift hypothesis; Roney & Simmons, 2017) and supporting data (e.g., Jünger et al., 2018a; Jünger et al., 2018b, Stern et al., 2020), suggests that mid-cycle estradiol peak/fertility window is associated with a general heightened sexual motivation, regardless of physical cues of the body, face, or behavior of male targets. Thus, studies of HC use effects on mate preferences are complicated by the fact that menstrual cycle-based shifts in hormone effects on mate preferences are still not well-understood. In any case, the hormonal cocktail in HCs has the potential to disrupt the naturally cycling shifts in mate preferences, for better or worse. Below we review literature pertaining to the effects of HCs on mate preferences and summarize them in Table 2.

Table 2.

Studies on the effects of HC use on mate preferences

Study	N	Design[1]	Comparison Group(s)	Key Outcome Variable[2]	Method[3]	Results	Effect Size
Bobst et al., 2014	62	Between	HC; NC (EF)	Male facial masculinity attractiveness preference	Forced choice	↔ no difference in masculinity preferences for HC vs NC	$d^{\times} = .21$
Cobey et al., 2015a	75	Between	HC; NC	Male facial masculinity attractiveness preference	Forced choice	↑ masculinity preference in HC vs NC	Insufficient data
Feinberg et al., 2008	~419	Between	HC; NC	Male facial and vocal masculinity attractiveness preference	Forced choice	↑ masculinity preferences in NC vs HC users	$d^{\times} = .11$
Gori et al., 2014	195	Between	HC (pseudo phases);	Masculine Characteristics Survey Scale: appearance,	Survey based masculinity ratings	↑ mid-cycle preferences for men who display masculine characteristics in	$\eta_p^{2\checkmark} = .10$ (interaction term of pill use x cycle phase)

			NC (EF, Mid, L)	status, social dominance, creative intelligence)		NC, not observed in HC users	
						↓ masculinity preference score in HC vs NC	$\eta_p^{2\checkmark}$ = .26 (main effect of pill use)
Jones et al., 2005 (Study 5)	2895	Between	HC; NC	Male facial perceived health attractiveness preference	Forced choice with rating of preference strength	↑ preference for healthy appearing faces in HC vs NC	$d^{\times}$ = .10
Jones et al., 2018	538	Mixed	HC (active, inactive); NC	Male facial masculinity attractiveness preference (separate judgements made for short- and long-term contexts)	Forced choice with rating of preference strength	↑ masculinity preference in HC vs NC (effects reported as stronger for short-term mating context)	$d^{\times}$ = .24
						↔ no within-subject difference in women who commenced or ceased HC use between sessions (N = 45)	$\beta^{\checkmark}$ = .08 [CI = -.02; .17]
						↔ no difference between active and placebo pill (N = 175)	Insufficient data
Koehler et al., 2002	56	Between	HC; NC (HF, LF)	Male facial symmetry attractiveness preference (separate judgements made for short- and long-term contexts)	Attractiveness ratings	↔ no difference in ratings of symmetrical faces for HC vs NC	Insufficient data
Little et al., 2002	158	Between	HC; NC	Male facial masculinity attractiveness preference (separate judgements made for short- and long-term contexts)	Digital facial manipulation	↑ preference for masculine faces when selecting mate for short- vs long-term context in NC, not observed in HC	$d^{\times}$ = .34
						↑ preference for masculine faces when NC women were partnered vs single, not observed in HC	$d^{\times}$ = .38
Little et al., 2007	108	Between	HC, NC	Male facial masculinity attractiveness preference (under 4	Forced choice	↔ no difference in overall masculinity preferences for HC vs NC	$d^{\times}$ = .03

				judgement contexts: long-term/harsh, long-term/safe, short-term/harsh, short-term/safe)		↑ preference for masculine faces when selecting mate for short-term context in NC, not observed in HC ↑ preference for masculine faces when selecting mate in conditions of economic stability, not observed in HC	No direct statistical comparison No direct statistical comparison
Little et al., 2013	55	Mixed	HC; NC (F)	Male facial masculinity attractiveness preference (separate judgements made for short- and long-term contexts)	Digital facial manipulation	↓ preference for masculine faces after commencing HC use (no interaction with mating context, short v long-term)	$\eta_p^{2\,\checkmark} = .12$
Marcink-owska et al, 2019	6482	Between	HC; NC	Male facial masculinity attractiveness preference	Forced choice with rating of preference strength	↔ no difference in masculinity preferences for HC vs NC	$d^{\times} = .01$
O'Connor et al., 2014 (Study 2)	66	Between	HC; NC	Male vocal masculinity attractiveness preference (separate judgements made for short- and long-term contexts)	Forced choice	↔ no difference in vocal masculinity preferences for HC vs NC	$\eta_p^{2\,\checkmark} = .01$
Penton-Voak et al., 1999	65	Mixed	HC; NC (HF, LF)	Male facial masculinity attractiveness preference (separate judgements made for short- and long-term contexts)	Forced choice	↑ mid-cycle preference for masculine faces when selecting mate for short-term context in NC, not observed in HC	No direct statistical comparison

Notes: 1 – All facial manipulation studies used repeated measures (i.e., rating multiple faces). We therefore use ‘design’ to describe whether comparisons were independent groups (between-group) or repeated in a group of women while using and not using HCs (within-group or mixed designs). 2 – Facial masculinity preference was calculated in various ways across different studies with some studies, for example, using the proportion of time the more masculine face of a face pair was selected while others summed the total number of times a more masculine face was selected. For ease of interpretation, we refer to preference for masculinity, though images of faces were manipulated on a continuum from masculine to feminine. 3 – Forced-choice experiment, participants are shown a pair/quartet of images and are instructed to select the image that they prefer. Digital facial manipulation, faces can be digitally masculinized (e.g., broad cheekbones, jaw height) or feminized (e.g., brow height, narrow cheekbones) along a spectrum until the participant has their ‘ideal’ face. HC, hormonal contraceptive users; NC, naturally cycling women; F, follicular. EF, early follicular; Mid, mid-cycle; L, luteal; HF, high fertility. LF, low fertility. Notes on Effect Sizes: $d^{\checkmark}$ = Cohen’s *d* provided by original authors. $d^{\times}$ = Cohen’s *d* estimated by review authors. $\eta_p^{2\,\checkmark}$ = Partial eta squared provided by original authors. Insufficient data = No effect size reported and insufficient information provided to calculate effect size for the effect of interest. No direct statistical comparison = Original analysis method involved testing patterns for HC users and NC women separately.

HCs and Mating Preferences

Across studies, the results of HCs of physical preferences are mixed. For research looking specifically at masculinity, two studies indicate that HCs strengthen women's preferences for masculinity in potential mates (Cobey et al., 2015a; Jones et al., 2018), two report no differences in masculinity preferences between HC users and NC women (Bobst et al., 2014; Marcinkowska et al., 2019), three report that HCs weaken women's preferences for physical masculinity (Feinberg et al., 2008; Gori et al., 2014; Little et al., 2013) and three did not directly compare masculinity preferences for HC users in NC women (Little et al., 2002; Little et al., 2007; Penton-Voak et al., 1999). Within the latter group, NC women demonstrated a preference for masculine men when selecting partners in a short-term context which was absent amongst HC users (Little et al., 2002; Little et al., 2007; Penton-Voak et al., 1999). Findings regarding same-sex facial attractiveness preferences are not relevant to mating preferences in the majority heterosexual samples recruited in this literature and thus, are not reviewed here.

Sample size was a limitation for the majority ($n = 8$) of studies investigating the role of HCs on masculinity preferences. Of the three studies adequately powered to detect differences in masculinity preferences between HC users and NC women, results remain mixed: Jones et al. (2018) found a stronger masculinity preference among HC users, Marcinkowska et al. (2019) found no effect of HCs on masculinity preferences, and Feinberg et al. (2008) found a weaker masculinity preference among HC users. Thus, while sample size is an important limitation, it seems unlikely that improvements in sample size alone would provide further clarity regarding the outcome.

In addition to facial masculinity, researchers have examined the effects of HCs on other traits related to genetic quality, such as vocal masculinity, facial symmetry and perceived health. Masculine voices were preferred significantly more often than feminized voices, although there was no effect of HC on preference for masculine voices (Feinberg et al., 2008; O’Conner et al., 2014). One study reported no difference in preferences for facial symmetry (Koehler et al., 2002), and another reports that HC users displayed a stronger preference for faces with greater apparent health (Jones et al., 2005). Overall, the inconsistent results and small (or absent) effect sizes suggest that mate preferences are not easily explained by HC use or by clear hormonal mechanisms. Alternatively, limited ecological relevance of study designs and ways of operationalizing mate choice in the lab has thwarted our ability to detect such relationships. In much of the reviewed research, participants must indicate a mate preference, often “forced choice,” based on remarkably limited and unidimensional information about the target male. It is unclear to what extent these paradigms appropriately mimic the complexity and constraints of mate choice in the natural environment (for discussion, Dougherty, 2020; Roff, 2015).

Mate Attraction and Retention

Following the establishment of mate preferences, women may engage in behaviors designed to attract and retain valued mates. Although there are wide individual differences in what qualities both men (and women) find attractive (for review, Buss & Schmitt, 2019), men’s preference for physical attractiveness tends to be higher relative to women (Walter et al., 2020; Whyte et al., 2021). Physical attractiveness in women is often associated with traits that indicate reproductive health and youthfulness, such as the presence of secondary sex characteristics (e.g., breasts), clear skin and small facial features (Fisher & Voracek, 2006; Jones et al., 1995; Perilloux et al., 2013). Given that men value partners that are physically attractive, women’s intrasexual competition is thought to be focused, at least in part, on enhancing their physical attractiveness (DelPriore et al., 2017; Wang et al., 2021, but see Blake, 2022 and Bradshaw & DelPriore, 2022 for discussion of the function of women’s appearance-enhancement strategies beyond mate competition).

Researchers have also investigated the relationship between hormones and mate attraction strategies. Durante et al. (2008) asked women to draw their ideal outfit for a social party, finding that women drew more revealing outfits on high-fertility days. Similarly, Haselton et al. (2007) found that when NC women were in the high-fertility phase, they attempted to look more attractive than during the low-fertile phase. From an evolutionary perspective, *perceptions* of one's own attractiveness and sexual desirability are also important for calibrating mating decisions. For instance, women who perceive themselves as attractive are more likely to rate themselves as a high-quality mate (Buss & Shackelford, 2008). In turn, these women strive for higher-quality partners and hold more stringent mating standards (Todd et al., 2007). Given the possible link between fertility and mate attraction behaviours, research has recently begun to investigate the role of HCs.

In addition to mate attraction, successfully retaining a mate is a core adaptive problem of any species forming pair-bonds and it has been studied extensively in the evolutionary literature (e.g., Kokko & Morrell, 2005). Men and women compete for mates and invest in offspring, meaning that both sexes have something to guard. In both sexes, mate guarding is triggered by intrasexual rivals of high mate-value and having a partner who shows signs of interest in extra-pair mating (Buss, 2002). HCs effects on mate retention has been studied through two lenses: jealousy and mate guarding. Jealousy is an emotional response that is activated when a valued relationship is threatened by another person (Buunk, 1997). Mate guarding includes any behaviors that minimize other female access to a partner; it can be directed toward one's partner or toward rivals, especially those who are physically attractive (Fink et al., 2014), sexually available (e.g., Vaillancourt & Sharma, 2011), or ovulating (Hurst et al., 2017; Krems et al., 2016). Both jealousy and mate guarding are considered competitive pursuits because they are reactions to the real or imagined threat of losing a valuable partner to a rival. Below we review literature pertaining to the effects of HCs on mate attraction and retention and summarize them in Table 3.

Table 3.

Studies on the effect of HC on Mate Attraction and Retention

Study	N	Design	Comparison Group(s)	Key Outcome Variable	Results	Effect Size

Arslan et al., 2018	1043	Mixed	HC (pseudo fertility probability); NC (continuous fertility probability)	Self-report perceived sexual desirability, clothing choices, jealousy and mate retention	↑ mid-cycle self-perceived desirability in NC women, not observed in HC users	Marginal R^2 = .001 Conditional R^2 = .360
					↔ no difference in clothing choice for HC users or NC women	Marginal R^2 = .003 Conditional R^2 = .391
					↔ no difference in mate retention for HC users or NC women	Marginal R^2 = .001 Conditional R^2 = .456
					↔ no difference in jealousy reported for HC users or NC women	Marginal R^2 <.001 Conditional R^2 = .444
Batres et al., 2018 (Study 1)	36	Between	HC; NC	Self-report make-up use	↓ time spent applying special occasion make-up for HC vs NC	$d^{\checkmark} = .80$*
					↔ no difference in time spent applying daily make-up	$d^{\checkmark} = .51$
Cobey et al., 2011	275	Between	HC only (comparison of estradiol and progestin low vs. ultra-low dose brands)	Self-report jealousy	↑ jealousy in low vs ultra-low synthetic estradiol dose HCs	$d^{\times} = .42$
					↔ no difference in jealousy for low vs ultra-low P dose	$d^{\times} = .20$
Cobey et al., 2012	29	Within	HC; NC (HF, LF)	Self-report jealousy	↑ jealousy in HC vs non-fertile NC, only among partnered women	Insufficient data
					↔ no difference in jealousy for HC vs fertile NC	Insufficient data
Cobey et al., 2013a	14	Within	HC; NC (HF, LF)	Self-report physical attractiveness	↔ no difference in self-perceived attractiveness for HC vs NC	Insufficient data
Geary et al., 2001 (Study 1)	138	Between	NC	Self-reported affective responses to vignettes about partner sexual and emotional infidelity	↑ jealousy, hurt, and anger following imagined emotional infidelity for HC vs NC	$d^{\times} = .41 - .63$
					↑ jealousy, hurt, and anger following imagined sexual infidelity for HC vs NC	$d^{\times} = .46 - .60$
Rosen & Lopez, 2009	21	Between	HC; NC	Performance on a dichotic listening task with courtship vs neutral distractors	↑ number of errors for NC vs HC overall (effect carried by monogamous NC women who were in fertile phase)	$d^{\times} = 1.19$

Schleifen-baum et al., 2021	872	Mixed	HC (pseudo probability); NC (continuous fertility probability)	Self-report grooming, perceived sexual desirability (N = 576) and physical attractiveness	↑ mid-cycle self-perceived desirability in NC women, not observed in HC users	Marginal R^2 = .003 Conditional R^2 = .192
					↑ mid-cycle self-perceived attractiveness in NC women, not observed in HC users	Marginal R^2 = .006 Conditional R^2 = .161
					↔ no main effect of HC use or cycle phase on grooming	Marginal R^2 = .001 Conditional R^2 = .089
Schwarz & Hassebrauck, 2008	59	Mixed	HC (pseudo phases); NC (HF, LF)	Self-report clothing choices, perceived physical attractiveness	↑ provocative dress for fertile NC, no cycle phase effects observed in HC users	No direct statistical comparison
Welling et al., 2012	104	Between	HC (comparison of estradiol and progestin dose); NC	Self-report mate retention (subscales for inter- and intra-sexually directed mate retention behaviors)	↑ use of self-reported mate retention tactics in HC vs NC (but see difference for inter/intra-sexually directed tactics below).	$d^{\checkmark}$ = 52
					↑ inter-sexually directed mate retention tactics in HC vs NC	$d^{\times}$ = .51
					↔ no difference in intra-sexually directed mate retention tactics HC vs NC	$d^{\times}$ = .34
					↑ overall mate retention score in high vs low synthetic estradiol dose HCs (not statistically sig)	$d^{\times}$ = .65
					↔ no difference in overall mate retention score for high vs low synthetic progesterone dose HCs	Insufficient data

Notes: when referring to phases in HC/men, the use of the term ‘pseudo’ indicates that these groups were tested at similar intervals to NC women. Abbreviations: HC, hormonal contraceptive users. NC, naturally cycling women. M, menstrual. EF, early follicular. F, follicular. O, ovulatory. L, luteal. PM, premenstrual. HF, high fertility. LF, low fertility. $^{++}$Association not robust in all models.

Notes on Effect Sizes: $d^{\checkmark}$ = Cohen’s *d* provided by original authors. $D^{\times}$ = Cohen’s *d* estimated by review authors. $H_p^{2\checkmark}$ = Partial eta squared provided by original authors. $B^{\checkmark}$ = Unstandardised regression coefficients reported by original authors. For multilevel models containing HC use as a predictor variable, Marginal R^2 provides variance explained only by fixed effects and conditional R^2 provides the variance explained by both fixed effects and random effects. Insufficient data = No effect size reported and insufficient information provided to calculate effect size for the effect of interest. No direct statistical comparison = Original analysis method involved testing patterns for HC users and NC women separately. MLM effect size omitted = effect sizes in multilevel models vary by model specification and have thus been omitted; we encourage readers to review the original article for detailed results and effect size estimates.

*This effect size corresponds to a t-test analysis in which the degrees of freedom show unexplained missing participants.

HCs and Mate Attraction & Retention

Mate attraction

The relationship between HCs and women's mate attraction strategies is mixed. In support of the hypothesis that HCs disrupt competitive mating behavior, research has shown that HC users spent less time putting on make-up compared to NC women (Batres et al., 2018). Compared to NC women in the fertile phase, HC users were less likely to wear provocative clothing (Schwarz & Hassebrauck, 2008) and reported feeling less sexually desirable and physically attractive (Arslan et al., 2018; Schleifenbaum et al., 2021). However, Arslan et al. (2018) and Schleifenbaum et al. (2021) found no effect of HCs on provocative clothing, and Cobey et al. (2013a) found that HCs didn't influence self-perceived attractiveness. In the only experiment of its kind, Rosen and Lopez (2009) used a dichotic listening task to determine whether HC use or cycle phase influenced attention to courting language; ultimately concluding that HC use did not suppress attention to courting language.

The differences in results may be explained by methodological variability. Two large scale diary studies (between 40 – 70 days) measured beautification and self-perceived attractiveness across the menstrual cycle for HC users and NC women (Arslan et al., 2018; Schleifenbaum et al., 2021). To observe trends across the cycle, fertility was estimated using actuarial data (Stirnemann et al., 2013) and backwards counting from the next menstrual cycle onset date. Using multi-level models, the researchers nested daily measures within individual participants and groups, appropriately capturing heterogeneity within individuals (i.e., change across time), and heterogeneity between the high-order groups (i.e., HC versus NC). Though no differences in beautification were observed between HC users and NC women, both studies observed fertile phase effects in self-perceived attractiveness and sexual desirability for NC women that were attenuated in HC users (Arslan et al., 2018; Schleifenbaum et al., 2021).

In contrast, Schwarz and Hassebrauck (2008) reported no differences in self-perceived attractiveness after aggregating ratings across fertile and non-fertile phases and analyzing differences using mixed analyses of variance. By using this approach, Schwarz and Hassebrauck's (2008) conclusions do not account for within-individual variability in self-perceived attractiveness across the menstrual cycle. Cobey et al. (2013a) did, however, assess within-person changes in self-perceived attractiveness, sampling from the same group of women when they used and ceased using HCs. Although Cobey et al. (2013a) found no change in self-perceived attractiveness after women ceased using HCs, the authors note that the sample size was small (n = 14) and warrants further investigation.

Overall, Arslan et al. (2018) and Schleifenbaum et al. (2021) have provided strong evidence of a mid-cycle increase in self-perceived desirability and attractiveness that is observed in NC women but attenuated in HC users. Their findings are especially convincing as they follow recommendations for conducting replicable research (see Funder et al., 2014) including transparent research practices (i.e., use of preregistration, open-source data and code, sufficiently powered samples sizes and multiple robustness tests). Therefore, current evidence suggests that HC use disrupts naturally-occurring peaks in self-perceived attractiveness, an effect which may systematically alter naturally cycling patterns of mate competition. Research regarding appearance enhancement via make-up and clothing choice is inconclusive and requires further investigation.

Mate retention

Unlike the results for mate attraction, evidence for an effect of HCs on mate retention is relatively consistent. Of the five studies that compared mate retention between HC users and NC women, four report a positive effect of HCs on some form of mate retention and, where reported, effects sizes are fairly moderate. Geary et al. (2001) reported that HC users experienced heightened feelings of hurt, anger and jealousy following an imagined infidelity, Welling et al. (2012) reported a positive effect of HCs on mate retention tactics (driven by higher intersexually directed mate retention tactics in HC users), while Cobey et al. (2012) reported higher jealousy when women were fertile or using HCs compared to when they were in the non-fertile phase. Welling et al. (2012) and Cobey et al. (2011) also found that HCs with higher relative doses of synthetic estradiol were associated with more mate guarding behaviors and self-report jealousy, respectively.

In contrast, Arslan et al. (2018) was the only article to report no main effect of HCs on jealousy or mate guarding behaviors. Although Arslan et al. (2018) reported a large sample size (3x larger than other work), in their own writing the authors note that their mate retention items did not reliably measure within-subject change, nor did they parse different mate retention strategies. As seen in Welling et al. (2012), which also had a higher sample size relative to other studies, separating inter- and intra-sexually directed mate retention tactics revealed that the positive effect of HCs on mate retention was driven by intersexually directed mate retention behaviors specifically. Thus, future research should take care to identify different strategies (e.g., intra- vs intersexual) that may be asymmetrically affected by HC use. Based on the research reviewed, there is generally supporting evidence to argue that HC users display higher jealousy compared to NC women, though more research in mate guarding is required.

Other considerations

One important consideration in the mate retention literature is the fact that HC use is associated with more sexual frequency. In a sample of nearly 900 women, HC use was associated with higher probability of sexual intercourse relative to nonuse, particularly within the first few months of use (Blumenstock & Barber, 2022). Thus, mate retention behaviors such as jealousy and guarding could result from perceptions of greater sexual investment or perceived greater costs of partner loss rather than direct hormonal mediation from HC use. Indeed, one of the studies that reported higher jealousy among HC users compared to NC nonusers (Geary et al., 2001) also reported that HC users were more likely to report a sexual relationship within the prior week and, that the sexual encounter was with a serious partner as opposed to a mere acquaintance or having “just met”. Another consideration for this area of research is the overreliance on self-report measures of jealousy and mate guarding, attitudes and behaviors that are generally considered negative and thus, subject to social desirability. The extent to which hormones and HC use regulate these behaviors within natural contexts (perhaps implicitly) remains unknown.

A second consideration is that across both the mate attraction and retention research, there is an over representation of partnered compared to single women. Arslan et al. (2018), Cobey et al. (2013a; 2013b) and Welling et al. (2012) exclusively recruited women in heterosexual relationships, making it impossible to compare results between single and partnered women. Although Schleifenbaum et al. (2021) did not restrict participation by relationship status, a coding error resulted in the collection of sexual desirability rating from partnered women only. In studies which recruited both HC users and NC women, single HC users were drastically underrepresented. For example, in Batres et al. (2018) the majority of HC users were in a monogamous relationship (85%) while the majority of NC women were single (81%). Similar differences were reported in Geary et al. (2001) and Schwarz and Hassebrauck (2008).

These differences are important because previous research has demonstrated a mediating effect of relationship status on mating relevant behaviours across the menstrual cycle (e.g., Haselton & Gangestad, 2006; Pillsworth et al., 2006). Relationship status also influenced the results covered in this review. For example, in Geary et al.’s (2001) analysis of jealousy, level of relationship commitment was coded as a continuous variable (1 – just met, 5 – spouse/fiancé), with higher commitment correlated with more intense feelings of hurt, anger and jealousy following an imagined infidelity. When relationship commitment was controlled for in the HC vs NC analysis, only differences in hurt remained significant. In their conclusions, Geary et al. (2001) report that patterns of jealousy varied significantly between HC users and NC women, however we caution that in this sample the effect of HCs may be conflated with relationship commitment because women in the HC group were significantly more likely to report that their most recent sexual relationship was in a committed relationship.

Differences in the use of beautification strategies may also differ based on relationship status. Arslan et al. (2018) found that provocative clothing was not influenced by HC use in a sample of heterosexual, partnered women. Contrasting this with a mixed sample of single and partnered women, Schleifenbaum et al. (2021) found that HC use attenuated a fertile phase peak in grooming observed in NC women. On the surface, this may suggest that single women are driving grooming behaviour in NC women. However, Schleifenbaum et al. (2021) found that partnered, fertile, NC women reported a small increase in grooming that was not observed in HC users or single, fertile, NC women. Thus, although relationships status may be an important variable to consider, it does not explain differences in beautification across these two studies. Research that includes both single and partnered women, and directly tests relationship status as a moderator of HC effects on behavior, is warranted.

Competition for Financial and Social Resources

In the contemporary world, entering into and winning a broad set of social and financial competitions provides a host of benefits to women that are only recently evident. The worldwide trend toward gender equity provides a novel environment where women and men can compete on an ostensibly equal playing field for renumeration and social and political power. Achieving gender equity is held as a solution to a range of adversities that disproportionately affect women, such as life-threatening intimate violence, substandard health care, poverty, and human trafficking (Casper et al., 1994; Doyal, 2000; Melander, 2005; Maxwell et al., 2021). Gender equity also leads to greater economic prosperity, greater national and international security and peace, and less child mortality (Bigio & Vogelstein, 2020).

To reach gender equity, women need to have equal opportunity, but also be motivated (and appropriated incentivized) to engage in competition and compete successfully. However, because economic and social resources are inherently limited in supply, and contests for them are often zero-sum, the tradeoff to investment in resource competition is reduced investment in social-bonding, nurturance, and cooperation (Frank, 2007; West et al., 2006; Wilkinson & Pickett, 2017), and risk to personal safety (Benenson, 2013; Campbell, 1999, van den Bos, 2013). Winning in direct contests often means that others lose, and this poses risks to the social relationship between competing parties. Because prior research on hormone-behavior relationships indicates that the hormonal cocktail of HCs should generally reduce competitive behavior (Table 1), HCs might benefit social affiliation and bonding. However, early evidence suggests that HCs could, paradoxically, reduce both competitive and affiliative behavior (Montoya & Bos, 2017; Scheele et al., 2016; Strojny et al., 2022).

Prior theory on endocrine-mediated resource competition in women is limited compared to the literature on mate preference, attraction, and retention. This is partly due to the fact that hormonal fluctuations across the menstrual cycle correspond to reproductive physiology, and therefore the focus is often on reproductive-relevant psychology and behavior. Competition for other economic and social resources could be influenced indirectly through menstrual shifts in mating competition (e.g., Blake et al., 2017; Eisenbrunch & Roney; 2016; Lazzaro et al., 2016; Stanton; 2017). However, there is fairly strong evidence from evolutionary demography research that investment in status competition is in direct conflict with, ‘trades off with’, investment in reproduction in large societies with established economic systems and opportunities for status attainment in women (Shenk et al., 2016). Indeed, contraceptive use is a prime example, taken for the express purpose of preventing reproduction to avoid the costs of parenthood and, delay or reduce overall fertility to, in some cases, advance one’s social and economic position in society.

Alternatively, resource competition could be influenced by endocrine patterns independent of fertility-associated mate competition. For the vast majority of the menstrual cycle, where fertility is low, there are other adaptive behavioral investment tradeoffs that could influence competitive behavior. One key mechanism could be menstrual shifts in levels of progesterone (Table 1; also, Buser, 2012; Schipper, 2015); the cycle consists of distinct phases marked by progesterone quiescence for ~14 of the ~28 days (follicular phase), and progesterone dominance the other half of the time (luteal phase). Therefore, a key comparison group in the literature testing HC effects on resource competition is NC women in their follicular phase: if total progestin/progesterone exposure affects competitive behavior, NC women in their mid-luteal phase should behave similarly to HC users. Of course, these predictions would depend on the assumption that progestin has relatively similar brain and body action as progesterone.

Resource competition may also be influenced by broader patterns of hormone shifts due to developmental stages and ecological context, beyond menstrual physiology. Given the substantial effects of HC use on reducing testosterone levels combined with testosterone's known role in competition for money and status within relevant contexts (e.g., Casto & Edwards, 2016; Casto & Mehta, 2018; Casto et al., 2020; Stanton et al., 2021; Vermeer et al., 2020), this hormone may be of particular relevance to understanding the mechanism for HCs effects on competitive behavior. As an alternative model to progestin/progesterone mediation, a testosterone mediation model would predict that HC users show reduced competitive behavior compared to both luteal and follicular phase naturally-cycling women. High progesterone and low testosterone could also have additive effects in downregulating competitive behavior. Thus, the menstrual cycle phase of the naturally-cycling comparison group, depending on the underlying mechanism, could be particularly important for the emergence of a HC use effect on financial and social resource competition.

Money

To attain limited financial resources, necessary for survival, humans must compete through complex social and economic negotiations. Unlike relative social position, attained through direct status conflict, money values can be divided and distributed between competing parties. Despite the fact that economic resources are relatively modern, as stated by Hill and Buss (2010) "money is the ultimate fungible resource, easily converted into an astonishing variety of resources relevant to reproductive success" (p. 221).

Tasks measuring financial competition often conceptualize decisions as pro-social or anti-social (see Brañas-Garza et al., 2016), suggesting that maximizing profits is considered selfish. For women, decisions which maximize profit are complicated by societal pressure related to gender role expectations (for review, Sent & van Staveren, 2019; Nelson, 2014). Accordingly, women must balance the potential of financial gains with unintended social costs associated with selfish or antisocial behavior (risks of retaliation and social judgement). Women tend to show greater sensitivity to accepting or rejecting offers on the basis of fairness compared to men, an affect that appears attenuated following estradiol treatment (Coenjaerts et al., 2021). Understanding the role of HCs on these kinds of self-interested behavior (already observed less frequently and socialized against in women) may be beneficial to improving our understanding of women's economic inequity.

Laboratory paradigms that have been designed to elicit individual differences in competitive behavior are highly variable, ranging from real-world money-making to laboratory economic bargaining games. Many economic games involve psychological risk, and risky decisions involve their own set of social, ecological, and survival pressures (e.g., Henrich et al., 2005; Hill & Buss, 2010). Further, decades of research have revealed that behavior in these tasks has much to do with a broader set of economic and social constructs. Individual differences in economic need, compliance to prosocial values (e.g., fairness, generosity) and perceptions about the person one is competing/negotiating with can all influence economic decision making (Engel, 2011; Kubota et al., 2013; Thielmann & Hilbig, 2018). The following section reviews the literature on HC use effects on competition for economic resources under the caveat that these behaviors may be highly constrained by other, non-hormonal, factors. Below we review literature pertaining to the effects of HCs on competition for financial resources and summarize them in Table 4.

Table 4.
Studies on the effects of HCs and competition for financial resources

Study	N	Design	Comparison Group(s)	Key Outcome Variable	Results	Effect Size
Buser, 2012	107	Between	HC (active vs non-active pill days); NC	Proportion of participants in each group who chose the competitive	↓ willingness to compete among the active vs nonactive pill phase groups for HC	Insufficient data

			(M, F, O, L, PM)	option in a piece-rate/tournament scheme[1]	↓ willingness to compete among the high vs low progesterone phase groups for NC	Insufficient data
Chen et al., 2013	51	Between	HC (pseudo phases); NC (M, F, O, L, PM); men	First-price auction[2] (FPA) bidding behavior	↑ cycle-phase variability in bidding behavior for HC, not observed in NC	No direct statistical comparison
Lucas & Koff 2013	60	Between	HC; NC (HF, LF)	Value of offers in the Dictator Game[3] (DG) and Ultimatum Game[4] (UG)	↔ no difference in DG or UG for HC vs NC	$d^{\times}$ = all < .55
					↓ offers in DG for fertile NC vs non-fertile NC	$r_{\text{partial}} = .30$
					↓ minimum acceptable offer in UG for fertile NC vs non-fertile NC	$r_{\text{partial}} = .26$
					↑ intrasexual resource guarding in NC, not observed in HC (see in text for details)	No direct statistical comparison
Miller et al., 2007	18	Mixed	HC (pseudo phases); NC (M, O, L)	Tip earning (among "lap dancers" in gentlemen's clubs)	↓ earnings for mid-cycle HC vs mid-cycle NC	No direct statistical comparison
					↔ no earning difference for HC vs NC in menstrual or luteal phase	No direct statistical comparison
Pearson & Schipper, 2013	187	Between	HC (active vs. non-active); NC (M, F, O, L, PM)	FPA[2] bidding behavior and profits	↔ no difference in profits for active vs inactive pill phase, relative to men	Model $R^2 = .27$
					↑ mid-cycle increase in risky but advantageous bidding behavior relative to men in NC, not observed in HC (consistently risk-averse)	No direct statistical comparison
Ranehill et al., 2018	333	Mixed (randomized, placebo-controlled and preregistered)	HC (placebo v treatment); NC (EF, O, L)	Value of offers in the DG[3], financial risk-taking, and willingness to compete in a piece-rate/tournament scheme[1]	↔ no difference in willingness to compete in HC vs placebo NC	Model $R^2 = .04$
					↔ no difference in DG offers or financial risk-taking, in HC vs placebo NC	Insufficient data

Schipper, 2015	93	Between	HC; NC	FPA[2] bidding behavior	↔ no association between bids or profits and basal estradiol, testosterone or cortisol levels, in HC or NC	Insufficient data
					↑ basal progesterone associated with increasing bids and decreasing profits in NC, but not HC	Insufficient data
Strojny et al., 2021	83	Between	HC; NC (F, L)	Value of offers in DG[3] and social value orientation (SVO) score[5]	↑ sharing (DG offer value) in NC vs HC	$d^{\checkmark} = 0.58$
					↑ prosocial allocation on SVO score in NC vs HC	$d^{\checkmark} = 0.49$
					↔ progesterone and estradiol levels not correlated with any outcome variable in combined HC and NC sample	$r^{\checkmark} = -.19 – .14$

Notes: When referring to phases in HC/men, the use of the term ‘pseudo’ indicates that these groups were tested at similar intervals to NC women. Abbreviations: HC, hormonal contraceptive users. NC, naturally cycling women. M, menstrual. EF, early follicular. F, follicular. O, ovulatory. L, luteal. PM, premenstrual. HF, high fertility. LF, low fertility. 1 – *Piece-rate/tournament entry scheme*: Groups of 4 participants rapidly complete arithmetic problems. In round one, each participant receives a small money unit for each correct answer (piece-rate scheme). In round two, only the highest performer on each problem receives 4x the money unit (tournament scheme – competitive option). In the third round, participants choose under which scheme they want to complete the task. Willingness to compete is measured as the proportion of participants who choose the tournament (competitive option) over the piece rate scheme in the third round (see Niederle & Vesterlund, 2007). 2 – *First price auctions* (FPA): in a sealed auction, participants bid the value of an items and the highest bid wins. 3 – *Dictator game* (DG): Player A (“the proposer”) is allocated an amount of money and is told to allocate a proportion to Player B (“the receiver”) who must accept whatever the amount is. 4 – *Ultimatum game* (UG): Player A again chooses how much to share, however if Player B decides that the amount is too small then they are able to reject the offer and both players receive nothing. 5 – *Social value orientation* (SVO): a continuous measure of preferred resource allocation of fictitious monetary amounts for self vs others; score determines SVO type (competitive, individualistic, prosocial and altruistic) (see Murphy et al., 2011).

Notes on Effect Sizes: $d^{\checkmark}$ = Cohen’s *d* provided by original authors. $d^{\times}$ = Cohen’s *d* estimated by review authors. $\eta_p^{2\checkmark}$ = Partial eta squared provided by original authors. Model R^2 = Variance explained by model including HC use as a variable. Insufficient data = No effect size reported and insufficient information provided to calculate effect size for the effect of interest. No direct statistical comparison = Original analysis method involved testing patterns for HC users and NC women separately. MLM effect size omitted = effect sizes in multilevel models vary by model specification and have thus been omitted; we encourage readers to review the original article for detailed results and effect size estimates.

HCs and Money

The experiments in this section suggest that HCs may influence competition for money, though contextual and methodological factors likely interact to influence the results. One factor seemingly influencing competitiveness is whether the contest involves money from real income streams. For instance, Miller et al. (2007) report that NC lap dancers earned higher tips from male customers when fertile compared to HC users and when NC women were in the non-fertile phase. The authors concluded that men were sensitive to subtle cues of female fertility (in physical appearance or behavior), and thus awarded more tips to NC women but not HC women during the mid-cycle phase. An alternative, one that is not mutually exclusive, is that NC women but not HC users behaved differently, i.e., when mid-cycle, and that these behaviors gave NC women a competitive edge in gaining additional tip earnings. Of course, this study is conceptually problematic in that there are numerous socialization factors involved in this context; presence of the opposite sex was also conflated with the fact that this is the only study of "real-world" behavioral outcomes.

Results from studies using behavioral economics tasks are considerably more varied. In one of the earliest investigations of HCs on economic decision making, Buser (2012) found that a lower proportion of participants in the active phase pill group were willing to compete than in the non-active pill phase group (using a questionable data-analytic approach). However, this study did not directly contrast willingness to compete between HC users and NC women. In a preregistered, experimental study with a large sample and randomized, placebo-controlled grouping of HC and NC, Ranehill et al. (2018) reported no effect of HCs versus placebo or cycle phase on the willingness to compete in a tournament payoff-scheme or engage in financial risk-taking. The quality of this study among the others gives the results more relative impact for understanding the effect, or lack thereof, of HC use on competition for economic resources.

Lucas and Koff (2013) explored the effects of high fertility, low fertility, and HC use on dictator and ultimatum game proposals and ultimatum game minimum acceptable offers (MAO). In NC women, fertility was a predictor of lower-value offers in the dictator game and lower MAOs in the ultimatum game, though HC users did not differ significantly from fertile or non-fertile NC women. To assess intrasexual competition, attractiveness and sex of the opponent varied between trials. In the ultimatum game, fertile women made lower-value offers to attractive females and higher-value offers to attractive males, while non-fertile women made higher-value offers to attractive opponents irrespective of opponent sex. Opponent sex and attractiveness did not influence offers made by HC users, nor was there evidence of HC or cycle phase effects in the dictator game. This finding suggests that HCs may attenuate cycle phase effects pertaining to resource guarding in the ultimatum game. However, these findings require replication with larger samples, as they are derived from multiple complex linear models and a 3-way interaction with 60 subjects (only 16 HC users).

In further examinations of the dictator game, results are mixed. The large and placebo-controlled study by Ranehill et al. (2018) showed no effect of HCs on the value of offers in the dictator game, while Strojny et al. (2021) showed that HCs are associated with greater resource guarding, i.e., lower offers/less sharing, compared to NC women (effect sizes were moderate). Using the Social Value Orientation (SVO) slider task (a continuous measure of hypothetical financial resource allocation; Murphy et al., 2011), Strojny et al. (2021) also found that HC users made financial decisions that were less prosocial compared to NC women. Perspectives from personality psychology may offer some insight into the disparate results between Ranehill et al. (2018) and Strojny et al. (2021). Previous research has demonstrated a link between personality factors and altruistic giving (e.g., Honesty-Humility trait, agreeableness; Hilbig et al., 2015). By using a within person design, it is possible that three months of HC use in Ranehill et al. (2018) experiment was insufficient to produce within-subject change in dictator game behavior. Future research utilizing tasks from behavioral economics should be careful to account for personality differences within and between groups.

Three final studies investigating financial decision making in HC users and NC women used 30 rounds of first-price auctions (FPAs; Chen et al., 2013; Pearson & Schipper, 2013; Schipper, 2015). FPAs are designed to provide a measure of risk taking regarding financial decision making (Chen et al., 2007). Two values were operationalized in each experiment: a) the value of the bid and b) the profit (i.e., the value of the item being bid on, minus the value of the bid). Analysis into patterns of bidding and profits across the cycle revealed minimal effects of HC use directly. However, Pearson and Schipper (2013) showed that a there was a slight mid-cycle increase in risky but advantageous bidding behavior relative to men in NC women, an effect that could not be determined in HC users whose risk aversion mirrored non-fertile NC women. Schipper (2015) found that between-subject difference in basal progesterone was positively correlated with bidding amount and negatively correlated with profit in NC women but not HC users. Chen et al. (2013) found that compared to the average of all HC users, HC users in the first half of the pill packet bid more than HC users in the second half, while NC women displayed no cycle phase effects. The results from the three auction games therefore provide little evidence that HCs disrupt financial decision-making in a meaningful way. Overall, the null findings reported by the only experimental and largest sample study (Ranehill et al., 2018) in this area suggests that competition for economic resources is not affected by HC use.

Social Status

Social status is a precursor to all other resources but is less immediate in its direct value. Competition for status allows people to improve their relative position within a community or group, which in turn leads to more access to resources directly linked to survival, such as food, water, and shelter (e.g., Montgomery & Elimelech, 2007; Sapolsky, 2004; Walker et al., 2010) as well as opportunities that benefit mental and physical health (Scott et al., 2014) and wellbeing (Anderson et al., 2012). There are also reproductive implications for women with low social status: Societies with high gender discrimination (i.e., lower social status of women compared to men) are associated with lower survival rates among women and poorer health outcomes for her and her offspring (Alami et al., 2020; Pennington et al., 2018).

One prominent perspective for understanding status-seeking behavior proposes that there are two separate behavioral strategies used to acquire status: dominance and prestige (Cheng et al., 2013; 2014). Dominance is used to gain status through power and intimidation, and is considered more antisocial, while status from prestige is granted via voluntary deference to people with advanced skill, competence, or knowledge, and is generally more prosocial (Henrich & Gil-White, 2001). A growing body of research suggests that although both strategies are effective in obtaining status (Cheng et al., 2013; McClanahan et al., 2021), women are more likely to engage in competitive tactics that are more subtle, safe, and solitary (Benenson & Abadzi, 2020; Hays, 2013).

Although intrasexual competition traditionally relates to same-sex competition for potential mates, status differentials are inherent in mate competition strategies (e.g., self-promotion and competitor derogation; Fisher et al., 2009). Self-promotion is achieved when individuals endeavor to appear more attractive or appealing than others (Buss, 1988), while competitor derogation is achieved by making rivals appear less attractive or appealing (Buss and Dedden, 1990). In both instances, social comparison to others and related intentions to dominate or defer is manifested through competitive behavior (Festinger, 1954; Garcia et al., 2013). There are obvious individual differences in motivation for social status which should predict the general tendency to compete for status, and these differences are thought to be best measured via implicit assessment of power motives (McClelland et al., 1989; Schultheiss, 2013; Winter, 1988). Finally, succeeding in competition (i.e., displaying superior social dominance or skill) often requires outlasting one's opponent in motivation, a greater commitment to exerting the energy and behavioral effort (Casto et al., 2020). Thus, behaviors under the broad category of status seeking reviewed here include self-reported intrasexual or generalized competitiveness, implicit power motivation, and competitive persistence. Below we review literature pertaining to the effects of HCs on competition for status and summarize them in Table 5.

Table 5.

Studies on the effects of HCs and competition for status

Study	N	Design	Comparison Group(s)	Key outcome variable	Results	Effect Size
Arthur & Blake, in review	270	Mixed	HC (pseudo probability); NC (fertility probability)	Self-report competitive orientation	↑ mid-cycle self-development competitiveness in NC women, not observed in HC users	Marginal $R^2 = .003$ Conditional $R^2 = .484$

					↓ hyper-competitiveness in HC vs NC^{++}	Marginal R^2 = .011 Conditional R^2 = .397
Ball et al., 2014	42	Mixed	HC (vaginal ring users only); NC (M, O, L)	Implicit power motives[1] derived from the Operant Multi-Motive Test	↑power motive score for NC in M and L phase vs. HC, no difference at O phase	$d^{\times}$ = .25 – .29
					↔ no association between hormones and implicit power motive for HC or NC	$r^{\checkmark}$ = -.43 – .31
Blake, in review	356	Mixed	HC (pseudo probability); NC (fertility probability)	Self-report status seeking	↑ mid-cycle prestige motivation in NC women, not observed in HC users	No direct statistical comparison
					↔ no difference in dominance motivation for HC vs NC	No direct statistical comparison
Bradshaw et al., 2020, Study 1	149	Between	HC; NC	Task perseverance (in visual detection)[2]	↓ perseverance in HC vs NC	$r^{\checkmark}$ = 0.20
					↔ no difference in task performance HC vs NC	$r^{\checkmark}$ = 0.16
Bradshaw et al., 2020, Study 2	175	Between	HC; NC	Task perseverance (in quantitative problems and anagrams)[2]	↓ perseverance in HC vs NC	$d^{\checkmark}$ = 0.58
					↓ task performance in HC vs NC	$d^{\checkmark}$ = 0.35
Casto et al., 2020, Study 1	124	Between	HC; NC	Competitive persistence[3]	↓ competitive persistence in HC vs NC	$d^{\checkmark}$ = 0.37
Casto et al., 2020, Study 2	114	Between	HC; NC	Competitive persistence[3]	↓ competitive persistence in HC vs NC (not statistically sig.)	$d^{\checkmark}$ = 0.33
Cobey et al., 2013b	28	Within	HC; NC (HF, LF)	Self-report intrasexual competitiveness	↔ no overall change in competitiveness when women moved from HC to NC	Insufficient data
					↓ intrasexual competitiveness in HC phase, compared to NC fertile and non-fertile phases, limited to pair-bonded women	Insufficient data
Cobey et al., 2015b	85	Between	HC; NC	Self-report dominance	↔ no difference for HC vs NC	$d^{\times}$ = 0.15
Piccoli et al., 2013, Study 1	66	Between	HC (pseudo risk); NC (continuous	Dehumanisation[4]	↑ dehumanisation of female targets with increasing conception risk in	$r_{\text{semi-partial}}$ = -.27

			conception risk)		NC, not observed in HC	
					↔ no difference in dehumanisation of male or elderly targets for HC vs NC	$r_{\text{semi-partial}}$ = all < |.20|
Piccoli et al., 2013, Study 2	59	Between	HC (pseudo risk); NC (continuous conception risk)	Dehumanisation[4] and self-report intrasexual competitiveness	↑ dehumanisation of female targets with increasing conception risk in NC, not observed in HC	$r_{\text{semi-partial}}$ = .42
					↑ intrasexual competitiveness with increasing conception risk in NC, not observed in HC	$r_{\text{semi-partial}}$ = -.28
Schultheiss et al., 2003	36	Mixed	HC (pseudo phases); NC (M, O, L)	Implicit power motives[1] derived from the Picture Story Exercise (PSE)	↔ no overall difference in power motivation for HC vs NC	$d^{\times}$ = 0.41
					↑ luteal phase power motivation in NC, not observed in HC	No direct statistical comparison
Stanton & Edelstein, 2009	40	Between	HC; NC	Implicit power motives[1] derived from the PSE	↔ no difference in power motivation for HC vs NC	$d^{\times}$ = 0.28
					↑ implicit power motivation with increasing estradiol in NC, not observed in HC	$q^{\checkmark}$ = 0.62
Stanton & Schultheiss, 2007	49	Between	HC; NC	Implicit power motives[1] derived from the PSE	↑ implicit power motivation with increasing estradiol in NC, not observed in HC	$q^{\checkmark}$ = 0.35

Notes: When referring to phases in HC/men, the use of the term ‘pseudo’ indicates that these groups were tested at similar intervals to NC women. Abbreviations: HC, hormonal contraceptive users. NC, naturally cycling women. M, menstrual. O, ovulatory. L, luteal. HF, fertility. LF, low fertility. 1 - Implicit power motives were measured using thematic analysis tools (e.g., Picture Story Exercise; McClelland et al., 1989) where participants view images and write a story about what they see before trained content-coders then use thematic analysis to code each story based on themes and language. 2 – Task perseverance was measured as the amount of time spent working on various cognitive tasks; Study 1 was a timed spot-the-difference (in visual images) task; Study 2, was time spent solving GRE quantitative problems and anagrams. 3 – Competitive persistence was measured using the Competitive Will task, a competition for time in which participants held a small weight with arm extended out and elevated at shoulder height . 4 – An implicit measure of dehumanisation using word lists to describe targets.

Notes on Effect Sizes: $d^{\checkmark}$ = Cohen’s *d* provided by original authors. $d^{\times}$ = Cohen’s *d* estimated by review authors. $q^{\checkmark}$ = Cohen’s *q* provided by original authors and indicates difference in slopes between HC and NC. For multilevel models containing HC use as a predictor variable, Marginal R^2 provides variance explained only by fixed effects and conditional R^2 provides the variance explained by both fixed effects and random effects. Insufficient data = No effect size reported and insufficient information provided to calculate effect size for the effect of interest. No direct statistical comparison = Original analysis method involved testing patterns for HC users and NC women separately.

HCs and Status Seeking

Overall, the findings regarding the relationship between HCs and dominance-related measures are mixed. Four studies reported no differences in self-reported dominance or intrasexual competitiveness between HC users and NC women (Blake, in review; Cobey et al., 2013b; 2015b; Stanton and Schultheiss, 2007), one study reported weak evidence that hyper-competitiveness was lower in HCs users compared to NC women (Arthur & Blake, in review), and one found HCs attenuated the positive association between fertility risk and intrasexual competitiveness observed in NC women (Piccoli et al., 2013). Using an implicit measure of intrasexual competition, Piccoli et al. (2013) showed a positive association between fertility and the dehumanization of female targets for NC women but not HC users. The over reliance on self-report measures in this literature, which are subject to social desirability bias, could obfuscate a full understanding of how HCs influence dominance-related behavior in more realistic contexts.

An alternative to measuring status-seeking through explicit self-report, researchers have investigated the effect of HCs on implicit power motives. Implicit motives are non-conscious preferences that drive human behavior (Schultheiss & Brunstein, 2010), including a need for power, achievement and affiliation. Within this literature, three studies reported that HC use diminished the relationship between implicit power motives and estradiol (Schultheiss et al., 2003; Stanton & Schultheiss, 2007; Stanton & Edelstein, 2009), though Ball et al. (2014) reported no association between estradiol and power motives. Stanton and Edelstein (2009) and Schultheiss et al. (2003) directly compared implicit power motives between HC users to NC women, finding no significant differences in either study. Given the lack of evidence for an effect of HCs, we suspect there are not substantial or systematic differences in implicit power motivation between HC users and NC women.

Unlike dominance-related research, the negative effect of HCs on prestige related status-seeking and competitive persistence were relatively consistent across studies and methodologies. Using self-report measures across the full menstrual cycle, HC use attenuated a mid-cycle increase in prestige-motivated competition that was observed in NC women (Arthur & Blake, in review). In a separate study, Blake (in review) also found that prestige increased mid-cycle among NC women, a pattern not evident in a separate sample of HC users. Further, three of four behavioral studies observed an inhibitory effect of HCs on competitive and achievement-based task persistence with fairly moderate effect sizes (Bradshaw et al., 2020; Casto et al., 2020). One of the four behavioral studies reported no significant difference between HC users and NC women, though the direction and size of the effect was consistent across all laboratory contexts (Casto et al., 2020, study 2). Taken together, Bradshaw et al. (2020) and Casto et al. (2020) demonstrate that HCs suppress persistence across cognitive and competitive physical tasks, respectively, thus strengthening the generalizability of these effects.

One factor which may influence dominance-based status seeking, particularly for studies that assess intrasexual competitiveness, dominance and dehumanization, is relationship status. Five of the nine reviewed studies on this topic reported at least one significant interaction with participants' current relationship status (i.e., single versus partnered). Cobey et al. (2013b) found HC use diminished self-reported competitiveness in partnered women but not in single women. Similarly, relationship status influenced NC women's dominance scores but was unrelated to dominance in either single or partnered HC users (Cobey et al., 2015b). Two studies reported a stronger positive relationship between estradiol levels and implicit power motives in single women (Stanton & Schultheiss, 2007; Stanton & Edelstein, 2009) and one reported a negative association between estradiol levels and implicit power motives in partnered women (Stanton & Edelstein, 2009). In contrast, Arthur and Blake (in review), Ball et al. (2014) and Piccoli et al. (2013) reported that relationship status did not influence the effect the relationship between HCs and variables related to individual differences in dominance.

Other Considerations

Due to the large differences in how competitive behavior is socialized in women (punished) compared to men (reinforced) in many cultures (e.g., Carpenter et al., 2018; Williams & Tiedens, 2016), women likely face different social pressures in competitive contexts that are not accounted for in study designs (for review, Casto & Prasad, 2017). Future research on HCs and competitive behavior should consider how society and culture shape and have shaped women's competitive and dominance motivated behavior, having evolved and currently existing within a structure in which these behaviors incur risk (social and physical) and require greater tact, strategy, and concealment (Campbell, 2004; Prentice & Carranza, 2002; Rudman & Phelan, 2008).

For example, when studying competition in women it may be necessary to use experimental designs which incentivize women according to more socially oriented outcomes. Cassar and Rigdon (2021) demonstrated that when women are able to share financial winnings with others, the gap in competitiveness between men and women disappears. Similarly, when competing for financial incentives designed to benefit the participant's offspring, the gender gap in competitiveness disappears (Cassar et al., 2016). This suggests that women are motivated to compete when provided the guise of competing for others' benefit, especially when incentivized with social- or familial-oriented rewards. Future research should consider new experimental designs that better address gender role expectations that may reveal nuanced competitive differences between HC users and NC women alike.

Discussion

This review provides a comprehensive synthesis of published research that has tested differences between HC users and NC women in competitive behavior. Prior research was synthesized across mating, financial, and status resource categories. Of the 46 total studies, 40 studies directly contrasted HC users and NC women, and of them, 30 studies supported at least one hypothesized main effect or interaction (75%), nine studies reported no differences between HC users and NC at any level of analysis (22.5%), and one explored dose-dependent effects of estradiol levels across different HCs (2.5%).

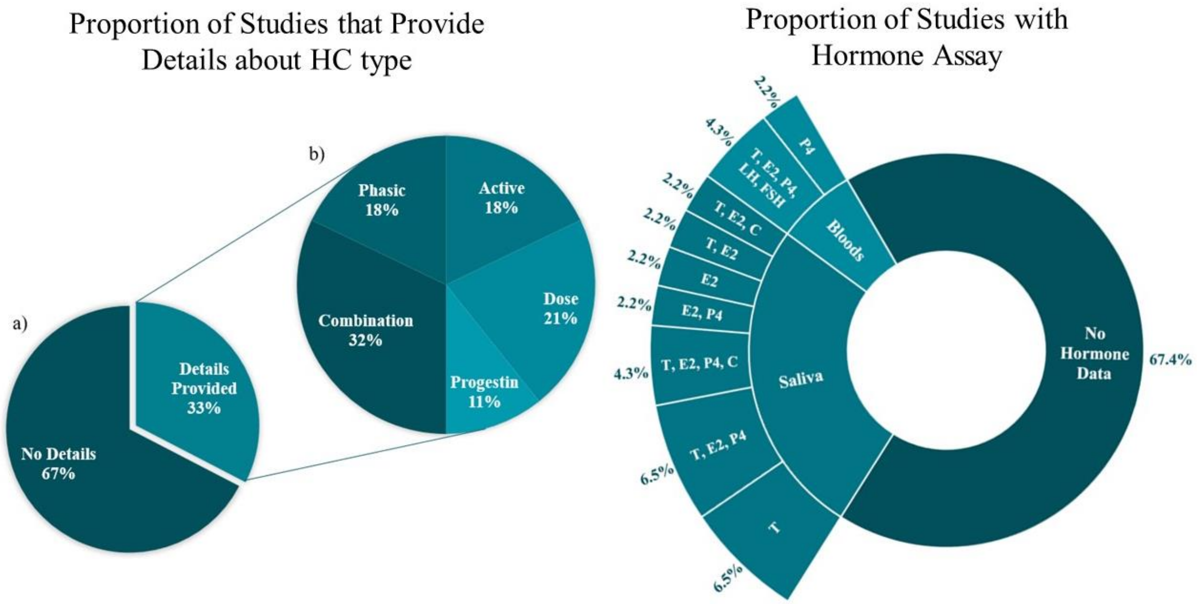
The key findings regarding the effect of HCs and competition can be summarized as follows. First, the mid-cycle increase in self-perceived sexual desirability and attractiveness that is present in NC women is attenuated in HC users. Second, jealousy appears heightened in HC users compared to NC women, though further research in larger samples in required. Third, there is not strong evidence to support an effect of HC use on competition for economic resources. Fourth, HCs were associated with lower achievement motivation and performance on tasks requiring persistence, outcomes which may be related to prestige-based status seeking. Fifth, relationship status of participants frequently interacted with the effect of HCs on mating and status-based competitiveness, suggesting it is an important variable in future research. However, this research was generally plagued by methodological drawbacks that limit the strength with which these conclusions should be endorsed (discussed below). Further, although effect size reporting was not consistent in this literature, effects sizes of main HC use effects were generally small to moderate.

There is currently insufficient clarity regarding the effect of HCs on mate selection preferences for physical characteristics (e.g., masculinity); beautification and grooming behaviors; mate guarding; competition for money; and more dominant-assertive status competition behavior. The research in these areas was either too scarce to draw conclusions, included contradictory results, used experimental paradigms that were too disparate in nature, or their designs were inconsistent in accounting for the menstrual cycle phase of the NC comparison group. Future research in these areas is warranted.

Methodological Limitations and Recommendations

Methodological limitations in the research reviewed inhibited our ability to draw firm conclusions regarding the effects of HCs. These limitations include inconsistent comparison groups, the absence of sufficient HC information, the lack of direct hormone measurement, insufficient sample sizes and open science practices (including incomplete reporting of statistics and effect sizes). These factors should be considered when designing future research. However, we also recognize that some of these recommendations increase the number of study variables/levels of variables and thus, exponentially increase the sample sizes required for adequately powered analyses. To encourage this critical research, we offer both ideal and more practical recommendations.

Finally, a general caveat of this literature is that lab and survey-based proxies of human mating and competitive behavior may not accurately reflect the more nuanced ways in which these behaviors emerge within natural contexts. Furthermore, ways of operationalizing and measuring these behaviors have undergone limited construct and measurement validation procedures to establish such generalizability. Inevitably, the ability to understand the true effect of HCs on social behaviors is predicated on sound measurement and transparent reporting of validation procedures (Flake & Fried, 2020). Larger samples, preregistration, effect size reporting, and greater design specificity will still fail to produce valid results if the study methods assess outcomes that bare no relation to the behaviors that hormones were evolved to regulate.


Proportion of Studies that Provide Details about HC type

Proportion of Studies with Hormone Assay

Figure Caption: <u>Left</u>: A pie-of-pie chart indicating a) the proportion of studies reporting HC data and b) details of what information is available within the subset of studies. Note. Studies which reported more than one detail are represented in each section of the secondary pie. Phasic = information about mono- or multi-phasic. Dose = dose of estradiol or progestin. Progestin = information about progestin type. Combination = information about combined or progesterone only contraceptive. Active = information regarding whether participants were on the active or inactive pill day. Right: Proportion of studies with direct hormone measurement. Abbreviations: C, cortisol; E2, estradiol; FSH, follicle stimulating hormone; LH, luteinizing hormone; P4, progesterone.

Inconsistent accounting of menstrual phase data for the NC comparison group

A major obstacle to effectively synthesizing this research was the inconsistent clustering of the NC women comparison group regarding their menstrual phase. If, in fact, synthetic ovarian hormones contained in HCs are meaningfully and systematically affecting behavior and these hormones also systematically vary across the cycle, effects could emerge on the basis of appropriate accounting of cycle phase for the NC women. A discussion about the challenges concerning cycle phase determination is outside the scope of this review (see Blake et al., 2016; Hampson, 2020), however, it is important that we acknowledge the many ways that NC women were described and how this relates to HCs. Half of studies controlled for cycle phase in NC women and the remainder did not. Of those which did control for cycle phase, considerable variation in the definition of phases introduced additional noise into the synthesis. For example, from 46 individual studies, the fertile phase was defined in 12 different ways, ranging from a brief 48-hour period (e.g., Cobey et al., 2012) to a broad 10-day window (e.g., Gori et al., 2014). This degree of variability limits the ability to draw simple comparisons between NC women in the fertile phase and HC users.

We do not advocate that cycle phase should always be controlled for because there are likely differences at the broader group level (see Prestige section above). Even so, (Recommendation 1) it would be ideal for the cycle phase of the comparison group to be clearly defined based on reliable and validated measures of cycle phase estimation (see Blake et al., 2016; Gangestad et al., 2016). However, existing methods for cycle phase determination are costly, cumbersome, and still not well-validated.

A practical recommendation for assessing menstrual cycle phase in NC women would be to collect detailed self-reported information about menstrual period dates before and after participation, typical length of the cycle, and menstrual timing-related abnormalities. In this case, researchers should be transparent about the validity issues in this design and cautious about interpretations. It may be best to present *descriptive* analysis of the outcome variable of interest visually plotted along estimated cycle days in lieu of formal statistical analysis. In our own research, we have inquired about whether our participants' use menstrual tracking apps, and if so, encourage them to use their app when filling out this information. Perhaps a more optimal method would be to inquire about calendar days of prior menstrual onset in a recruitment survey and invite participants to the lab on days that are within an estimated mid-follicular, mid-cycle, or mid-luteal day range depending on hypothesized comparison group (see Casto et al., 2021). Attending to the next recommendation may also aid in increased accuracy in estimating cycle phases for NC women.

Lack of hormone data

One way to overcome the challenge of cycle phase estimation is by measuring the hormone of interest via bioassay. Hormonal assays have the added benefit of uncovering mechanisms of hormonal disruptions and informing likely pathways between hormones and behavior. Despite these benefits, only a minority of studies collected hormone data through saliva or blood samples, see Figure 2. Of the number of studies reviewed, 24.5% of studies assayed for testosterone, 22.4% assayed for estradiol, and 18.4% assayed for progesterone. This means that the hormonal modulation of competitive psychology and behavior has only been directly assessed in ~30% of the research. While it isn't necessary to collect hormone data when making comparisons between HC users and NC women, research without this information is limited in the ability to make inferences about hormonal mechanisms. Thus, we recommend that future research collect samples to assay for hormone levels when possible (Recommendation 2).

However, hormonal assays, particularly derived from saliva samples, are vulnerable to a separate set of validation limitations (for review, Prasad et al., 2019). For instance, although mass spectrometry is often regarded as the 'gold-standard' for steroid hormone measurement, the high costs and technical complexity associated with mass spectrometry limit the number of labs who can access this method

(Stanczyk & Clarke, 2010; Taylor et al., 2015). Further, despite of concerns regarding the sensitivity and accuracy of immunoassays (Arslan et al., 2022; Handelsman & Wartofsky, 2013; Herold & Fitzgerald, 2003) researchers often rely on these tests due to the technical simplicity and lower relative cost (Prasad et al., 2019).

Imputing hormone levels from NC women based on daily, diary-based cycle day is another potential solution that appears more valid for some hormones than saliva measurement (especially estradiol; Arslan et al., 2022), and future work should continue to investigate this possibility (Recommendation 3).

Lack of data on HC user type, brand, formula and duration of use

Many of the studies in this review do not appear to have been intentionally designed to test HC effects per se, but rather, included HC users as a quasi-control group to compare to NC women; the goals of the study being more about menstrual cycle phase effects. A drawback of this approach is that the HC group contains a wide variety of types of users, e.g., pill, patch, injection, or implant. An investigation into the appropriateness of HC users as a control group in exercise performance studies demonstrated that the type and brand of oral contraceptives had a significant impact on circulating estradiol and progesterone (Elliott-Sale et al., 2013).

In the current review, one study recruited only vaginal ring users, 28 (61%) studies recruited only oral contraceptive users, 17 (37%) recruited a mix of all HC users, of which less than half (*n* = 8) provided a breakdown of the type (e.g., pill, IUD). As indicated in Figure 2, the majority (67%) of studies reported no details regarding pharmacological formulation of the HCs currently used by participants. The remaining 33% provided at least one detail regarding the use of a single (i.e., progesterone only) or combined synthetic classes of hormones, the dose of each hormone, the phase of hormone release (e.g., monophasic, multiphasic, extended phase) or the type of progesterone administered (e.g., androgenic, anti-androgenic). Finally, despite some evidence suggesting that age of onset (e.g., pubertal vs. adult) and duration of HC use may be associated with differences within HC users (e.g., Sharma et al., 2020), no study reviewed here reported duration of use or data regarding age of onset.

We recommend that instead of treating HC users as a quasi-control group that researchers recognise the potential research opportunities within this sub-set of the population (Recommendation 4). For example, there are ample opportunities for future work to investigate the dose dependent effects of synthetic ovarian hormones, the effect of different chemical formulas of the synthetic hormones, differences between adult and pubertal onset users, and the effects of week-to-week dosage differences resulting from different phasic-release patterns.

For researchers intending to contrast NC women with HC users, consider recruiting HC users with the same type and brand or with comparable formulations. We acknowledge the methodological challenge of recruiting a sufficient sample size if analyses are a restricted to a single HC type. Alternatively, or in addition, our recommendations align with Hampson (2020) which suggest that researchers should collect and report data regarding the dose, brand, and route of administration of the HCs used by participants as well as data on participants' duration of use and age of onset (Recommendation 5). For the purpose of future meta-analysis on specific hormone-behavior effects, researchers should also report the specific chemical composition of the HC formulas used by participants in their sample, and if possible, correlations to behavioral outcomes by brand.

Need for improved sample size reporting, larger sample sizes and open science practices

Effect size reporting communicates the magnitude of the reported effects and allows for future researchers to determine meta-analytic effect sizes across different studies. Effect sizes from prior publications are also used to estimate sample sizes needed for adequate power in replication attempts (Open Science Collaboration, 2015; Schäfer & Schwarz, 2019). However, of the 82 key findings presented in Tables 2-5, effect size estimates were reported in less than half (47.6%) of the original research papers. To facilitate future meta-analyses and replications, researchers should report standardized effect sizes for all HC effects and associations, including confidence intervals for effect sizes (Recommendation 6).

Collectively, sample size limitations may explain the conflicting results across several sections of this review. By our calculations, based on a small effect (assuming $d = 0.20$) and t-tests as an example, the necessary sample size to reach 80% statistical power is 393 participants per group in a between-subjects design or 198 participants in a paired-samples within-subjects design. Required sample sizes to reach adequate power also increase considerably in designs proposing attenuated interactions (Blake & Gangestad, 2020). Although there were a number of significant effects observed in the research reviewed, researcher degrees of freedom (i.e., flexibility in data collection, analysis and reporting) could mean that the small samples were vulnerable to the detection of false positives (Simmons et al., 2011; Wicherts et al., 2016). We therefore suggest that researchers should strive to predetermine the sample size of their study based on the necessary sample to achieve adequate power for the hypothesized effect (Recommendation 7). To improve the transparency of this research more broadly, open data practices and preregistration of methods analysis should be used (Recommendation 8).

Critical Reflections and Diverse Perspectives

HC use is more common among industrialized Western countries and among the relatively wealthy, due to inequities in access to health care as well as cultural norms and religious practices (Cole & Giest, 2021; Colleran, 2016; Ewerling et al., 2018; Hawkey et al., 2018). Additionally, research on HC effects on behavior has been almost exclusively studied in Western, educated, industrialized, rich, and democratic (WEIRD) populations. These two facts combined mean that interpretations and conclusions from this review are limited in their generalizability. In addition, daily-use oral contraceptives are the most common form of hormonal contraceptive in the United States and other Western countries (Kavanaugh and Jerman 2018) and are the primary form of contraception in the research here. Little is known, however, about how long-acting reversible contraceptives (LARCs)—which include hormonal forms (implants and injections)—might affect the brain, cognition, and behavior. LARCs are increasingly the focus of public health campaign programs to increase contraceptive access for women, particularly from lower income and minority ethnic backgrounds (Kelly, Lindo, and Packham 2019; Lindo and Packham 2017; Manchikanti Gomez, et al., 2014). Given that the type of HC used by women may assort along racial and social-economic lines, it is critical that future research study the social, emotional, cognitive, and behavioral effects of an expanded range of HC methods.

The notion that ultimate evolutionary pressures like mating and reproduction can influence the behavior and psychological motivation of individuals sits tenuously with some people. At first glance, this perspective appears dismissive of variability among individuals such as personality and sexuality, the effect of the social situation, and differences in cultural norms. Evolutionary theories can be falsely interpreted as being overly deterministic and thus in conflict with an individual's sense of free-will and autonomy. There is also a history of biological ideas being used to oppress women as mere vehicles of animalistic processes, as controlled by their biology and especially their wombs. We point to more informed and nuanced perspectives in Buss and Schmitt (2010) as well as Vandermassen (2005; 2011) for excellent history and discussion on the intersection of evolutionary psychology and feminism. Though the two approaches are often considered to be opposed, there is a wealth of potential in using biological and evolutionary insights to improve the lives of women.

We do not take a naturalistic fallacy position that "naturally cycling" is inherently good or better; nor do we take a stance on medical recommendations for HC use. HCs have been highly beneficial to women's reproductive autonomy with notable benefits to women's independence, career prospects and social/financial elevation (e.g., Goldin & Katz, 2002). Our 'HCs as disruptors' framework includes both behavioral costs and benefits to HC use and with it, we aim to connect HC research with the essential background of evolved hormone-behavior mechanisms and life-history trade-offs. The goal of the review is to synthesize the potential social and behavioral impacts of HCs so that this research will continue to enable greater understanding and stimulate discussion. HCs use is a phenomenal, world-wide natural experiment in behavioral endocrinology and modelling its effects will inform more detailed understandings of hormone-behavior relationships.

Conclusions

This review of prior research on the differences in competitive outcomes between HC users and NC non-users contributes to a broader understanding of the potential social and behavioral consequences of HCs beyond the intended purpose of preventing pregnancy. Across 46 studies (N = 16,290) examining competition for mating, financial and social resources, we find that HCs have the potential to disrupt some aspects of competitive behavior, depending on the resource category. Results regarding differences between HC users and NC non-users on mate selection, attraction, and retention outcomes were mixed. One particularly consistent effect in well-powered studies was the attenuation of the fertile phase peak in self-perceived attractiveness and sexual desirability that was observed in NC non-users but not HC users. In contrast, there was a lack of reliable evidence for group differences on physical mate preferences (e.g., cues of masculinity). Evidence for HC users differ from NC non-users in mate guarding and mate attraction remains limited; though jealousy may be elevated in HC users (perhaps due to social-relational factors), more well-powered research is required to confirm this effect. Our review of competition for financial resources provided no support for an experimental effect of HCs or consistent group differences in economic behavior between HC users and NC non-users, though this was the resource category with the smallest number of studies. Finally, there is initial support that HC users compared to NC non-users show reduced persistence and performance on competitive or achievement-oriented tasks.

Although there is evidence that HC users and NC non-users differ systematically on some competitive behaviors, the underlying hormonal mechanisms remain unclear. Disentangling key mechanisms of action would provide a more comprehensive understanding of HC effects on social and adaptive behaviors. Further, substantial methodological shortcomings, small effects, and ambiguity in the prior literature limit the ability to draw firm conclusions. Based on the limitations of the reviewed studies, we provide eight key recommendations for future research: (1) clearly define the NC comparison groups based on theory and past research; (2) collect hormone data whenever possible; (3) if not, or alternatively, employ longitudinal methods to impute hormone levels based on cycle day; (4) avoid treating HC users as a homogenous quasi-control group and instead consider within group differences among users (e.g., age of first use, duration of HC use); (5) collect and report data on specific HCs used by participants (e.g., brand, dose, type), especially when treating HC users as a homogenous comparison to NC women; (6) report standardised effect sizes for HC effects or HC use group differences; (7) predetermine the sample size necessary to achieve adequate power for the hypothesized effect; and (8) engage in open science practices. Given the sheer number of HC users around the world, subtle differences between users and non-users may unintentionally yield wide reaching social consequences, for better or worse. The potential impact of this research is thus expansive and should remain a research priority.

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Chapter 3: Fertility predicts self-development-oriented competitiveness in naturally cycling women but not hormonal contraceptive users

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Abstract

A growing body of research has begun investigating the relationship between hormones and female competitiveness. Specifically, researchers have focused on the effect of the menstrual cycle and hormonal contraceptives. Despite many attempts at understanding hormone-behavior associations, contradictory findings have made it difficult to determine the existence of true effects. The aim of the current research was to use a robust methodological design to investigate the effect of fertility probability on four competitive orientations in naturally cycling women and hormonal contraceptive users. Using a longitudinal diary study with over 3,900 observations from 21 countries, we explore the effect of fertility probability on four self-report competitive orientations after controlling for menstruation: self-developmental competition, hyper competitiveness, competition avoidance, and lack of interest toward competition. Using Bayesian estimation for ordinal mixed models, we found that fertility probability was associated with an increase in self-development competitiveness amongst naturally cycling women but not hormonal contraceptive users. We also found weak evidence that hormonal contraceptive users show reduced interest in competing compared to naturally cycling women. There were no other robust effects of fertility or hormonal contraceptive use. These results suggest that fertility probability is associated with increased fluctuations in self-development competitive motivation and that hormonal contraceptives interfere with this effect. This research contributes to the growing body of literature suggesting that

hormonal contraceptives may influence psychology and behavior by disrupting evolved hormonal mechanisms.

Introduction

From the simplest unicellular organisms (Baker, 2011), through to complex multicellular species, survival and reproduction are subject to competition (West-Eberhard, 1979). Human competition is generally thought to center around access to material resources, such as shelter, food, safety and mates (Smolla et al., 2015). However, competition for social status is an important social and behavioral outcome that humans use to acquire other goods and services. By competing for status, individuals improve their relative position within a community or group. High-status groups and individuals can then leverage their status in order to access resources that aid survival and reproduction, as evidenced by better physical and mental health amongst high-status individuals (Anderson et al., 2012; Scott et al., 2014). To help understand the social and biological drivers of female competition, researchers have begun to explore within-sex differences in competition and competitive motivation.

One avenue of research suggests that female competitiveness may vary across the menstrual cycle and with the use of hormonal contraceptives (HCs). Hormones originate at different organs within the endocrine system and regulate important bodily functions by sending signals around the body. In women[4], gonadal hormones (e.g., estradiol, progesterone) are primarily produced in the ovaries and are vital to sex differentiation, healthy development and reproduction (Burrows, 2013). However, a growing body of research suggests that these same hormones are implicated in a range of other functions, including immunoregulation (Bereshchenko et al., 2018; Bouman et al., 2005), cognitive functioning (Sherwin, 2003; 2012; Toffoletto et al., 2014) and the coordination of adaptive social behavior (Adkins-

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[4] We use women/woman throughout this manuscript to indicate human persons with a menstrual cycle, however we acknowledge that not all people who experience a menstrual cycle identify as women.

Regan, 2005: Roney, 2016). Of interest to this paper is the potential for hormones to coordinate adaptive behaviors which enrich competitive outcomes for women.

Across the menstrual cycle gonadal hormones fluctuate to enable healthy reproduction, and many researchers have proposed that certain times of the cycle may be associated with increased competition in naturally cycling (NC) women. One theory – the ovulatory competition hypothesis (Durante et al., 2014; Nikiforidis et al., 2017) – posits that competitiveness may be elevated in women who are approaching ovulation, compared to women in other times in the cycle. Evidence for this theory derives from research revealing a mid-cycle increase in intrasexual competition, including the use of beauty products and desire to wear sexy clothes (Batres et al., 2018; Durante et al., 2008; Saad & Stenstrom, 2012). Adding additional support for an association between hormones and competitiveness comes from research suggesting that women using HCs display a reduced level of competitive motivation compared to NC women (e.g., Buser, 2012; Bradshaw et al., 2020; Casto et al., 2020; 2021a), suggesting that exogenous hormones in HCs may suppress underlying (likely non-conscious) competitive motivations.

Critically, in recent years, several well-powered non-replications have cast doubt on the association between fluctuating fertility and psychological and behavioral outcomes (e.g., Arslan et al., 2018; Hahn et al., 2016; Jones et al., 2018a; Ranehill et al., 2018). The repeated non-replication of early research has sparked ongoing debate in the literature, including critiques of methodological designs, analyses and resulting theories (Jones et al., 2019; Stern et al., 2019; but see, Gangestad et al., 2019a; 2019b). Further, a recent review by Arthur et al. (2022) concludes that the association between HCs and competitiveness is highly variable and that critical methodological limitations restrict researchers from drawing firm conclusions about HCs. Taken together, there is a need to conduct large-scale, methodologically robust studies examining menstrual cycle effects on competitiveness with both NC women and HC users.

The aims of this paper were twofold. First, we aimed to investigate the effect of fertility probability on four competitive orientations (self-developmental competition, hyper competitiveness, competition avoidance, and lack of interest toward competition) in NC women and HC users. Second, we sought to address limitations in previous research that would help provide a better understanding of mixed findings. The current study contains several key strengths. Using a longitudinal within-subjects design and continuous measure of fertility, we provide a clearer and more complete picture of self-report competitiveness across the cycle compared to sampling from only fertile and non-fertile phases (Gangestad et al., 2016; Roney, 2018). The decreased reliability of fertile-phase identification is also compensated for by the increase in sample size (Arslan et al., 2018). By using a nuanced measure of competition that includes four competitive orientations, we demonstrate that cycle phase is associated with some, but not all, competitive orientations. Finally, our sample contains over 3900 observations from 21 countries, providing this field with much-needed cross cultural data.

The Menstrual Cycle and Hormonal Contraceptives

The average menstrual cycle occurs over a 28-day period, with 21-to-35-day cycles considered within the normal range (Azari & Kaminski, 2019). Each ovulatory cycle is made up of three key phases – the follicular, ovulatory, and luteal phases – which are each characterized by fluctuations in estradiol and progesterone. Based on the average 28-day cycle, the first 14 days (i.e., the follicular phase) are marked by low progesterone and rising estradiol, which peaks during ovulation (roughly day 14). The final 14 days (i.e., the luteal phase) are characterized by progesterone dominance, which subsides again before the start of the next cycle. Different behaviors have been observed at different times in the cycle, leading researchers to believe that those behaviors may be associated with cycling levels of estradiol and progesterone.

For HC users, the natural menstrual cycle is disrupted through the provision of exogenous hormones. HCs contain progestin (a synthetic form of progesterone) or a combination of progestin and synthetic estradiol (Melo & Creinin, 2016). Several methods of administration are used, including an oral pill taken daily (widely referred to as “the pill”), devices inserted into the body (e.g., the intrauterine device [IUD], the implant/rod), contraceptive injection or the vagina ring. Regardless of the administration method, HCs usually prevent pregnancy by suppressing ovulation or creating an inhospitable environment for a fertilized embryo (Baird & Glasier, 1993). Given that HCs largely disrupt naturally occurring fluctuations in endogenous estradiol and progesterone, this suggests that if the menstrual cycle is associated with fluctuating competitiveness, that HCs may disrupt this pattern.

Hormones and Competition

Given the reproductive relevance of the menstrual cycle, research investigating the relationship between hormones and female behavior has often focused on shifts in mating relevant psychology and behavior. As briefly outlined above, the ovulatory competition hypothesis (Durante et al., 2014; Nikiforidis et al., 2017) posits that ovulation is associated with an increase in intrasexual competitiveness, with a focus on mate-seeking. Support for this theory comes from studies demonstrating that fertile (compared to non-fertile) women self-report increased intrasexual competitiveness, assertiveness, and use of mate attraction strategies, including heightened use of make-up, other grooming behaviours, and desire to wear sexy clothing (Batres et al., 2018; Blake et al., 2017; Durante et al., 2008; Piccoli et al., 2013; Saad & Stenstrom, 2012). However, several well-powered non-replications (e.g., Arslan et al., 2018; Hahn et al, 2016; Schleifenbaum et al., 2021) have since failed to find a robust association between fertility and increased intrasexual competition for mates, casting doubt on the reliability of this association.

Another way researchers have conceptualized competition across the menstrual cycle is by looking at fluctuations in mate preferences. While both sexes compete for access to mates, males see greater fitness gains by securing more mating opportunities, whereas females see greater gains by accessing higher quality mates (Clutton-Brock & Huchard, 2013; Rosvall, 2011). The ovulatory shift hypothesis (Gangestad & Thornhill, 1998; 2008) proposes that during phases of high fertility, women display heightened attraction to men with traits indicating high genetic quality (e.g., masculinity). A meta-analysis of women's mating preferences indeed suggests that when selecting partners for a short-term relationship, fertility is associated with a small (Hedge's $g = 0.21$) preference for masculine partners (Gildersleeve et al., 2014a). Meanwhile, a second meta-analysis (using similar papers) and two critical commentaries argue that the effect of fertility on masculinity preferences is subject to publication bias and "p-hacking" through the use of flexible fertility estimates (Harris et al., 2014; Wood & Carden, 2014; Wood et al., 2014; but see Gildersleeve et al., 2014b). In addition to the contradictory meta-analyses, more recent well-powered research report no association between cycle phase and masculinity preferences (e.g., Jones et al., 2018a; Marcinkowska et al., 2019; Stern et al., 2021; van Stein et al., 2019), though rebuttal commentaries have been proposed (Gangestad et al., 2019a; 2019b).

Given high variability within the mate seeking literature, other theories may better explain cycle shifts in competition for mates, such as the motivational shift hypothesis (Roney & Simmons, 2017). According to Roney and Simmons (2017), women experience cycle related shifts in motivational priorities between reproductive and other survival behaviors (e.g., feeding). The mid-cycle increase in estradiol is thought to be associated with a general increase in sexual motivation and intrasexual competition, while this same period is associated with a decrease in self-reported food intake. Several well-powered studies find support for this theory, arguing that fertility may be associated with a broad increase in sexual motivation, rather than a specific preference for mates with masculine features (Jünger et al., 2018a; Jünger et al., 2018b, Stern et al., 2020).

Given that HCs reduce hormonal variation across the ovulatory cycle, researchers have also investigated whether HCs are associated with systematic differences in intrasexual competition for mates, though the research is again mixed. Batres et al. (2018) found that HC users spend less time putting on make-up compared to NC women. Similarly, Schwarz and Hassebrauck (2008) found that although NC women increased the use of sexualized clothing during the middle of their cycle, the same pattern is not observed in HC users. Regarding mate selection, there is some evidence that HC users do not report a general preference for masculine men (Feinberg et al., 2008; Gori et al., 2014), suggesting that they are not motivated to compete for high quality genes for their offspring. However, mirroring the mate seeking literature for NC women, contradictory research can be found regarding the association between HCs and intrasexual competition (e.g., Jones et al., 2018a; Marcinkowska et al., 2019; for review, Arthur et al., 2022).

Competition for Status

In addition to competition for mates (which may increase status indirectly; for review, Buss & Schmitt, 2019), some research suggests that the menstrual cycle is associated with fluctuations in status-seeking through other pathways. Durante et al. (2014) demonstrated that as women approached the fertile phase of the cycle, they preferred higher relative status (i.e., more value relative to others), while Fisher (2004) and Piccoli et al. (2013) reported that derogation of other women increased with fertility risk in NC women. These three studies suggest that fertility is associated with a desire to maximize one's social position relative to other women. When status is achieved through direct competition with others, HC users displayed poorer competitive persistence compared to NC women, as seen in both physically and psychologically difficult tasks (Bradshaw et al., 2020; Casto et al., 2020). This work collectively suggests that endogenous hormones may lead to fluctuations in status motivation and that HCs may blunt this effect.

The literature regarding competition for economic resources (which can also enhance status) is again mixed. In a novel study, Miller et al. (2007) recorded tip earnings for professional lap dancers, finding that HC users earned less than NC women in the fertile phase. Although the authors conclude that men are more attracted to fertile women, it is also possible that HCs suppress a mid-cycle increase in competitiveness experienced by NC women. Other researchers have used a combination of tasks from social psychology (e.g., social value orientation; Anderl et al., 2015) and behavioral economics, such as the dictator and ultimatum games (Eisenbruch & Roney, 2016; Lucas & Koff, 2013), auction games (Chen et al., 2013; Pearson & Schipper, 2013; Schipper, 2015), and the piece-rate or tournament entry scheme (Buser, 2012; Ranehill et al., 2018; Wozniak et al., 2014), many of which report contradictory or null associations between HCs and competitive outcomes. A detailed analysis of this literature is presented in Arthur et al. (2022) and Nikiforidis et al. (2017).

Despite the importance of accurately measuring female competitiveness, researchers in this field face social and methodological constraints. For example, experimental lab competitions are often male-biased and fail to account for gender differences in the socialization of competitive behavior (Casto & Prasad, 2017). Further, in the mate competition literature, researchers often make assumptions about what is motivating female behavior. For example, women's beautification (e.g., provocative dress, use of make-up) has often been used as evidence of increased mating motivation. While mating likely motivates some appearance enhancement, women's beautification also leads to benefits beyond mating, including improved social interactions and personal status acquisition (see Blake, 2022; Bradshaw & DelPriore, 2022). It is important to consider these limitations when reviewing the existing research and when designing future investigations. By measuring competitive inclinations directly, researchers are able to bypass these limitations.

Theoretical justification for shifting levels of competitiveness

As with all evolved traits and behaviors, engaging in competition can be costly and often involves trade-offs with other adaptive behaviors. For women, an underlying tension regarding the costs of competition is that securing valuable resources requires some level of competition, but if a woman is outwardly perceived by others as a threat, then she may herself become the victim of competition. For example, despite the advantages conferred upon high-status individuals, blatant status-seeking in women is often met with backlash due to gender norm violations (Benenson, 2013; Campbell, 2013). Women and girls also express distress when other women outperform them in terms of appearance, popularity, employment and academic success (Benenson & Benarroch, 1998; Simmons, 2002; Vigil, 2007; for review, Reynolds, 2020). Maintaining a continuous level of high competition may therefore inhibit a woman's ability to maintain positive relationships with others, especially other women.

Instead, we propose that women alternate (or, ‘trade-off’) between periods of high and low competitive motivation, a process which may be mediated by underlying hormonal mechanisms (Arthur et al., 2022). Specifically, it is possible that women limit competition to conditions in which it is most beneficial, such as periods of high fertility when potential reproductive gains are highest. Elsewhere the costs of competing may outweigh the benefits, resulting in an energetic shift away from competition and toward other motivational priorities (e.g., affiliation). This theoretical framework presumes that high competitiveness during the fertile window is a byproduct of increased mating competition during this period. It bears distinct conceptual cohesion with the motivational shift hypothesis (Roney & Simmons, 2017) which posits that when reproductive gains are highest (i.e., the fertile phase) women experience an increase in sexual motivation, while the non-reproductive phase is associated with increases in survival (i.e., feeding) behavior. Understanding how competition fluctuates across the menstrual cycle is the one step towards unpacking this theoretical model.

The Current Study

In the current study, we sought to resolve existing uncertainty regarding menstrual cycle shifts in competition for NC women and HC users. Using an online self-report diary study, we collected data regarding HC use, menstrual cycle phase and self-report competitiveness across four competitive orientations: self-developmental competitiveness, hypercompetitive, competitive avoidance, and lack of interest toward competition (Orosz et al., 2018). We used menstrual onset dates to form a continuous measure of fertility probability, providing a clearer understanding of how competitiveness changes across the full menstrual cycle. The method and analytic strategy reported here was pre-registered as part of a separate investigation from this project (https://osf.io/zw8qx). The predictions here were not preregistered, however the first author formulated the hypotheses without prior access to the data and before any analyses had been conducted.

To avoid making assumptions about what women are motivated to compete for, we used a general measure of competition that assessed competitive inclinations without specifying the competitive strategy or competitive outcome. Measuring competition through four sub-domains further broadened understanding whether some competitive orientations demonstrate a stronger association with certain cycle phases relative to others. Self-development (i.e., relating to achievement motivation and success) and hyper-competitiveness (i.e., a strong results-based motivation and a desire to dominate others) are both approach-based orientations, with high scores representing a desire to compete. In contrast, high scores in competitive avoidance (i.e., an avoidance of competitions) and lack of interest in competition (i.e., an overall disinterest in competition) represent a desire to avoid competitive situations. Based on existing research demonstrating a mid-cycle increase in competitiveness in naturally cycling women but not hormonal contraceptive users, we predicted:

Hypothesis 1: *An ovulatory increase in self-reported a) self-development competitiveness and b) hyper competitiveness, in naturally cycling women but not hormonal contraceptive users.*

Hypothesis 2: *An ovulatory decrease in self-reported a) competition avoidance and b) lack of interest toward competition, in naturally cycling women but not hormonal contraceptive users.*

Method

Participants

Three hundred and thirty-six cis-gender women (M_{age} = 26.51, *SD* = 6.25) were recruited from the University of Melbourne undergraduate participation pool and the general community for a study involving daily surveys on the menstrual cycle and psychological phenomena. Selection criteria for eligibility were fluency in English; regular menstrual cycles; self-reported confidence about menstrual cycle length exceeding the scale mid-point (i.e., '3 – somewhat confident' and above); menstrual cycle length between 22-35 days (*M* = 28.13, *SD* = 2.94); aged between 18-45 years; pre-menopausal; no emergency contraception or breastfeeding or pregnancy use within the past three months; no polycystic ovarian syndrome or endometriosis; and no medically diagnosed fertility or endocrine issues, leaving n = 278 (M_{age} = 26.34, SD = 6.08).

Most participants were exclusively heterosexual (62.78%), 25.94% were occasionally or more than occasionally homosexual, 4.51% were bisexual, 5.64% were pansexual, 1.88% were exclusively homosexual and 1.13% were asexual. More than half (56.5%) of participants reported being in a relationship (n = 157) and the remaining 43.5% were single (n = 121). The largest proportion of participants of participants (18.96%) were from Australia/New Zealand, 18.59% reported mixed ethnicity, 15.24% were South-East Asian, 10.41% were North American, 7.43% were Southern European, 7.06% East Asian, 6.69% were Northern European and the remaining 15.61% each occupied less than 4% each and were collectively from Southern, Western or Central Asia, Latin America, Eastern or Western Europe, African or unspecified. Most participants reported average relative socio-economic status (57.25%), 4.09% reported low socio-economic status, and 38.66% reported high socio-economic status. For religion, 65.43% report no religious affiliation, 24.91% report being religious and 9.67% did not respond to this question.

Hormonal Contraceptive Use

The final sample included 69.63% NC women (n = 192) and 30.37% HC users (n = 86). Of the HC users, 74.39% used combined oral contraceptives, 4.88% used the vaginal ring, 3.66% used the contraceptive implant, 2.44% used the contraceptive patch and 14.63% (n = 12) did not provide sufficient information to determine contraceptive type. Most HC users (65.85%) used contraceptives containing androgenic progestins, 19.51% contained anti-androgenic progestins and 14.63% (n = 12) did not provide sufficient information to determine androgen type.

Procedure

Participants were invited to join the study in exchange for a personalized feedback report, including information about how their menstrual cycle relates to individual changes in a range of variables from the ongoing study (e.g., mood, big-5 personality, health, assertiveness, self-esteem and impulsiveness). The undergraduate participants were also provided with course credit. This study was conducted using formR (Arslan et al., 2020), an open-source survey framework that was specifically designed for longitudinal diary studies. A brief prescreening and baseline survey were used to collect demographic and menstrual cycle characteristics, followed by 28-days of daily surveys. During the daily survey stage, participants were automatically issued a daily email link at 5pm local time. After 28 days, participants were offered the opportunity to complete the study or continue collecting data for an additional 28 days (median number of daily entries = 10, *M* = 14.34, *SD* = 12.87, range = 1–53). Following the final daily survey and a 10 day pause, participants were emailed a link to the follow-up survey. Feedback reports were generated and shared with participants shortly after the final survey. All surveys were accessed via participants personal devices (including laptops, tablets and mobile phones). This study was approved by the University of Melbourne Human Research Ethics. All data were collected between September 2020 to June 2021.

Measures

Two sets of measures were used in this study: person-level variables (measured during the prescreening, baseline or follow up survey) and within-person variables (measured daily). Person-level variables included questions regarding HC use and the menstrual cycle. To identify group level differences between NC women and HC users, person-level data was also collected for depression, anxiety, stress, mate value and sociosexual orientation. As part of a larger study, within-person measures included questions regarding current menstrual cycle status, competitiveness, self-objectification, affect, Big-5 personality (i.e., agreeableness, conscientiousness, extraversion, neuroticism, openness), agency, impulsiveness, self-regulation, health, and sexual behavior. Measures related to competitiveness are reported in the current paper. Examples of each scale measure are provided in Table 1.

Competitiveness. Competitiveness was measured using the Multidimensional Competitive Orientation Inventory (MCOI; Orosz et al., 2018), a 12-item scale with four subscales: hypercompetitive orientation (α = .83), self-developmental competitive orientation (α = .83), competition avoidance (α = .83), and lack of interest toward competition (α = .77). All items were ordinal and measured on a 5-point scale ranging from strongly disagree, disagree, neither, agree, strongly agree. One item within each subscale was randomly presented each day.

Cronbach's alpha after reverse coding where appropriate found low internal consistency across the four sub-scales (α = .495) and Pearson's correlations between the two approach (R = .33) and two avoidant (R = .20) competitive orientations were small suggesting that retaining the four orientation types (as opposed to averaging values across orientations) was appropriate for these data.

Sociosexual Orientation (SOI-R). Sociosexual orientation was measured using the Revised Sociosexual Orientation Scale (SOI-R; Penke & Asendorpf, 2008). In the baseline survey, participants were asked a total of nine questions about their sexual behavior, attitudes and desires.

Mate Value. Mate value was measured using the Mate Value Scale (Edlund & Sagarin, 2014). In the baseline survey, participants were asked a total of nine questions about their perceptions of themselves as a romantic partner.

Depression, Anxiety and Stress. Mood disorders were measured in the baseline survey using the short-form Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995).

Contraceptive use. Participants indicated their contraceptive use via the following multi-choice categories: hormonal contraceptives (e.g., the pill, hormonal implant/rod, depot injections, vaginal ring, hormone plasters), barrier method (e.g., condoms, diaphragm), period/fertility tracking app (e.g., Clue, Flo, Glow), fertility awareness method (e.g., diary, calendar, temperature), having no (or less) sexual intercourse when fertile, hormonal intrauterine device (e.g., Mirena), copper intrauterine device, morning-after pill, other contraceptive, or none. Participants were also offered an opportunity to write the name of their current HC. This information was used to determine details such as route of administration (e.g., pill, patch) and androgen content (see *Participants* section above). As noted in the Participants section, anyone indicating usage of the morning after pill within the past three months were excluded from the study.

Menstrual Cycle Characteristics. Fertility probability was estimated using the backward-counting method. This method counts backward from the reported or estimated onset of menses to the day on which the outcome variable is sampled. For example, a daily survey completed 5 days prior to a participant's next menstrual onset would be assigned as backward-counted Day -5. Each backward-counted day corresponded to a specific fertility probability value based on the estimates generated by Stirnemann et al. (2013), a method advocated for by Gangestad et al. (2016). Fertility probability estimates were assigned to all participants (irrespective of HC and NC grouping), enabling us to compare patterns between HC users and NC women. Cycle-phase variation among HC participants would suggest variation unrelated to endogenous hormones.

To gather the necessary cycle data, the baseline survey asked participants to report their average cycle length and the start date of their current cycle. In each daily survey and at follow-up, participants were asked if and when their subsequent cycle had started. This survey question was accompanied by a calendar, as recommended by Welling and Burriss (2019) to assist recall accuracy. All responses were checked for consistency and where discrepancies emerged with multiple onsets reported within the same week, we used the median date. In a small number of cases where onsets were reported within the same fortnight (1.26%), we excluded these data from analysis. In cases where the next menstrual onset date was not reported (31.94% of cycles), we inferred it from the average cycle length reported by the participant at baseline (as recommended by Welling & Burriss, 2019). Each day, participants also indicated whether they were currently menstruating. In some cases, participants indicated that their cycle had started but did not indicate that they were bleeding, thus we coerced the first day of each cycle to contain values indicative of menstruation.

Table 1.
Scale measures and example questions.

Survey	Measure Name	Example Question
Baseline	**DASS**	*Thinking back over the past 4 weeks, how much do each of the following apply to you?*
	Depression	I felt that life was meaningless
	Anxiety	I felt I was close to panic
	Stress	I found it difficult to relax
	Mate Value	*Thinking about yourself overall, answer each of the following questions.*
	Total	How would you rate your level of desirability as a partner?
	Sociosexual Orientation	*Respond to each of the following questions/statements.*
	Behaviour	With how many different partners have you had sex within the past 12 months?
	Attitudes	Sex without love is OK.
	Desire	How often do you have fantasies about having sex with someone you are not in a committed romantic relationship with?
Daily	**Competitiveness**	*Over the past day…*
	Hyper competitiveness	I was willing to do whatever it took to win
	Self-development competitiveness	I enjoyed testing myself in competitive situations
	Lack of interest in competition	I didn’t care about competitions
	Competitive avoidance	I felt pressured in competitive situations

Data Analysis

HCs and Menstrual Cycle Effects

Bayesian estimation for ordinal mixed models is required to test the effects of fertility and HCs on ordinal outcomes. We used default (uninformative) priors, which ensured that our parameter estimates were maximally influenced by the data and were asymptotically equivalent to those obtained under maximum likelihood estimation. Model convergence was determined by PSR values reaching < 1.05, after which the number of Bayesian iterations was doubled to ensure stable convergence was reached. We concluded there was evidence for an effect whenever the 95% credible intervals did not cross zero. Bayesian multilevel models correct for problems of multiple comparisons through the use of partial pooling and low group level variation (see Gelman et al., 2012). The inflation of type 1 errors is therefore unlikely. Due to the nature of Bayesian models and random number generation in r simulations (including brms), output can vary between replications of the same model. To create reproducible output we applied set.seed(123) to all primary models. By setting a uniform seed value simulations can be reproduced.

Our primary model controlled for menstruation and included a random slope for fertility probability and a random intercept for the individual (model 1). The main predictor of interest was the interaction between fertility probability and HC, with support for mid-cycle shifts in outcome variables indicated by an interaction where fertility probability affected the outcome variable in the NC group only. In Wilkinson notation (Bates et al., 2014; Wilkinson & Rogers, 1973), model 1 equation can be formalised as:

$$\text{outcome}_{ti} \sim 1 + (\text{menstruation}_{ti} + \text{fertility\_probability}_{ti}) * \text{hormonal\_contraceptive\_user}_{i} + \\ (1 + \text{fertility\_probability}_{ti} \mid \text{person})$$

Robustness Tests

In models including evidence of an interaction, we ran additional robustness tests. First, we ran analyses excluding participants who did not reported a next menstrual onset date, as fertility probability for these participants was inferred based on the reported cycle length (model 2). We then repeated models among participants who were most likely to ovulate (model 3) by excluding people who were aged over 40, had highly variable cycle lengths (varied by over 7 days), were heavy smokers (1+ pack per day), high self-reported high stress levels or had recently lost a large amount of weight (over 8 kgs), had a BMI below 18.5 or above 25, or were professional and semi-professional athletes. To account for possible progestogenic effects we also created a *luteal phase* variable by backwards counting four to ten days before the onset of the next menstrual cycle and included it as an additional control variable to the primary model (model 4). Finally, we ran additional models controlling for the potential confounders of age (model 5), relationship status (model 6) and sociosexual orientation (model 7). Previous research suggests competition may vary based on age (Mayr et al., 2012) and relationship status (Cobey et al., 2013), and HC users in our sample reported higher scores on the SOI than NC users (see Table 2 below).

Datasets, model specification code and sample output are available in the Open Science Framework (https://osf.io/rs6bm).

Power and effect size estimates

To approximate a minimum detectable effect size, we simulated power for identical models to the Bayesian formula but modelled using the R package lme4. We used the simr package to estimate the power obtained to detect effects of particular sizes for the primary interaction of interest (HBC × fertility probability). To do so, we imputed the average observed fixed effect for the other variables in the model (i.e., averaged across all outcome variables), then simulated power to detect an interaction at effect sizes ranging from 0.1–0.3 (at intervals of 0.05). One thousand simulations indicated that we had 80% power to detect a minimum effect of $b = \sim.18$. To estimate Marginal R^2 and Conditional R^2 values we calculated Nakagawa's R^2 (Lüdecke et al., 2021) for the GLMM models with identical formula specification to the Bayesian models. Marginal R^2 provides variance explained only by fixed effects and conditional R^2 provides the variance explained by both fixed and random effects (Nakagawa & Schielzeth, 2013).

Data Visualization

To continuously visualize outcome variation according to cycle phase without imposing discrete phases such as menstruation and the fertile window, we fit Bayesian mixed models with a Gaussian family and cyclic cubic splines over backward-counted cycle days by HC status. For slight regularization, we set half-normal priors with a SD of 1 on the random intercepts. We then took 100 random samples from the posterior and visualized the conditional means for the continuous splines by HC status, as well as the difference in splines between NC and HC groups. The resulting visualized variation reflects the average patterns in the data and includes the uncertainty resulting from the person-level clustering in the data.

Results

Descriptive Statistics

Compared to NC women, HC users had less restrictive sociosexual behavior and attitudes. No other differences emerged for person level variables (see Table 2).

Table 2.

Person level variables for NC women and HC users

Variable	NC (n = 192)		HC (n = 86)		P value
	M	SD	M	SD	
Demographics					
Age	26.8	6.64	25.4	4.61	.231
Weight (kg)	62.5	12.7	64.6	15.9	.470
Height (cm)	164	7.73	164	6.22	.583
Mate Value					
Total	3.37	0.80	3.53	0.79	.119
DASS					
Depression	1.92	0.69	1.97	0.66	.586
Anxiety	1.66	1.57	1.62	1.57	.354
Stress	2.37	0.51	2.39	0.54	.911
SOI-R					
Total	2.58	1.03	2.84	0.90	.015*
Behaviour	2.26	1.66	2.69	1.59	.001***
Attitude	3.13	1.16	3.60	0.99	.002**
Desire	2.35	0.29	2.21	0.83	.267

Note. M and SD are used to represent mean and standard deviation, respectively. Data are compared by Mann-Whitney U-test. Significant items are highlighted in bold.
* indicates p < .05. ** indicates p < .01. *** indicates p = .001.

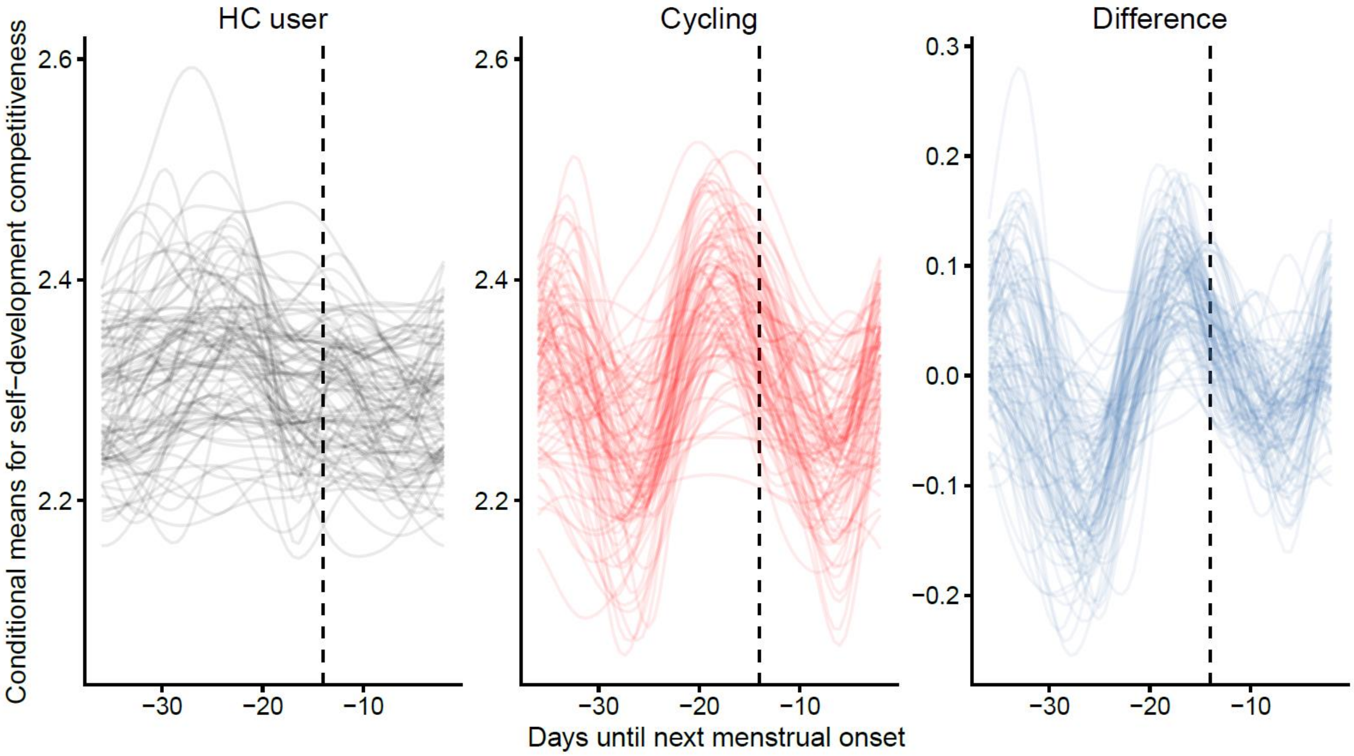
Hypothesis Testing

Table 3 contains the results of the primary mixed models (model 1) for competitive orientation. As hypothesized, there was evidence for an interaction between Fertility x HC use for self-development competitiveness (H1a; see Figure 1). NC women (b = 0.73, SE = 0.28, CrI = 0.18, 1.29), but not HC users (b = -0.12, SE = 0.37, CrI = -0.85, 0.59), experienced a mid-cycle increase in self-report self-development competitiveness. Robustness tests indicated that this effect was 23% stronger when we restricted the sample to women who we didn't infer ovulation without a next menstrual onset date (b = 0.90, SE = 0.32, CrI = 0.28, 1.52). However, restricting the sample to women most likely to ovulate did not provide evidence of an effect (b = 0.34, SE = 0.58, CrI = -0.81, 1.50), likely owing to the 59.6% reduction in sample size (n = 76). The interaction effect was not moderated by age (CrI = -0.04, 0.30), relationship status (*CrI* = -1.32, 3.00) or sociosexual orientation (*CrI* = -0.59, 1.40). For competitive avoidance (H2a), there was weak evidence for a Fertility x HC use interaction. Although this interaction suggests cycle shifts may vary between NC women and HC users, the large credible interval (which almost crosses zero) suggests a high degree of uncertainty and visual inspection of competitive avoidance (Figure 2) produces no clear patterns for either group.

Counter to our hypotheses, hyper-competitiveness and lack of interest in competition did not provide evidence for a Fertility x HC interaction. Even so, a negative association between HCs and *hyper-competitiveness* was observed, indicating that HC users report less hyper-competitiveness compared to NC women. Conversely, a positive association between HCs and *lack of interest in competition* indicates that HC users may lack interest in competing compared to NC women. For both variables, large credible intervals (and credible intervals close to zero) suggest a high degree of uncertainty. Further, for *hyper-*

Figure 1

Levels of self-development competitiveness as a function of backward-counted cycle day.



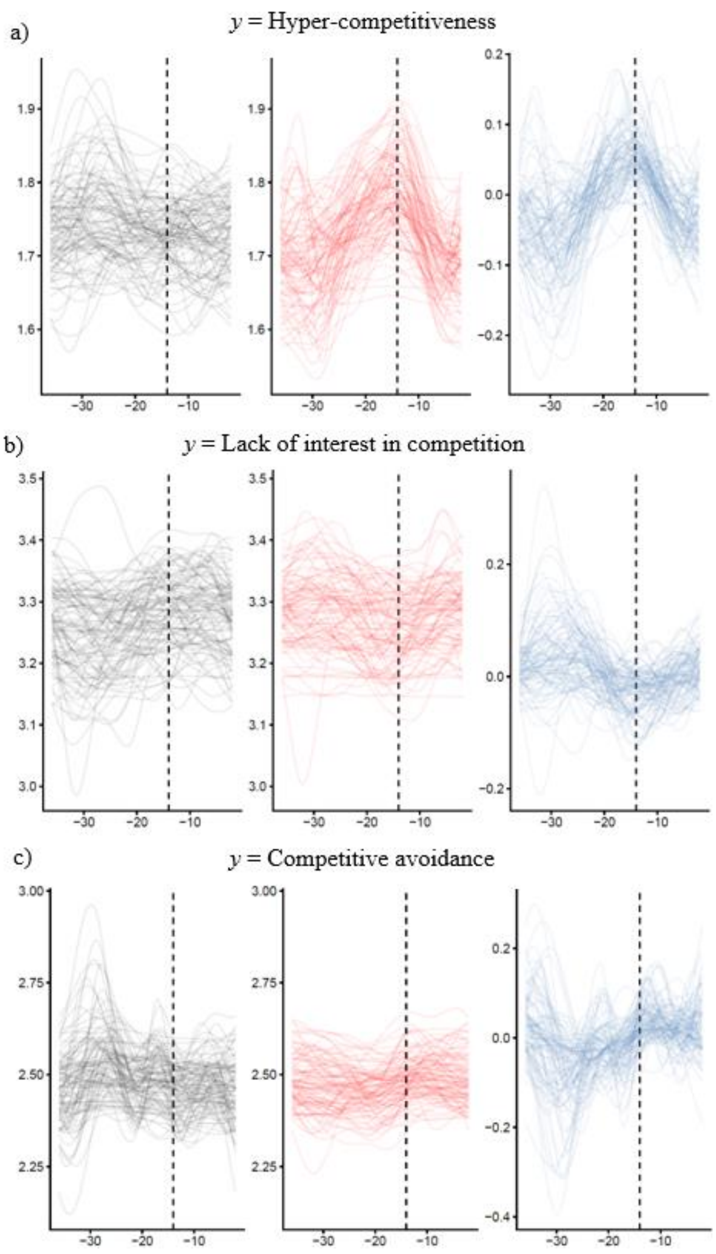
Note. This figure shows the conditional mean for self-development competitiveness (y-axis), plotted based on backward-counted cycle day (x-axis). Black = Hormonal contraceptive users; Red = Naturally cycling women; Blue = difference in splines between NC and HC groups; dashed line = estimated day of ovulation.

competitiveness, *competitive avoidance* and *lack of interest in competition*, setting a different seed value (or resetting the model to randomly generate a seed value) produced some credible intervals that crossed zero.

Plotting the effects of backward counted cycle day on the remaining outcome variables, delineated by HC and NC subgroups, depicts an interesting, albeit exploratory, relationships between variables (see Figure 2). Hyper-competitiveness visually peaked for NC women around the estimated day of ovulation, where such effects are not seen for HC users. In contrast, lack of interest in competition and competitive avoidance displayed no clear patterns for HC users of NC women.

Figure 2

Levels of hyper-competitiveness, lack of interest in competition and competitive avoidance as a function of backward-counted cycle day.



Note. This figure shows the conditional mean for a) hyper-competitiveness; b) lack of interest in competition; c) competitive avoidance (y-axis), plotted based on backward-counted cycle day (x-axis). Black = Hormonal contraceptive users; Red = Naturally cycling women; Blue = difference in splines between NC and HC groups; dashed line = estimated day of ovulation.

Table 3. Multi-level model output showing associations between cycle phase, HC use and competitive orientation

	Competitive Orientation											
	Self-development competitive			Hyper-competitive			Competitive avoidance			Lack of interest		
	Est	SE	CrI	Est	SE	CrI	Est	SE	CrI	Est	SE	CrI
Intercept	2.03	0.12	1.81, 2.27	1.69	0.11	1.49, 1.93	2.02	0.11	1.81, 2.25	1.61	0.09	1.43, 1.80
Main Effects												
Fertility	**0.76**	**0.28**	**0.22, 1.30**	0.25	0.27	-0.29, 0.77	-0.36	0.27	-0.89, 0.19	-0.01	0.24	-0.48, 0.48
Menstruation	0.13	0.11	-0.09, 0.35	0.01	0.11	-0.20, 0.22	-0.03	0.10	-0.23, 0.17	0.13	0.10	-0.06, 0.33
HC Use	0.13	0.33	-0.52, 0.77	**-0.60**	**0.30**	**-1.17, -0.02**	-0.06	0.32	-0.71, 0.58	**0.55**	**0.27**	**0.00002, 1.08**
Interaction												
F x HC	**-0.95**	**0.47**	**-1.88, -0.03**	-0.48	0.47	-1.42, 0.44	**0.90**	**0.46**	**0.005, 1.82**	-0.01	0.41	-0.83, 0.78
M x HC	-0.02	0.19	-0.40, 0.36	-0.00	0.20	-0.40, 0.40	0.04	0.18	-0.32, 0.41	-0.09	0.18	-0.44, 0.26
*N**	270			270			270			271		
Observations	3,819			3,865			3,854			3,875		
Conditional R^2	0.484			0.397			0.496			0.372		
Marginal R^2	0.003			0.011			0.001			0.006		

Note. Model output based on set.seed(123) and are reported to two decimal places except when values equal <0.01. Est = Estimate, representing unstandardised regression coefficients. SE = Standard error. CrI = 95% credible interval. Bold font shows credible intervals that do not cross zero. To estimate Conditional and Marginal R^2 values we re-ran the Bayesian models as frequentist analysis using lme4 package in r. Marginal R^2 provides variance explained only by fixed effects and conditional R^2 provides the variance explained by both fixed effects and random effects. *7 participants were excluded from the main analysis due to missing fertility probability data.

Discussion

We used a longitudinal diary study to investigate the relationship between competitiveness, menstrual cycle shifts and HC use. We investigated fertility probably effects for four competitive orientations: self-developmental competition, hyper competitiveness, competition avoidance, and lack of interest toward competition. Each orientation captured a different aspect of competition and was domain general, providing nuanced insights regarding hormones and competition that avoided making inferences about the outcome of competition or the competitive strategy. Much like the menstrual cycle literature more broadly, results were mixed across the four competitive orientations. We found evidence of a mid-cycle increase in self-development competitiveness for NC women but not HC users. We also found preliminary evidence for a negative association between HCs and hyper-competitiveness and a positive association between HCs and lack of interest in competition, but note that large credible intervals (and credible intervals close to zero) suggested a high degree of uncertainty. Competitive avoidance was not reliably associated with fertility probability, HC use or their interaction, with credible intervals for the interaction likewise suggesting a high degree of uncertainty and visual inspection of competitive avoidance yielding no clear patterns. Below we review each orientation within the context of existing literature and in relation to the theoretical framework we presented in the introduction.

Self-development competition is an approach-based orientation, related to achievement motivation and success (Orosz et al., 2018). We found evidence of this outcome being associated with the interaction between HC use and fertility probability. Sub-group analysis revealed that when fertility probability was high compared to low, NC women but not HC users self-reported higher self-development competitiveness. To our knowledge, this is the first study to identify a mid-cycle increase in a domain-general motivation to compete and achieve in order to benefit the self, a pattern that is not observed in HC users. Compared to fertility x HC interactions observed in similar studies (e.g., Arslan et al., 2018; Schleifenbaum et al., 2021), the size of this fixed effect (marginal $R^2 = .003$) was of a similar magnitude, while the size of the fixed and random effects (conditional $R^2 = .484$) and the size of the unstandardized[5] regression coefficient of the interaction was considerably larger. The conditional R^2 reflects the between level variance (i.e., differences in intercepts among subjects), and variance around the effect of fertility probability for each individual (i.e., if the slope varies among different people). This suggests that we had considerably more heterogeneity at the between-person level, which may reflect cross-cultural differences in our diverse participant pool compared to similar studies (e.g., Arslan et al., 2018; Schleifenbaum et al., 2021). From a theoretical perspective, mid-cycle increases in self-development competition that is only observed in NC women provides support for both the ovulatory competition hypothesis (Durante et al., 2014; Nikiforidis et al., 2017) and the theory of HCs as endocrine mediated behavioral disruptors (Arthur et al., 2022).

Competitive avoidance is an avoidance-based orientation, with scores indicating a general anxiety towards competitive situations (Orosz et al., 2018). In our study, weak evidence for an interaction between fertility and HC use revealed that the effect of fertility on competitive avoidance differed for NC women and HC users. However, analyzing each group separately revealed no evidence for an association between fertility and competitive avoidance. In other words, while the slope of fertility differed between the groups, neither slope was significantly

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[5] The use of unstandardized 5-point outcome variable is comparable to similar longitudinal designs (e.g., Arslan et al., 2018; Schleifenbaum et al., 2021). However, we note that previous studies used surveys with a greater number of items and thus may better reflect a continuous outcome variable.

different from zero. This result could indicate that the current work was insufficiently powered to detect a small true effect, though sensitivity analysis suggested that our work was powered to detect a minimum effect size of *b* = ~.18. It is also possible that there is no notable association between fertility or HCs and competitive avoidance, replicating past work (e.g., Hahn et al., 2016; Lucas & Koff, 2013; Ranehill et al., 2018). Given the large credible interval for this interaction, and that the interval approached zero (or included zero, depending on the seed value), our data suggests that competitive avoidance is probably not associated with fertility or HC use to any meaningful magnitude. We note that this does not rule out the possibility that competitive avoidance is associated with other endogenous hormones and expand upon this possibility in the 'Future Directions' below.

Results for hyper-competitiveness and lack of interest in competition provided weak evidence in favor of lower competitive motivation in HC users. Specifically, HC use was negatively associated with hyper-competitiveness and positively associated with a lack of interest in competition. A general reduction in competitiveness for HC users is in line with previous research demonstrating that HCs are associated with reduced competitive motivation. For instance, Casto et al. (2020; 2021a) reported that when competing in a physical task, NC women were willing to compete longer than HC users. Bradshaw et al. (2020) reported a similar association between reduced competitive persistence and HCs, whereby NC women persist for longer and thus outperform HC users on a series of tasks. For both of our findings, however, credible intervals were large and close to zero, suggesting a high degree of uncertainty. We recommend that these results be interpreted as preliminary and suggest that future research should aim to replicate these effects in a larger sample.

As highlighted by a reviewer, visual inspection of Figure 1 (self-developmental) and Figure 2 (specifically, hyper-competitive and competitive avoidance) indicates some variability around menstruation. Although our statistical analysis did not detect evidence for an association between menstruation and any competitive orientation, it is possible that there are other cycle related peaks (or troughs) in competitiveness that our data did not detect. Future investigations into patterns across the entire cycle, including statistical operationalization of other cycle events (i.e., luteal phase, pre-menstrual phase) may provide further insight into shifting motivational states.

Several null findings are also worth investigating. Counter to our hypotheses, hyper-competitiveness, competitive avoidance and lack of interest in competition were not associated with fertility probability in NC women, nor was there an interaction between fertility probability and HC for hyper-competitiveness or lack of interest in competition. Women are known to face societal pressure in competitive contexts (see Benenson, 2013; Campbell, 2013; Reynolds, 2020) and self-report surveys may have been vulnerable to impression management when responding to questions about hyper-competitiveness. In support of this possibility, the intercept for hyper-competitiveness was lower than self-development competitiveness (see Table 3), indicating that women were less likely to rate themselves as hyper-competitive overall. Another possibility is that desire to win and to beat others is not associated with cycle phase or HC use. Critically, previous studies reporting that cycle phase and HCs are not associated with overt competitiveness (e.g., Hahn et al., 2016; Ranehill et al., 2018) have used measurement tools that are undermined by the socialization of competition in women, including self-report measures or male-biased experimental designs tasks (for review, Casto & Prasad, 2017). Research investigating behavioral avoidance of (or disinterest in) competitions (as opposed to competitive motivation) is lacking and limits our ability to theorize regarding hormonal correlates of competitive avoidance. Using behavioral measures to investigate associations between cycle phase and the avoidance of socially competitive situations may provide a novel approach to measuring competition in women.

Nuanced Competitive Strategies in Women: Insights for status seeking among users and non-users

The results reported here demonstrate that when studying competition in women, it is important to differentiate between different types of competition. Although self-developmental competitiveness and hyper-competitiveness are both approach-based orientations, each orientation was associated with different behavioral strategies and status outcomes. One theory of status-seeking in humans indicates that there are two main pathways to status attainment: the prestige route and the dominance route (Cheng et al., 2013; 2014; Henrich & Gil-White, 2001). Prestige-based strategies involve displays of skills and knowledge, while dominance-based strategies involve using power to coerce or influence others. Of the two approach-based competitive strategies studied here, self-development competition aligns with prestige while hyper-competitiveness aligns with dominance. For instance, self-development competition is centered on the improvement of personal skills and abilities, while hyper-competitiveness represents a desire to win at any cost (Orosz et al., 2018). Research also shows that both prestige and self-development competition are negatively correlated with aggression (Johnson et al., 2007; Ryckman et al., 1996).

Within the context of status research, a potential implication of our findings is that HC use may decrease the mid-cycle peak in prestige-seeking observed in NC women, and that HC use may decrease dominance-based status-seeking strategies overall. Although both dominance and prestige are effective in obtaining status (Cheng et al., 2013; McClanahan et al., 2021), women are more likely to use prestige (Hays, 2013). A mid-cycle suppression of prestige-motivated competitiveness may thus have implications on HC users' ability to gain status. For instance, while fertile women may use prestige to signal that they are competent and skilled, an attenuation of this relationship suggests that HC use diminishes the desire to signal competence and instrumental value to others. Given that we did not measure dominance and prestige, we acknowledge that the link between our research and these constructs is highly speculative and requires direct investigation. Even so, given the importance of status in human society this is an important area for future research.

Proposed Hormonal Mechanisms Affecting Hormones and Competition

Although we did not measure hormone levels directly, the fertile phase is accompanied by rising estradiol until ovulation occurs (Baird & Fraser, 1974). A fertile phase increase in self-development competition may thus be driven by an increase in estradiol. Existing hormone research has illustrated several ties between estradiol and competitive behaviors in humans. In adolescent girls, estradiol is positively correlated with aggressive risk taking (Vermeesch et al., 2008), while women show positive correlations between estradiol and implicit power motivation (Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007) and assertiveness (Blake et al., 2016). In men, estradiol has also been associated with psychological aggression (Erikson et al., 2003), which includes behaviors women commonly use to compete with others (e.g., social isolation, humiliation). For these reasons, we propose further studies investigating the role of estradiol on self-developmental competition.

The mechanisms through which HCs are associated with competition is not yet well understood, though it is possible that HCs influence competition through multiple pathways (for review, Arthur et al., 2022). One possibility is that HCs suppress a mid-cycle increase in estradiol. This possibility is supported by previous research demonstrating both a positive correlation between endogenous estrogens and competition, and that HCs attenuate the relationship between estradiol and power that is experienced by NC women (Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007). Here we find that HCs attenuated the mid-cycle increase in self-developmental competition, which may support the role of estradiol in achievement-based competitiveness. Direct tests of the relationship between estradiol and competition in HC users presents a fruitful opportunity for research.

Another possible mechanism that HCs may disrupt competition is through the relationship between HCs and testosterone. Testosterone has been linked to competition in men (for review, Archer, 2006) and, to a lesser extent, women (Casto et al, 2019; Edwards & Casto, 2013). A well-documented effect of HCs is the lowering of serum total and free testosterone levels by an average of 31% and 61%, respectively (Zimmerman et al., 2014). Linking HCs and testosterone in a sample of NC women and a subset of HC users (oral contraceptive users only), Casto et al. (2021) revealed that lower testosterone levels in HC users explained differences in competitiveness between HC users and NC women. In our study, the main effect of HC use on hyper-competitiveness may thus be explained by the depression of testosterone across the full cycle for HC users. Some women also experience a small-to-moderate mid-cycle increase in testosterone (Bui et al., 2013 Rothman et al., 2011) which may explain the mid-cycle increases in self-development competitiveness in NC women but not HC users. However, few studies have explicitly tested the effect of testosterone and competitiveness in fertile NC women, limiting our ability to draw further conclusions.

One final possibility is that HCs disrupt competition through the extended delivery of synthetic progestins. During reproduction, an important physiological role of progesterone is to maintain a healthy pregnancy. Some research suggests that the luteal phase is associated with increased health-related risks. For example, pathogen avoidance is elevated for women in the luteal phase compared to follicular phase (Miłkowska et al., 2021; but see, Jones et al., 2018b; Stern & Shiramizu, 2022), and for female mice following injection with progesterone (Bressan & Kramer, 2022). Progesterone is also associated with higher subjective anxiety in general (Reynolds et al., 2018; but see, Hahn et al., 2020). It may be that progesterone also inhibits risk taking that is specific to social settings, including competition (Casto et al., 2021b). For example, in the case of hyper-competitiveness, high levels of synthetic progesterone in HC may lead HC users to avoid situations that require them to compete with others. It is important to note that few studies have directly investigated the link between competition and progesterone, providing an opportunity for future research.

Though we have presented several possible mechanisms through which hormones may influence competition, it is likely that competition is mediated through a range of complex and specialized neuroendocrine pathways. For instance, mating relevant competition may be concentrated in the fertile phase, when estradiol is high, and conception is most likely. In contrast, testosterone levels may influence baseline levels of competitiveness and not competitive fluctuations across the cycle. And finally, progesterone may drive avoidance of competitions that are physically or psychologically risky to a woman (or her future offspring). An important takeaway point is that these questions warrant further investigation and that investing time and money in understanding female physiology is important because it affects a significant proportion of the world’s population.

Limitations and Future Directions

The research presented here has several limitations. Our design relied on self-report measures of competition, raising concerns about social desirability bias and self-enhancement (Paulhus & Vazire, 2007). Future research testing the link between the self-report measures used in this study (i.e., MCOI; Orosz et al., 2018) and actual behavior would enhance the strength and validity of our conclusions. Our design also uses a general measure of competition (which could mean different things to different people) and assumes that participants are aware of changes to their own competitive motivations, despite the fact that hormones may mediate behavior through non-conscious mechanisms. Each day, our survey structure presented participants with one of three possible questions for each of the four competitive orientations. Although we did not use a single item measure (which are less reliable than scales with multiple items; Diamantopoulos et al., 2012), the presentation of questions did vary across participants and days, which may have led to an increase in measurement error. A replication of this study using a larger number of survey items or demonstrating changes to competitive behavior (in place of competitive motivation) would strengthen the impact and validity of these findings.

Our design also had limitations in terms of fertility estimates and sample size. In addition to estimating fertility using daily diary entries, employing non-counting methods (e.g., luteinizing hormone tests) would have further improved the validity of our estimates. Even so, research has shown that studies with large samples and repeated measures have many strengths, including accounting for reduced accuracy in identifying the fertile phase (Arslan et al., 2022). Although our analyses included almost 3,900 observations, sensitivity power analyses indicated that we were only sufficiently powered to detect effect sizes of *b* = ~.18. Robustness tests which restricted our analyses to women who reported a next menstrual onset date (i.e., excluding participants that we did not need to infer a menstrual onset date; model 2) and women most likely to ovulate (model 3), increased the validity of our cycle phase estimates but further reduced the overall samples size. A larger sample of HC users would have allowed us to investigate within-group differences among HC users, including comparisons of administration type, chemical formula and duration of HC use. These limitations could be addressed in future research by introducing direct hormone measurement (e.g., salivary assays, luteinizing hormone tests) and increasing the total sample.

A final limitation of this study is that causal effects of HCs cannot be concluded based on the current quasi-experimental design. It is possible that HC users differ from non-users in a meaningful way, leading to unobserved selection effects that may influence competitive motivation. Botzet et al. (2021) attempted to disentangle causal effects from selection effects in a study investigating the relationship between HCs and measures of relationship quality and sexual function. In their analysis, they found that age and relationship duration were significant predictors of contraceptive choice (e.g., hormonal vs non-hormonal), suggesting that HC users and non-users vary in meaningful ways. In any case, to truly determine causation, a randomized control trial or longitudinal design where participants are tested both on and off HCs would be needed.

Theoretical and Practical Implications

The theory presented in our introduction proposes that women alternate (or, ‘trade-off’) between periods of high and low competitive motivation. Our data partially supports this theory while also highlighting limitations in the way competition is researched among female populations. To better understand the relationship between the menstrual cycle and competitiveness, researchers should consider using (or developing) measures which bypass (or are sensitive to) the socialization of female competitiveness. Further, although this theoretical framework presumes that high competitiveness during the fertile window is a byproduct of increased mating competition during this period, the data collected in the current study cannot test this hypothesis. To investigate what drives increased competitiveness during the fertile phase, researchers may seek to correlate mating related competition with other forms of competition.

One final caveat is that our study looked at possible high and low phases of competition, though a more developed theoretical framework requires a trade with other biologically relevant behaviours. As outlined above, the motivational shift hypothesis (Roney & Simmons, 2017) proposes that the fertile phase is associated with an increase in sexual motivation and decrease in feeding behavior. Investigating a trade-off between competition and affiliation, or competition and cooperation may better inform our understanding of the functional benefits of cycling competitive motivation. Future research should continue to investigate the possibility of an endocrine-mediated trade-off between competition and other key behaviours.

Understanding how the menstrual cycle and HCs influence competition is important because it contributes to our holistic understanding of female competition. Engaging in competitive situations provides women with a host of benefits that are only available to those willing to compete against others. For example, achieving gender equality requires that men and women compete for access to the same resources. Likewise, the finite number of mates in an environment means that only women who compete effectively will gain access to high-quality mates and the resources that they hold. Failing to investigate the way behavior changes across the menstrual cycle limits our understanding of an important biological correlate of status behaviors, and suppressing it risks the perpetuation of masculinity as the dominant biological framework for humans. Identifying potential barriers to competition – be it social, political or biological – is of value to women around the world.

Conclusion

Our research suggests that NC women experience fluctuations in achievement-oriented competitiveness across the cycle. HC use eliminated the mid-cycle peak in self-developmental competitiveness and may be associated with reduced competitive motivation overall. By understanding the effect of HCs and fertility on competitiveness, this information can be used to inform women of the possible costs and benefits of HC use. This study improves our understanding of hormones and competition while providing new information regarding the potential psychological consequences of HCs.

Data and Code Availability

The data generated during the current study are available in the Open Science Framework repository, https://osf.io/rs6bm

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Chapter 4: Hormonal contraceptive use, not menstrual cycle phase, associated with reduced interest in competition

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Abstract

Despite numerous studies attempting to understand the influence of fertility and hormonal contraceptives on competitive outcomes, the association between these variables remain a contentious issue. Using a longitudinal, online diary study with over 5,600 daily observations (*N* = 302 community and undergraduate student participants), we explored the effects of fertility probability and hormonal contraceptive use on a range of self-report competitive outcomes. Specifically, we sought to replicate existing findings by examining whether self-reported competitive motivation increases mid-cycle and how hormonal contraceptive use affects these patterns. We also sought to extend this literature by collecting a range of self-report measures of competitive behavior across the menstrual cycle. Using an evolutionary and data-driven framework, we combined six behaviors females use to compete for mates and status: gossip, social comparison, negative evaluations of others, appearance enhancement, giving advice and taking sexy self-portraits. Contrary to our predictions, fertility probability was not associated with fluctuations in self-reported competitive motivation or behavior. However, replicating existing literature, hormonal contraceptive users reported a general lack of interest in competition compared to non-users. This latter finding raises important questions about the long-term implications of hormonal contraceptive use and suggests a need

for further research to investigate the psychosocial effects of hormonal contraceptives. Finally, as a near direct replication of an existing longitudinal study, the current research offers a unique contribution by considering the role of context in hormone mediated research. We question the idea that a failure to replicate reflects the quality of the theory or the research, but instead suggest that context should be considered when developing psychological theory.

Introduction

Competition arises when an individual's use of a resource reduces the availability of that resource for others, irrespective of whether individuals meet in direct contest (Andersson, 1994; Birch, 1957). Across generations, human biological systems and behaviors have evolved to optimize reproduction and survival in response to competitive ecological pressures (Ellison, 2017; Stearns, 1989). Behavioral endocrine research explores the relationship between evolved hormonal mechanisms and psychological or behavioral outcomes. For instance, an extensive body of work investigates whether changes in fertility and ovarian hormone levels are associated with short-term competitive interactions, such as competition for mates and status among females (e.g., Casto et al., 2023; Casto & Edwards, 2016; Denes et al., 2023; Ranehill et al., 2018; Stern et al., 2023). Despite the ever-increasing size of this literature, evidence regarding an association between ovarian hormones and competitive motivation and behavior is mixed and thus necessitates further investigation (Jones et al., 2019; Nikiforidis et al., 2017).

In the current paper, we investigated associations between fertility, competitive motivation, and self-report competitive behavior. We used a multi-national, longitudinal diary design to capture rich within-person data across the full menstrual cycle. By contrasting competitive motivation and behavior reported on high and low fertility days, we were able to identify cycle related shifts in outcomes that may increase women’s access to mates and opportunities for status. Given strong disagreement currently reported in the menstrual cycle literature, the current study provides a methodologically robust test of the effects of fertility on competitive motivation and behavior.

Hormonal processes and adaptive trade-offs

Behavioral endocrine models argue that the prototypical function of hormones is to coordinate multiple physiological and behavioral systems according to internal and external inputs (Beach, 1974; Roney, 2016). Put another way, hormones help coordinate the alignment of physiological and behavioral responding to changes in the environment. Such coordination is the result of a combination of transient (e.g., cortisol reactivity in response to a stressor; Helminen et al., 2019) and sustained (e.g., post-menopausal estradiol decline; Dalal & Agarwal, 2015) hormone changes. These hormonal mechanisms enable organisms to adapt flexibly to varying environmental demands and life stages, optimizing survival and reproductive success across different contexts and time scales.

The menstrual cycle is characterized by cyclical fluctuations in estradiol and progesterone, typically lasting an average of 28 days. During the early follicular phase, menstruation is characterized by low levels of estradiol and progesterone (Hampson, 2020). Estradiol begins rising in the mid-late follicular phase and peaks just prior to ovulation. After ovulation, estradiol levels decline briefly before rising again during the luteal phase, though not as high as the pre-ovulatory peak. Progesterone rises steadily during the luteal phase, peaking roughly one week after ovulation and falling rapidly before the onset of the next menstrual period (Hampson, 2020). Although ovarian hormones act on the reproductive system to prepare the body for pregnancy (Thiyagarajan et al., 2023), receptors for these hormones are found in cells throughout the brain and body (McEwen & Milner, 2017).

Given their proliferation across multiple physiological systems, ovarian hormones are associated with processes that are not directly related to reproduction (Beltz & Moser, 2019; McEwen & Milner, 2017). For example, estradiol positively predicts some cognitive function (e.g., verbal memory, information processing), positive mood, cardiovascular health, bone integrity, and metabolic regulation (Balzer et al., 2015; Cauley, 2015; Luine, 2014; Mauvais-Jarvis et al., 2013; Mendelsohn, 2002; Russell et al., 2019; Sherwin, 2006, 2012). Conversely, although progesterone may have neuroprotective properties (Singh, 2006; Stein et al., 2008) and may predict spatial cognitive performance (Shirazi et al., 2021), high progesterone has been associated with impaired cognitive performance (e.g., memory, Barros et al., 2015). Finally, disruption to endogenous hormone production through synthetic hormone use also appears to influence cognition and mood (Beltz, 2022; Beltz et al., 2015; Robakis et al., 2019), further demonstrating effects of ovarian hormones beyond the reproductive system.

Variation in estradiol and progesterone may also coordinate adaptive trade-offs through dual endocrine signaling. The motivational priorities theory (Roney, 2018, 2023) proposes that high estradiol during ovulation is coupled with increased mating relevant behaviors, while high progesterone orients individuals towards increased caloric consumption necessary for growth and maintenance. In support of this theory, estradiol reliably correlates positively with self-reported sexual desire (Marcinkowska et al., 2023; Shirazi et al., 2019) and negatively with appetite and food intake, while opposing associations are observed for progesterone (Jones et al., 2018; Roney & Simmons, 2013, 2017). Sexual desire and appearance enhancement also peak around ovulation in longitudinal diary studies, meanwhile, feeding behaviors increase during the luteal phase (Saad & Stenstrom, 2012; Schleifenbaum et al., 2024). Trade-offs may also occur between cycles in the same individual, whereby sexual motivation is highest during cycles with higher fecundity (i.e., shorter, more regular cycles) relative to potentially anovulatory cycles (i.e., long, irregular cycles), though further research is required (Mengelkoch et al., 2024). Together these studies provide empirical support for an adaptive trade-off between reproductive and other survival needs.

Ovarian hormones and competition

The current paper is interested in cycle-related shifts regarding competition for mates and status. Mating competition involves competing for mates with desirable traits, such as intelligence and kindness, physical attractiveness, and access to financial resources (Buss et al., 2001; Walter et al., 2020). Securing a high-value mate can lead to higher quality reproductive opportunities, greater offspring investment, and improved access to resources, relative to low-value mates (Clutton-Brock, 2017; Krems et al., 2023; Stockley & Bro-Jørgensen, 2011). Among human females, Cashdan (1996) proposes two broad forms of mating competition: direct (i.e., competitor derogation and fights) and indirect (i.e., appearance enhancement and status seeking). Other models of female intrasexual competition similarly propose dual pathways, such as competitor derogation and self-promotion (Buss, 2023; Buss & Schmitt, 2019; Fisher et al., 2009; Krems et al., 2023). Depending on the context and whether a competitor is seeking high- or low-partner investment, individuals may adopt direct or indirect strategies to attract and secure desirable partners.

Although status is not a physical resource, high status positions are scarce and thus subject to competition. Status can be achieved through success in many domains, including employment and education (Deary et al., 2005; Mirowsky, 2017), wealth or income (Cutler et al., 2008), social connectedness (Hoffman et al., 2023; Kalkhoff et al., 2010), and physical attractiveness or strength (Blake, 2022a; Blaker & van Vugt, 2014; Bradshaw & DelPriore, 2022). High relative status is associated with health and reproductive benefits (Adler et al., 1994; Prall & Scelza, 2024; von Rueden & Jaeggi, 2016; Zhang & Santtila, 2022), though the pursuit of status is often fueled by its potential to enhance mating opportunities (von Rueden et al., 2011).

Despite the potential benefits of competition described above, engaging in competition can lead to inflated risks (Marshall & Uller, 2007; Kokko & Jennions, 2008). Physical contests increase the likelihood of injury or death, and involve energetic and opportunity costs (i.e., energy and time that cannot be allocated to other critical processes; Briffa & Sneddon, 2007; Stearns, 1989). Social costs are also common, including social isolation, negative stereotyping, and restricted access to resources (Clutton-Brock & Huchard, 2013; DelPriore et al., 2018; Reynolds, 2022; Stockley & Campbell, 2013). Given the potential costs of competition, selectively competing when gains are high (and costs are low) may have been advantageous (Arthur & Blake, 2022). Formalizing this idea, the ovulatory competition hypothesis proposes that ovulation boosts a woman's desire for positional advantage when the potential gains (e.g., fertilization) are elevated, relative to other periods (Durante et al., 2014; Nikiforidis et al., 2017).

In the remainder of the introduction, we examine evidence on menstrual cycle effects on common competitive strategies, namely appearance enhancement, self-promotion, and competitor derogation. Note, however, that ovarian hormones may be associated with other competitive strategies (e.g., mate guarding, economic contests; Hurst et al., 2016; Krems et al., 2016; Necka et al., 2016; c.f., Ranehill et al., 2018; Strojny et al., 2021) and some research suggests female vocal and facial attractiveness peak during ovulation (e.g., Pipitone & Gallup, 2008; Puts et al., 2013; Roberts et al., 2004). Due to space constraints, a detailed discussion of these processes is not included in this paper and can be reviewed elsewhere (e.g., Botzet et al., 2024; Galindo-Caballero et al., 2023; Haselton & Gildersleeve, 2011; Schleifenbaum et al., 2022).

Appearance enhancement

Appearance enhancement involves improving or altering physical attributes and is often cited as a core competitive strategy among women (Arnocky & Vaillancourt, 2017; Cashdan, 1996; Davis & Arnocky, 2022). Given that attractiveness and youthfulness are valued highly in women, physical attractiveness theoretically increases a woman's desirability for potential mates (Bech-Sørensen & Pollet, 2016; Davis & Arnocky, 2022; Walter et al., 2020). Appearance enhancement can also create opportunities for status acquisition by increasing individual agency and through social benefits conferred upon attractive women (Blake, 2022a; Bradshaw & DelPriore, 2022). Although women likely want to appear attractive throughout the entire menstrual cycle, the potential genetic benefit of attracting a high-quality partner is arguably highest (or most salient) when conception risk is elevated (Nikiforidis et al., 2017).

Many cycle-related studies have focused on ovulatory changes to appearance enhancement and clothing choice. Early research suggested that fertility and elevated estradiol both positively predict women's desire to buy or wear sexualized (e.g., tight, revealing) clothing (Blake et al., 2017; Durante et al., 2008, 2011; Grammer et al., 2004; Saad & Stenstrom, 2012; Schwarz & Hassebrauck, 2008) and the amount of time spent on grooming (Röder et al., 2009; Saad & Stenstrom, 2012). In contrast, two well-powered longitudinal diary studies failed to find robust evidence of fertility effects on appearance enhancement, grooming behavior, or preferences for sexualized clothing (Arslan et al., 2018; Schleifenbaum et al., 2021). Stern et al. (2024) similarly found no evidence that fertility, estradiol, or progesterone concentrations positively predicted any appearance enhancement strategy. Thus, despite early support for an ovulatory increase in appearance enhancement and clothing choice, repeated non-replication has cast doubt on this effect.

Self-promotion and competitor derogation

A variety of methods have been used to measure women's desire for relative status. Whilst mating outcomes are not the only reason women compete for status (see Blake, 2022a; Bradshaw & DelPriore, 2022), given the reproductive significance of fertility, ovulatory increases in status seeking are likely to be strongest for processes with potential reproductive rewards. For this reason, we focus on strategies consistent with women's mate attraction: namely, self-promotion and competitor derogation (Buss & Schmitt, 1993; Schmitt & Buss, 1996).

Recent longitudinal diary studies suggest that achievement- and prestige-based competitive motivation increase mid-cycle, though evidence for other forms of competitive motivation is limited. Arthur and Blake (2022) used self-report measures to investigate four types of competitive motivation. Fertility was associated with an increase in achievement-based motivation, though no effect of fertility was observed for hyper-competitiveness (i.e., desire to beat others), competitive avoidance, or a general lack of interest in competition (Arthur & Blake, 2022). Similarly, Blake (2022b) found an association between fertility and motivation to obtain status through prestige (but not dominance) processes. This work suggests that women are motivated to appear competent (via prestige and achievement) during the fertile phase but do not want to appear dominant, possibly due to backlash evoked by dominance behavior among women (Williams & Tiedens, 2016). These results are consistent with self-promotion, whereby individuals maximize their attractiveness to potential partners (Buss, 1988; Buss & Schmitt, 1993).

Mixed effects of fertility on competitor derogation and intrasexual competitiveness have also been reported. The goal of competitor derogation is to gain status by making rivals appear less attractive (Buss, 1988; Buss & Schmitt, 1993). When fertility probability is high, some women report engaging in competitor derogation through increased dehumanization of other women (Piccoli et al., 2013) and by rating other women as less attractive (Fisher, 2004). A between-subject study also found that self-reported intrasexual competitiveness was associated with fertility probability (Piccoli et al., 2013). Conversely, several large within-subject designs found no effect of fertility, estradiol, or progesterone on attractiveness ratings of other women (Stern et al., 2021) or self-report intrasexual competitiveness (Hahn et al., 2016; Stern et al., 2023). Critically, when reviewing research investigating intrasexual competition and dominance motivation among women, social desirability biases likely influence responding due to the backlash experienced by women who behave competitively (Rudman et al., 2012; Rudman & Glick, 2001; Williams & Tiedens, 2016). Given large variation in the methods and risk of self-report bias, it is difficult to compare results across studies, prompting a need for further research into the true effects of fertility and estradiol on competitor derogation and intrasexual competitiveness.

In addition to the research outlined above, women use several other strategies to gain status, though it is currently unclear whether these behaviors shift across the menstrual cycle. Regarding self-promotion, work by Blake et al. (2018) suggests that women use sexualized photographs (‘sexy selfies’) to enhance their status in environments with limited high-quality partners. Self-promotion can also be achieved by giving advice to others, as this behavior can induce a sense of status by influencing the decisions of others (Rader et al., 2017; Schaerer et al., 2018). In contrast, gossip is a form of competitor derogation favored by females, presumably due to its low costs and high potential to damage the reputation of others (Davis et al., 2019; Vaillancourt, 2013). Gossip requires individuals to engage in related behaviors, such as social comparison and the negative evaluations of others, with the intention of gaining a competitive advantage (Garcia et al., 2013). Research investigating these strategies is largely absent from the literature and thus provides a ripe opportunity for future research.

Hormonal contraceptives and competition

Research into the effects of hormone variation on competition would be incomplete without also considering the role of hormonal contraceptives. Hormonal contraceptives disrupt cyclic hormone variation through the provision of synthetic ovarian hormones (Melo & Creinin, 2016). Synthetic forms of progesterone (called progestins) and, in some cases, estradiol are delivered to the body through a variety of administration methods (e.g., oral pills, intrauterine devices, injections). These synthetic hormones create a negative feedback loop in the HPG-axis by attenuating endogenous hormone production signals in the hypothalamus (Hampson, 2023). Though hormonal contraceptives were primarily created to suppress ovulation, increasing evidence suggests that they can have considerable effects on the brain and cognition (Griksiene et al., 2022; Pletzer et al., 2023).

A recent review of 46 studies attempted to understand the relationship between hormonal contraceptives and competitive outcomes (Arthur et al., 2022). Arthur et al. (2022) argue that because hormonal contraceptives disrupt natural hormone variability, the behaviors associated with those hormones should also be disrupted. Aligned with research in naturally cycling participants, published effects of hormonal contraceptives on competition are largely mixed and clear effects are difficult to establish due to methodological limitations, including small sample sizes and poor treatment of heterogeneity within hormonal contraceptive users (Arthur et al., 2022; Beltz, 2024). Nevertheless, in line with our review of fertility effects on appearance enhancement, self-promotion and competitor derogation, we briefly outline past research examining the role of hormonal contraceptives on these outcomes.

Research regarding hormonal contraceptive use and women's appearance enhancement reveals inconsistent results. Some research indicates that hormonal contraceptive users spend less time applying makeup compared to non-users (Batres et al., 2018) and may be less likely to wear revealing clothing compared to fertile non-users (Schwarz & Hassebrauck, 2008). Although not a direct measure of appearance enhancement, hormonal contraceptive users also report feeling less sexually desirable and physically attractive compared to naturally cycling participants in the fertile phase (Arslan et al., 2018; Schleifenbaum et al., 2021). In contrast, Arslan et al. (2018) and Schleifenbaum et al. (2021) found no effect of hormonal contraceptives on wearing provocative clothing, and Cobey et al. (2013) found no influence of hormonal contraceptives on self-perceived attractiveness. If hormonal contraceptives do alter appearance enhancement, the most likely effect is the suppression of a fertility increase in beautification compared to non-users.

There is mounting evidence that hormonal contraceptive users are less competitive in domains that could contribute to status through prestige or self-promotion. When completing difficult tasks, hormonal contraceptive users display less task persistence compared to non-users overall (Bradshaw et al., 2020; Casto et al., 2020) or non-users in the follicular phase (Casto et al., 2023), and less achievement motivation compared to fertile non-users (Arthur & Blake, 2022). Given the quasi-experimental nature of most hormonal contraceptive research it is important to consider whether hormonal contraceptives causally influence competitiveness or whether users differ from non-users on relevant but unobserved variables (Botzet et al., 2021). In a novel finding attempting to disentangle pre-existing group differences from hormonal mechanisms, reduced effort from hormonal contraceptive users appears to be explained by blunted cortisol and progesterone reactivity that is observed during a competitive physical task in non-users (Casto et al., 2023). This work suggests that use of synthetic hormones may attenuate adaptive responding to competitive situations.

Research on the relationship between hormonal contraceptives and competitor derogation is also mixed. While some studies report no significant differences in self-reported dominance, intrasexual competitiveness, or implicit power motives between hormonal contraceptive users and naturally-cycling participants (Ball et al., 2014; Cobey et al., 2013; 2015; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007), others find weak evidence of lower hyper-competitiveness (i.e., desire to beat others) or attenuated associations between fertility[6] and intrasexual competitiveness in hormonal contraceptive users (Arthur & Blake, 2022; Piccoli et al., 2013). Relationship status has been identified as a potential moderating factor, with several studies reporting interactions between hormonal contraceptive use and relationship status on self-reported competitiveness and dominance scores (Cobey et al., 2013; 2015; cf. Arthur & Blake, 2022; Ball et al., 2014; Piccoli et al., 2013). As with non-users, the over-reliance on self-report measures, which are susceptible to social desirability bias, may obscure a clear understanding of how hormonal contraceptives influence dominance-related behavior in real-world contexts.

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[6] Although hormonal contraceptive users do not experience changes in fertility, studies in this literature often assign fertility estimates to users. Effects of fertility estimates among hormonal contraceptive users can then be compared with effects observed in naturally cycling participants (Arslan et al., 2021). For more information about these methods, see section “2.3.4. Menstrual Cycle Characteristics” in the current paper.

The Current Study

The current study had two core aims. First, we aimed to replicate findings showing that achievement-based competitive motivation increases around ovulation in naturally cycling participants, and that hormonal contraceptive users report less interest in competitions (Arthur and Blake, 2022). Second, we sought to extend the operationalization of competition to include a range of self-report behaviors that are theoretically informed but not commonly measured in academic research. To address these ideas, we utilized data from the Daily Cycle Diary, a large, online longitudinal self-report diary study, collecting data regarding hormonal contraceptive use, menstrual cycle phase, and a range of psychological and behavioral outcomes (including competitiveness, the focus of this paper).

Based on existing research (Arthur & Blake, 2022), achievement-oriented competitiveness (i.e., achievement motivation) and lack of interest in competition (i.e., disinterest in competition) were chosen as daily self-report measures of competitive orientation. We predicted to replicate existing effects, such that our investigation would yield a mid-cycle increase in achievement-oriented competitiveness in naturally cycling participants but not hormonal contraceptive users; and a main effect of hormonal contraceptive use such that hormonal contraceptive users would report a stronger lack of interest in competition. We also asked participants daily whether they engaged in six behaviors relevant to mate attraction and status-seeking: appearance enhancement, giving advice, gossiping, social comparison, negative evaluations of others, and taking selfies. Based on existing research demonstrating mid-cycle increases in appearance enhancement and other status seeking behaviors, we predicted a mid-cycle increase in competitive behavior among naturally cycling participants but not hormonal contraceptive users.

To test these hypotheses, we created a continuous measure of fertility probability to determine whether competitiveness is elevated when individuals are fertile compared to other times during the menstrual cycle. Although elevated estradiol (and possibly low progesterone) is the mechanism theoretically expected to influence competitiveness, collecting daily hormone samples from a multi-national sample is not feasible. Instead, fertility probability estimates were used as a proxy for expected estradiol elevation, offering an alternative to costly hormonal testing (Arslan et al., 2023). The hypotheses and analyses used here were not preregistered, however hypotheses were formulated before data were accessed and before any analyses had been conducted. Exclusion criteria and methods for estimating fertility probability have not changed from previous iterations of the daily cycle diary (e.g., Arthur & Blake, 2022; Blake, 2022b; Blake et al., 2022).

Method

Participants

Three hundred and forty-eight females (M_{age} = 23.32, *SD* = 7.65) were recruited from the University of Melbourne undergraduate participation pool and general community. This sample is entirely unique from Arthur and Blake (2022). Eligibility criteria were fluency in English; regular menstrual cycles; self-reported confidence about menstrual cycle length exceeding the scale mid-point (i.e., '3 – somewhat confident' and above); menstrual cycle length between 22-35 days (*M* = 28.92, *SD* = 2.75); aged between 18-45 years; pre-menopausal; no emergency contraception, breastfeeding, or pregnancy use within the past three months; no polycystic ovarian syndrome or endometriosis; and no medically diagnosed fertility or endocrine issues, leaving n = 302 (M_{age} = 22.30, SD = 6.74). Table 1 contains demographic characteristics for the final sample, made up of 231 naturally cycling participants and 71 hormonal contraceptive users.

Table 1. Demographic characteristics and details of hormonal contraceptives used in the sample of users

Demographics (N = 302)	**Number**	**Responses**
Sexuality	205	Heterosexual
	70	Always or occasionally bisexual
	12	Pansexual
	6	Exclusively homosexual
	3	A-sexual
	6	Did not disclose
Relationship status	184	Single or casually dating
	109	Monogamous relationship
	6	Open relationship
	3	Did not disclose
Ethnicity	74	Mixed
	72	Australia/New Zealand
	48	East Asian
	42	European
	33	South-East Asian
	27	Southern, Central or West Asian
	6	Other
Hormonal contraceptive details		
Contraceptive type (n = 71)	55	Combined oral contraceptive
	8	Hormonal IUD
	8	Did not disclose
Progestin generation (oral contraceptive users; n = 55)	14	1st Gen: cyproterone acetate/norethindrone
	30	2nd Gen: levonorgestrel
	1	3rd Gen: norgestimate
	10	4th Gen: drospirenone/nomegestrol acetate

Procedure

This study was conducted using the formR (Arslan et al., 2020) survey platform and was approved by the University of Melbourne Human Research Ethics Committee. All data were collected between July 2021 and October 2023. The study was part of a larger, ongoing longitudinal study called the *Daily Cycle Diary,* and as the procedure used here is analogous to that reported in Arthur & Blake (2022), we summarize it briefly here. Participants joined the study in exchange for course credit (*N* = 221) or volunteered in exchange for a personalized feedback report on their menstrual cycle (*N* = 81). A brief prescreening and baseline survey firstly collected demographic and menstrual cycle characteristics. A daily survey was then automatically issued to participants at 5pm local time for a minimum of 28 days. After 28 days, participants could complete the study or continue providing data for an additional 28 days (median daily entries = 17, *M* = 18.56, *SD* = 13.40, range = 1–55). Ten days after the final survey was completed, participants were invited to a follow-up survey to record their next menstrual onset. Feedback reports were provided to participants shortly after the final survey.

Measures

Person-level variables were collected during the prescreening, baseline and follow-up surveys, including demographics, hormonal contraceptive use, and menstrual cycle data. As part of a larger study, within-person measures were collected daily and included questions regarding current menstrual cycle status, competitiveness, self-objectification, affect, personality, agency, impulsiveness, self-regulation, health, and sexual behavior. Measures related to competitive motivation and behavior are reported in the current paper.

Competitive orientation. Competitiveness was measured using two sub-scales from the Multidimensional Competitive Orientation Inventory (MCOI; Orosz et al., 2018): Self-developmental competitive orientation and lack of interest toward competition. Self-developmental competitive orientation refers to a desire to achieve and was measured using three items (e.g., “Competitive situations allowed me to bring out the best of myself”). Lack of interest in competition refers to a general disinterest in competitive situations and was measured using three items (e.g., “I didn’t care about being the best”). All items were measured on a 5-point

Likert scale (strongly disagree, disagree, neither, agree, strongly agree). All three items of each sub-scale were presented each day and then averaged to create a daily measure (Cronbach's αs range from .81 - .93).

Competitive behavior. To our knowledge, there are no validated scales measuring competitive daily behavior. We thus asked participants to indicate daily ("Over the past day, I…") whether they engaged in behaviors that can contribute to competitive advantage via self-promotion or competitor derogation. Behavioral questions included gossip ("gossiped about someone"), appearance enhancement ("spent time on my appearance (e.g., hair, make-up, clothes)"), taking self-portrait photographs ("took photos of myself, including selfies"), giving advice to others ("gave someone advice"), engaging in internal social comparison ("compared myself to others") and internally observing negatives in others ("looked for negatives in others"). All competitive behaviors were measured on a 5-point Likert scale (not at all, not very much, somewhat, very much, a great deal). To determine if these variables reliably covaried, we ran a reliability analysis. This analysis indicated that all six behaviors were positively correlated and had high internal consistency ($\alpha = .72$). Reliability was not increased by removing any item. As such, we averaged all six items into a single measure of competitive behavior. Results for each competitive behavior tested individually can be found in the Supplementary Materials.

Contraceptive use. Participants indicated their contraceptive use via the following multi-choice categories: hormonal contraceptives (e.g., the pill, hormonal implant/rod, depot injections, vaginal ring, hormone plasters), barrier method, period/fertility tracking app, fertility awareness method (e.g., diary, calendar), abstinence, hormonal intrauterine device (e.g., Mirena), copper intrauterine device, morning-after pill, other contraceptive, or none. Participants were also asked to provide the name of their current hormonal contraceptive to determine details such as route of administration and androgen content. Anyone indicating usage of the morning after pill within the past three months was excluded from the study (*n* = 2 exclusions).

Menstrual Cycle Characteristics. During the baseline survey, participants reported their average cycle length and start date of their current cycle. In each daily survey and at follow-up, participants indicated whether and when their next cycle had started. When the next menstrual onset date was not reported (71.85% of cycles), we inferred it from the average cycle length reported by the participant at baseline (as recommended by Welling & Burriss, 2019). Because our method asked participants about their most recent menstrual cycle onset date multiple times, some discrepancies emerged (i.e., participants reporting adjacent or similar—but not exact—onset dates). We thus checked all dates for consistency, and where multiple onsets were reported within the same week, we used the median date as the onset date.

Fertility probability was estimated using the backward-counting method. This method counts backward from the reported or estimated onset of menses to the day on which the outcome variable is sampled. Each backward-counted day corresponds to a specific fertility probability value based on the estimates generated by Stirnemann et al. (2013)[7]. Compared to discrete measures (i.e., fertility windows), continuous measures of fertility are better predictors of true conception probability and are thus recommended for use in ovulatory research (Gangestad et al., 2016).

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[7] Using ultrasound technology to test fetal size in females who had recently conceived, Stirnemann et al. (2013) estimated the day of conception in 5,830 participants. By matching estimated conception and certain menstrual onset dates, Stirnemann et al. (2013) created a continuous measure of fertility probably, indicating the probability that a female was fertile on any given day of the cycle. Estimation methods included relevant covariates (e.g., age, ethnicity).

Fertility probability estimates were assigned to all participants (irrespective of hormonal contraceptive and naturally cycling grouping; as recommended by Arslan et al., 2018). By assigning fertility estimates to hormonal contraceptive users, we were able to test for fertility effects that are unique to naturally cycling participants. A significant positive interaction between hormonal contraceptive use and our measure of fertility probability indicates a fertility effect that is only observed in naturally cycling participants.

Data Analysis

Linear mixed effect models were used to test the effects of fertility and hormonal contraceptive use on our three competitive outcomes: achievement-oriented competitiveness, lack of interest in competition, and competitive behavior. Our primary model controlled for menstruation and included a random slope for fertility probability and a random intercept for the individual (Model 1). In Wilkinson notation (Bates et al., 2014; Wilkinson & Rogers, 1973), Model 1 equation can be formalised as:

$$\text{outcome}_{ti} \sim 1 + (\text{menstruation}_{ti} + \text{fertility\_probability}_{ti}) * \text{hormonal\_contraceptive\_user}_{i} + (1 + \text{fertility\_probability}_{ti} \mid \text{person})$$

Previous within-subject research has shown an interaction between hormonal contraceptive use and relationship status, such that hormonal contraceptive use was associated with reduced intrasexual competition in pair-bonded (but not single) participants (Cobey et al., 2013). We therefore ran a second model including relationship status as a main effect and moderator of the fertility × hormonal contraceptive use interaction, including all corresponding lower order terms (Model 2).

Data, codebook information, and model specification is available on the Open Science Framework (https://osf.io/tw38u/).

Results

Descriptive statistics for demographic variables are included in Table 2. No significant demographic differences were observed between naturally cycling participants and hormonal contraceptive users. A chi squared goodness of fit test was conducted to examine the distribution of participants in a monogamous relationship between naturally cycling participants and hormonal contraceptive users. The test revealed a significant difference, X^2 (1, N = 299) = 18.221, p = <.001, whereby, naturally cycling participants were more likely to be single or casually dating compared to hormonal contraceptive users.

Lack of interest in competition was negatively correlated with self-development competitiveness (r = -.40, p <.001) and competitive behavior (r = -.19, p <.001), while self-development competitiveness was positively correlated with competitive behavior (r = .19, p <.001).

Table 2. *Demographic variables for naturally cycling participants and hormonal contraceptive users.*

Variable	Naturally cycling (n = 231[a])		Hormonal contraceptive users (n = 71)		p
	M	SD	M	SD	
Age	22.43	7.06	22.08	5.76	.162
Height (cm)	164.75	7.45	165.52	6.66	.637
Weight (kgs)	60.05	12.13	62.52	11.27	.794
Age of Menarche	12.57	1.39	12.66	1.35	.890

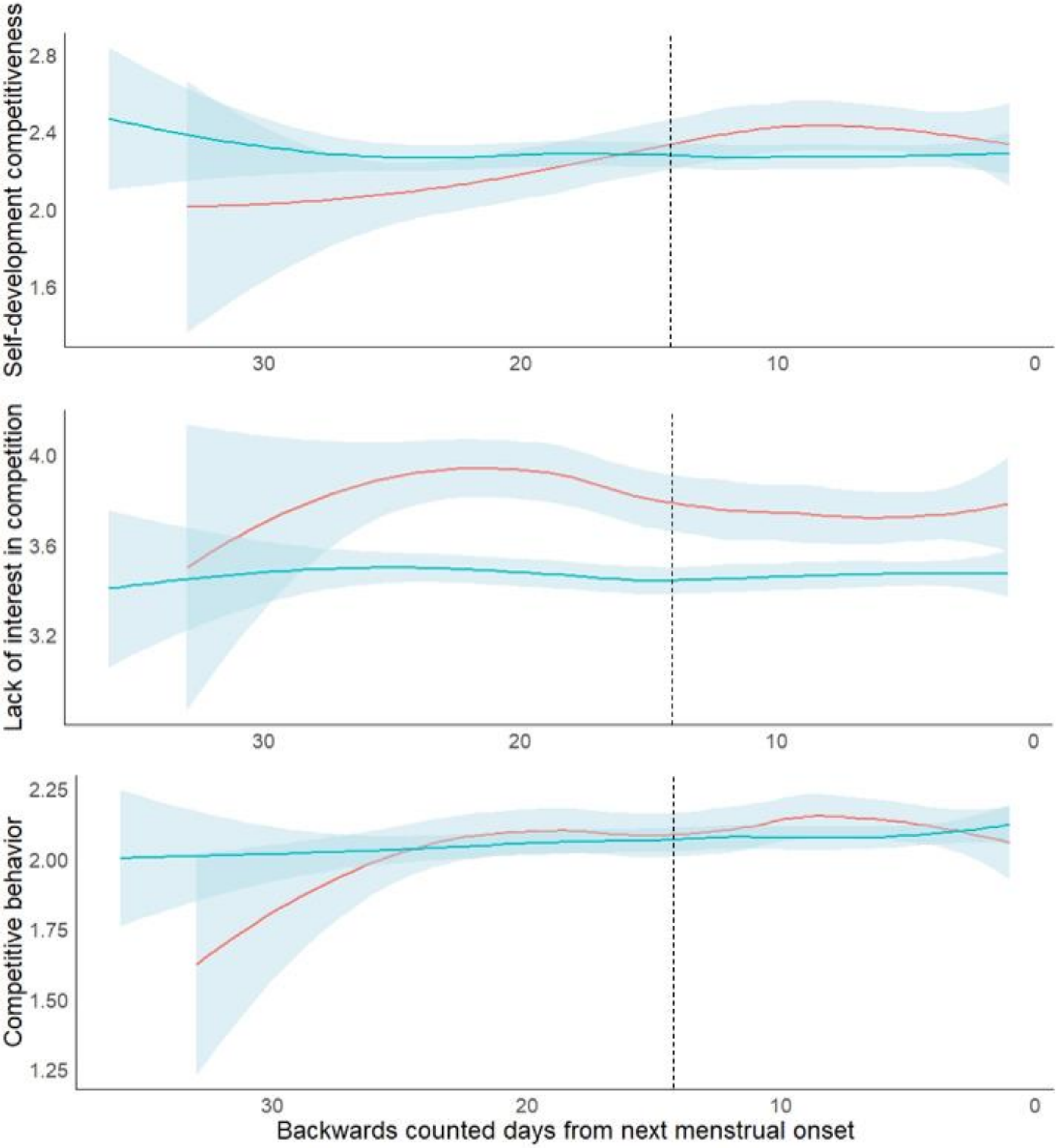
Note. *M* and *SD* are used to represent mean and standard deviation, respectively. [a] Height and weight are missing for one naturally cycling participant.

Results for Models 1 and 2 are shown in Table 3. Counter to our hypotheses, neither self-development competitiveness nor competitive behavior were associated with fertility probability, hormonal contraceptive use, or their interaction in our primary model (Model 1). As hypothesized, a main effect of hormonal contraceptive use on lack of interest in competition was observed in our primary model (b = .294, SE = .102, *95% CI* = .096 – .494, p = .004; see Figure

1). This effect was not moderated by relationship status (Model 2: *95% CI* = -.080 – .338). In Model 2, a significant, positive main effect of hormonal contraceptive use was observed for competitive behavior (*95% CI* = .02 – .43). Results from Model 1 replicate when using Bayesian models (see Model S1, in the Supplementary Materials).

For each competitive outcome, we evaluated the two models to determine their fit to the data. The Akaike Information Criterion (AIC) was utilized for model comparison, where lower AIC values indicate better model fit (see Table 3). For all three competitive outcomes, Model 1 exhibited lower AIC value compared to Model 2, indicating that Model 1 provides the best fit to the data.

Figure 1. Mean daily levels of self-development competitiveness, lack of interest in competition and competitive behavior as a function of backwards counted cycle day.



Note. This figure shows the means for each competitive outcome (y-axis) as a function of backwards counted cycle day (x-axis). Red = Hormonal contraceptive users. Blue = Naturally cycling participants. Dashed line = estimated day of ovulation.

Table 3. *Multi-level model output showing associations between cycle phase, hormonal contraceptive use, relationship status and competitive outcomes*

	Self-development competitiveness				Lack of interest in competition [a]				Competitive behavior			
	Est	SE	*t*	*p*	Est	SE	*t*	*p*	Est	SE	*t*	*p*
Model 1												
Intercept	2.38	.06	41.33	<.001	3.31	.05	66.98	<.001	2.16	.04	60.42	<.001
Fertility (F)	-.04	.08	-.49	.626	.03	.08	.03	.701	.02	.05	.47	.638
Menstruation (M)[b]	<.01	.02	.04	.969	.04	.03	1.64	.101	-.01	.02	-.63	.530
HC use (HC)[c]	<-.01	.12	-.03	.979	**.29**	**.10**	**2.90**	**.004**	.10	.07	1.36	.174
F x HC	.06	.15	.40	.689	.01	.16	.05	.958	-.09	.10	-.86	.390
M x HC	-.04	.05	-.72	.470	-.04	.05	-.83	.408	-.06	.04	-1.69	.092
Model 2												
Intercept	2.37	.07	34.82	<.001	3.27	.06	55.81	<.001	2.17	.04	51.17	<.001
Fertility (F)	-.02	.09	-.28	.783	-.12	.10	-.13	.896	.07	.06	1.14	.258
Menstruation (M)	-.02	.03	-.62	.537	.06	.03	1.86	.064	<.01	.02	.17	.865
HC use (HC)	.23	.17	1.34	.182	.16	.15	1.08	.283	**.23**	**.11**	**2.13**	**.034**
Relationship (RS)[d]	.01	.13	.06	.955	.13	.11	1.23	.219	-.04	.08	-.49	.624
F x HC	-.18	.22	-.84	.401	.16	.23	.71	.480	-.05	.14	-.33	.743
M x HC	-.02	.07	-.25	.800	-.11	.08	-1.40	.160	-.05	.06	-.94	.349
F x RS	-.04	.16	-.23	.815	.15	.17	.87	.386	-.14	.11	-1.34	.183
M x RS	.06	.05	1.16	.247	-.04	.16	-.82	.415	-.05	.04	-1.18	.239
HC x RS	-.41	.24	-1.70	.091	.17	.21	.82	.417	-.19	.15	-1.24	.217
F x HC x RS	.46	.31	1.47	.145	-.36	.33	-1.12	.270	<-.01	.20	-.04	.968
M x HC x RS	-.05	.10	-.52	.605	.13	.11	1.21	.227	<-.01	.08	-.13	.897

Note: N = 302, *Observations* = 5,636. [a] = Three daily observations are missing for Lack of Interest in Competition. [b]Menstruation: 0 = not menstruating, 1 = menstruating. [c]Hormonal contraceptive (HC) use: 0 = naturally cycling participants, 1 = hormonal contraceptive users. [d]Relationship Status (RS): 0 = single, casually dating, or open relationship, 1 = monogamous relationship. Bold indicates significant effects.

Model 1. Self-development competitiveness: Conditional R^2 = .650, Marginal R^2 = <.001, *AIC* = 11,186.11. Lack of Interest in Competition: Conditional R^2 = .564, Marginal R^2 = .018, *AIC* = 11,555.17. Competitive Behaviors: Conditional R^2 = .551, Marginal R^2 = .003, *AIC* = 7,788.47. **Model 2.** Self-development competitiveness: Conditional R^2 = .652, Marginal R^2 = .007, *AIC* = 11,205.34. Lack of Interest in Competition: Conditional R^2 = .566, Marginal R^2 = .027, *AIC* = 11,572.48. Competitive Behaviors: Conditional R^2 = .554, Marginal R^2 = .016, *AIC* = 7,809.02.

Discussion

The current study used a longitudinal, within-subjects design to investigate relationships between fertility probability, hormonal contraceptive use and competitive outcomes. Using two measures of self-report competitive motivation – achievement-oriented competitiveness and lack of interest in competition – we sought to understand whether fertility or hormonal contraceptive use was associated with how competitive participants felt across the cycle. We also collected daily measures of self-report competitive behavior to understand whether cycle-related variables influenced how competitively participants behaved. Based on high internal consistency, one composite measure of competitive behavior was created, combining daily reports of gossip, social comparison, negative evaluations of others, appearance enhancement, giving advice and taking selfies. These motivational and behavioral measures were selected based on previous intrasexual competition research, proposing that females compete for mates and status using a range of direct and indirect strategies, including appearance enhancement, self-promotion, and competitor derogation (Buss, 2023, Buss & Schmitt, 2019; Cashdan, 1996).

Aligning with the broader menstrual cycle and hormonal contraceptive literature, the results of the current study were mixed. Contrary to our hypotheses, no robust associations were observed between achievement-oriented competitiveness, competitive behavior, and any of our cycle-related variables. This suggests that fertility is not associated with cognition or behavior related to indirect competitive strategies (e.g., self-promotion, appearance enhancement; Cashdan, 1990). Conversely, replicating Arthur and Blake (2022) we found evidence that hormonal contraceptive use was associated with a lack of interest in competition compared to non-use, suggesting that hormonal contraceptives may be associated with avoidance of direct competitive strategies (e.g., derogation, fighting; Cashdan, 1990). This effect was not moderated by relationship status, suggesting that the effect of hormonal contraceptive use on lack of interest in competition did not vary between single and pair-bonded participants. When controlling for relationship status, a positive main effect of hormonal contraceptive use was also observed for competitive behavior. Although relationship status appears to account for some unexplained variance in the data, the overrepresentation of hormonal contraceptive users in a monogamous relationship means that all analyses including relationship status should be considered preliminary and thus interpreted with caution.

Our analysis of model fit indicated that Model 1 is the preferred model based on the AIC criterion, suggesting that the inclusion of relationship status did not enhance the model's explanatory power. For this reason, we focus on interpreting Model 1 results within the context of the existing literature and in relation to the theoretical frameworks outlined in the introduction.

Implications for models of hormone mediated female competitiveness

No associations were observed between achievement-oriented competitiveness, lack of interest in competition, self-report competitive behavior, and any of our cycle-related variables. These findings replicate recent self-report longitudinal cycle studies suggesting the absence of meaningful cycle phase shifts in competitiveness. For example, our findings are similar to Stern et al. (2023) who found no evidence of fertility effects in a well-powered longitudinal test of self-reported intrasexual competitiveness and jealousy. No effects of estradiol or progesterone concentrations were associated with any competitive outcome either (Stern et al., 2023). Our results further bolster other longitudinal studies finding no cycle phase effects in intrasexual competitiveness or jealousy (Arslan et al., 2018; Hahn et al., 2016). Taken together, there is limited support for the ovulatory competition hypothesis, which proposes that ovulation boosts women’s desire for positional advantage when the potential gains are elevated (Durante et al., 2014; Nikiforidis et al., 2017; cf. Blake, 2022b).

Beyond the ovulatory competition hypothesis, other theories propose cycle phase shifts that enhance reproduction and survival more broadly. As described earlier, the motivational priorities theory (Roney, 2018; 2023) argues that women experience cycle related shifts in motivational states, shifting between reproductive priorities around ovulation and feeding at other times in the cycle. A mounting body of work offers partial support for this theory, demonstrating that self-report outcomes related to reproductive success (e.g., sexual desire, self-perceived desirability) reliably increase around ovulation in naturally cycling females (Arslan et al., 2018; Jünger, Kordsmeyer, et al., 2018; Jünger, Motta-Mena, et al., 2018; Marcinkowska et al., 2023; Schleifenbaum et al., 2021; Shirazi et al., 2019; van Stein et al., 2019). While the current study cannot directly comment on reproductive outcomes, it is possible that previous support for the ovulatory competition hypothesis is better explained by elevated reproductive motivation during ovulation and less by a desire for positional advantage. Future research may attempt to disentangle reproductive competition from other forms of competition, though this distinction may be irrelevant in the evolutionary context where reproductive and status competitions are both motivated by maximizing fitness.

The effects of hormonal contraceptives on competitive motivation were also mixed. Partially replicating Arthur and Blake (2022) we found evidence that hormonal contraceptive users reported less interest in competition compared to naturally cycling participants. However, contrary to our hypothesis, we did not replicate the interaction between fertility and hormonal contraceptive use on self-development competitiveness, nor did we observe an effect of hormonal contraceptive use on self-report competitive behavior. As with proposed fertility effects, our mixed results are representative of the broader literature, where some research suggests that hormonal contraceptive users display less competitiveness or task persistence compared to naturally cycling participants (e.g., Bradshaw et al., 2020; Buser, 2012; Casto et al., 2020), while other work indicates no variation in competitiveness between groups (e.g., Lucas & Koff, 2013; Ranehill et al., 2018).

The results of the current study neither support nor refute the potential role of hormonal contraceptives as disruptors of competitive outcomes presented in Arthur et al. (2022). According to this framework, because hormonal contraceptives disrupt natural hormone variability, then behaviors associated with those hormones should also be disrupted. However, in the current study, self-report competitive motivation and behavior did not vary in naturally cycling participants and thus the capacity for hormonal contraceptives to disrupt natural variation was evaded. To further improve our understanding of hormonal contraceptives it is important that theoretical models are supported by research testing the hormonal mechanisms thought to influence competition. For instance, work by Casto et al. (2023) reports that blunted progesterone and cortisol reactivity to a competitive task partially mediated variation between hormonal contraceptive users and naturally cycling participants. By combining theoretical and endocrine models, future research can shed new light on the complex interaction between endogenous and exogenous hormones on competitive outcomes.

Non-replications and mixed results in the literature

While we successfully replicated some results from Arthur and Blake (2022), we also record important deviations, underscoring the inherent challenges associated with replication research (Milfont & Klein, 2018; Stevens, 2017). Non-replications are common in psychology, with many critics arguing that failed replications are the result of publication biases, low quality research practices, and methodological constraints (Shrout & Rodgers, 2018). However, other researchers outline an alternative framework that understands non-replication through the lens of context dependency (Gollwitzer & Schwabe, 2022; Pettigrew, 2018). According to this framework, conceptually relevant context characteristics can enhance psychological theorizing because they create conceptual boundaries where researchers can expect to observe a hypothesized effect.

While contextual factors may not be relevant in all research areas, dynamic fields such as social and evolutionary psychology should be particularly sensitive to the importance of context. Within psychology, context-dependency is understood to mean that the value of a decision or behavior depends on the options available and the context that a decision will be made within (Otto et al., 2022). Further, it is argued that evolution has shaped human physiology and behavior based on the specific challenges and opportunities presented to populations across space and time (Brown et al., 2011). Thus, evolved social processes – such as those arguably related to endogenous hormone variation – should be particularly sensitive to context (Botzet et al., 2024).

Diary studies allow researchers to obtain a rich understanding of individual behavior across time, however this increased richness simultaneously introduces an immeasurable number of contexts that may influence our ability to replicate effects. Gollwitzer and Schwabe (2022) define context as anything that can threaten the generalizability of a finding, including sample characteristics (i.e., participant demographics), treatment and outcome characteristics (i.e., experimental manipulations, measures), and the setting in which a study was conducted (i.e., culture, physical setting, temporal characteristics). Future research may benefit from the development of clear boundary conditions that constrain (or define) the boundaries within which a particular theory, effect, or phenomenon is expected to occur (Busse et al., 2016). Below we consider boundaries in our own research, followed by reflections about how context may influence related menstrual cycle literature.

Disparate results between this study and previous work (e.g., Arthur and Blake, 2022; Casto et al., 2023) led us to explore the role of context, focusing on sample and outcome characteristics. Variation in the proportion of volunteers to compensated participants may explain differences between this study and Arthur and Blake (2022). In Arthur and Blake (2022), 87% of participants were community members motivated by a feedback report about their cycle. Selection-bias may limit the generalizability of those results as volunteers may be particularly motivated to understand their cycle because they experience more cycle-related effects compared to other females (Jukic, 2020). Conversely, 73% of participants in the current study were undergraduate psychology students participating for course credit or payment. Evidence of reduced engagement is seen in the low number of participants (28.15%) who reported their next menstrual onset, requested after participants received credit or payment. Using a homogenous student sample may also limit generalizability, as undergraduate psychology students are often not representative of the broader population (Hanel & Vione, 2016; Peterson, 2001).

Another contextual difference is the measurement of competitive behavior through self-report rather than behavioral tests. The current study focused on internal (e.g., social comparison) and indirect (e.g., gossip) competitive behaviors, chosen because females often use these tactics to attract mates or gain status (Davis et al., 2019; Vaillancourt, 2013). Unlike direct contests, indirect strategies have fewer physical and energetic costs, making them low-risk and potentially unaffected by cycle phase effects. In contrast, physical demonstrations of competitive persistence, as seen in Casto et al. (2023), carry energetic costs that may be less suited to specific times in the cycle, such as the luteal phase when fertilization may have occurred. Thus, engaging in indirect competition may produce fundamentally different outcomes compared to direct and energetically costly forms of competition.

Beyond the current study, context has important implications for the wider menstrual cycle literature, and we argue that the field would benefit from the development of boundary conditions. Within models of behavioral endocrinology, hormonal and social inputs are often described as additive pathways (Roney, 2018; 2023). Although an outcome may be more likely under specific hormonal profiles, social and environmental characteristics also have a powerful effect on behavior. In many circumstances contextual factors likely have a stronger effect than hormonal inputs. Despite this important limitation being clearly articulated within endocrine models of behavior (Roney, 2023), contextual factors are rarely described in published menstrual cycle research.

To further illustrate this point, we consider how context may partially explain disagreement regarding ovarian effects on mating behavior. Environmental factors that influence mating competition have been widely researched, including operational sex ratio, resource distributions, social mating systems, and anthropogenic factors (Møller, 2021; Moss & Maner, 2016; Wong & Candolin, 2015). Individual level characteristics (e.g., stress, relationship quality, self-perceived mate value; Casey et al., 2007; Lass-Hennemann et al., 2010; Polo et al., 2019) also influence mating competition and may create inconsistencies regarding sample characteristics across studies. Despite these factors being known to influence mate competition and selection, they have largely been overlooked within cycle related research. Further, reviews documenting mixed effects of ovarian hormones on mating behavior tend to focus on methodological and analytical challenges of past research (e.g., Arthur et al., 2022; Gangestad et al., 2019; Jones et al., 2019; Stern et al., 2019). While it is probably true that methodological limitations contribute to non-replication, in order for the menstrual cycle literature to move forward, researchers should endeavor to provide information about the context relevant to their findings.

Over time, the inclusion of contextual factors in research may facilitate the development of boundary conditions that can be used to understand inconsistent results across multiple locations and demographics. We acknowledge that collecting or publishing details of contextual factors presents a new challenge for research in this literature. However, we encourage researchers to draw from methods used in other areas of psychology and human behavior, such as personality and organizational psychology (e.g., Beck & Jackson, 2022; Busse et al., 2016). Carefully mapping the boundary conditions around reliable menstrual cycle effects should be an important goal as this literature continues to evolve, and a priori consideration of key contextual influences may help resolve persisting inconsistencies.

Limitations

An important critique of the current study is that diary designs are restrained in their ability to capture variation in social behavior associated with endocrine signaling. Although longitudinal diary studies offer a useful approach to capturing self-reported psychological states that are easily amenable to change (Scollon et al., 2003), understanding changes in social behavior requires designs that capture details of the physical and social environment. To take an example from the menstrual cycle literature, Arslan et al.'s (2018) finds that although sexual desire increases during the peri-ovulatory phase, actual dyadic sexual behavior does not increase, likely owing to the need for a willing partner, time, and location. In our own research, several competitive behaviors also require specific environmental and social alignment. For instance, engaging in gossip requires at least one coconspirator and a target, while social comparisons are interpersonal processes and thus necessitate interactions with others. Competitive motivation can also be influenced by characteristics of the target, resource, and tactics that are appropriate in each environment. Understanding the limits of diary designs to capture social behavior allows us to appropriately situate the current results within the context of the broader literature.

Diary studies also fail to capture hormone reactivity in response to changes in the social and physical environment. Research investigating menstrual cycle effects in psychology assume that an individual's response to changes in the environment may vary depending on the internal hormonal state of the individual (Roney, 2016; 2023). Observing both the internal and external context is thus critical for understanding how prolonged hormone changes interact to influence behavior. Research in both humans and animals demonstrate the importance of hormone reactivity in response to a competitor, such that transient hormone variation can influence the likelihood of engaging in competition and the result of the competitive interaction (Archer, 2006; Casto et al., 2022; Casto & Edwards, 2016; Wingfield, 2017). Therefore, although diary studies may capture variation in motivations and desires in accordance with reproductive processes, the ability to dynamically observe how individuals respond flexibly to environmental demands (achieved through hormone plasticity) is missed when recording behavior at one timepoint each day.

Another limitation in the current study is the reliance on forward counting cycle phase estimation due to the limited number of participants reporting a next menstrual onset date (*N* = 85). Research suggests that individuals are limited in their ability to recall previous menstrual onset dates and average cycle length, resulting in recall inaccuracies (Jukic et al., 2008; Small et al., 2007). Compared to forward counting, backwards counting is thought to provide a more precise estimation regarding ovulation because participants can retrospectively report their new menstrual onset and because the length of the luteal phase is considered less variable compared to the follicular phase (Baird et al., 1995; Blake et al., 2016; Gildersleeve et al., 2013). Despite only one third of participants providing sufficient data for backwards counting methods, the current study utilized a continuous measure of fertility probability, which outperforms discrete measures (i.e., 'fertile windows') for both forward and backwards counting methods (Gangestad et al., 2016). Even so, future research should incentivize participants to complete the follow-up survey by reimbursing paid participants after their next menstrual onset.

Finally, the current study has several limitations regarding the design of daily questions. Participants were not given an option to "opt out" of behaviors that weren't relevant to them on any given day, which would have allowed participants to skip irrelevant behaviors. Although we used a validated measure of competitive motivation (Orosz et al., 2018), the questions were relatively general (e.g., 'I enjoyed testing myself in competitive situations') and therefore may have been interpreted differently across time and between participants. Social desirability bias and self-enhancement may have biased results (Paulhus & Vazire, 2007), particularly when asking participants about behaviors that are portrayed as anti-social (e.g., gossip) or self-aggrandizing (e.g., selfies). Finally, although the behaviors used in this study were theoretically informed, they represent a relatively narrow set of competitive mechanisms that can be used to compete, thus potentially limiting our ability to detect cycle-phase effects. Therefore, although we found no evidence that our outcomes were associated with fertility, the design of these questions may have unintentionally increased the likelihood of reporting false negatives in our results.

Conclusions

The current research suggests that hormonal contraceptive use is associated with reduced interest in competition, while fertility probability is not associated with fluctuations in self-reported competitive motivation or behavior. These results add to a mixed literature, where the influence of hormones on competitive outcomes remains uncertain. Here, we question the idea that a failure to replicate reflects the quality of the theory or research, but instead suggest that it signals a need to control for contextual factors that introduce noise into empirical human research. While experimental and lab-based measures of competitive behavior aim to capture robust evidence of competitive effort, self-report measures collected daily provide researchers access to rich, real-world, longitudinal data. With different methodologies comes unique strengths and weaknesses. Researchers should thus continue to utilize a variety of methods to improve our understanding of female competitiveness, though particular attention should be paid to how we understand these results across different contexts.

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Appendix: Supplementary Materials

Methodological differences compared to Arthur and Blake (2022)

Below we outline methodological differences between Arthur and Blake (2022) and the current study, including a brief explanation about the choice to use a different analysis technique.

Participants. The data set used in the current study is entirely unique from Arthur and Blake (2022). The daily cycle diary is an ongoing platform where participants can sign up at any time, allowing them to produce a personalized feedback report. The sample used in Arthur and Blake (2022) was collected from September 2020 to June 2021. Changes to the measures were applied at the end of June 2021, when data collection for the current study commenced. Therefore, data in the current sample were collected between July 2021 and October 2023.

Measures and analysis. Arthur and Blake (2022) presented participants with four daily questions from the Multidimensional Competitive Orientation Inventory (one from each of the four sub-scale: self-developmental competitiveness, hyper-competitiveness, lack of interest in competition, and competitive avoidance). By randomly presenting one question per sub-scale, each daily measurement contained just 5 possible responses (not at all [1] – a great deal [5]) on an ordinal Likert scale. Ordinal data represent an ordered ranking system, however the distances between discrete answers is not measured and therefore may not be equal (Liddell & Kruschke, 2018). For example, the difference between answering ‘not at all’ and ‘not very much’ may be different than the difference between ‘not very much’ and ‘somewhat’.

Frequentist methods rely on the assumption of normally distributed residuals (Ernst & Albers, 2017). With a limited number of discrete response categories (as in the case of Arthur and Blake, 2022), responses will cluster around the limited number of ordinal values and thus residuals cannot be normally distributed (Bürkner & Charpentier, 2020). This violation can lead to unreliable p-values, distorted effect size estimates, and inaccurate confidence intervals (Liddell & Kruschke, 2018). Instead, Bayesian ordinal mixed models were used as these models do not rely on normality assumptions. Instead, these models estimate the relationship between the latent continuous variable underlying the 5-item responses and the predictor variables (Agresti, 2010; Bürkner & Vuorre, 2019).

Due to survey-length restrictions when collecting data in the current sample, just two-subscales (self-developmental competitiveness, lack of interest in competition) were included. Participants responded to three daily items per sub-scale that were averaged to create a single daily outcome. Through the averaging process, the discrete categories were dispersed and daily participant responses fell across a wider range of numerical values (including decimals). This revised data structure increases variability in participant responses, meaning it is possible to approximate a continuous normal distribution and can thus be analyzed using frequentist statistical methods (Norman, 2010). Because frequentist analysis techniques dominate cycle-related diary studies (e.g., Arslan et al., 2021; Schleifenbaum et al., 2024; Stern et al., 2023) and psychological research more broadly (Liddell & Kruschke, 2018; van Zyl, 2018), we chose to use frequentist linear mixed effects models to enhance comparison of results and effect size estimates across similar research.

It is worth noting that debate regarding the use of frequentist and Bayesian statistical methods is ongoing. For example, some researchers argue that all self-report data is ordinal because Likert scales do not include a true zero (from which magnitudes can be defined) and because distances between responses (even when averaged across multiple questions) are not necessarily equal (Bürkner & Vuorre, 2019; Liddell & Kruschke, 2018). Further, previous research from the authors of this paper has used Bayesian analyses (for reasons described above). To address these potential concerns, we ran Model 1 using both frequentist and Bayesian approaches. Results presented below use Bayesian techniques and fully replicate findings from our main manuscript.

Supplementary Analysis Technique

Bayesian mixed effect models were used to test the effects of fertility and hormonal contraceptive use on our competitive outcomes. Table S1 shows results for achievement-oriented competitiveness, lack of interest in competition, and competitive behavior, replicating Model 1 in our primary analysis. Table S2 shows results for each individual competitive behavior: appearance enhancement, giving advice, gossiping, social comparison, negative evaluations of others, and taking selfies.

We used default (uninformative) priors, which ensured that our parameter estimates were maximally influenced by the data and were asymptotically equivalent to those obtained under maximum likelihood estimation. Model convergence was determined by PSR values reaching < 1.05, after which the number of Bayesian iterations was doubled to ensure stable convergence was reached. We concluded there was evidence for an effect whenever the 95% credible intervals did not cross zero. Bayesian multilevel models correct for problems of multiple comparisons through the use of partial pooling and low group level variation (see Gelman et al., 2012). The inflation of type 1 errors is therefore unlikely. Due to the nature of Bayesian models and random number generation in r simulations (including brms), output can vary between replications of the same model. Model specification and output used to populate Table S1 can be found on the Open Science Framework (https://osf.io/tw38u/).

Our supplementary model controlled for menstruation and included a random slope for fertility probability and a random intercept for the individual (Model S1). The main predictor of interest was the interaction between fertility probability and hormonal contraceptive use, with support for mid-cycle shifts in competitiveness indicated by fertility probability affecting the outcome for the naturally cycling group only.

In Wilkinson notation (Bates et al., 2014; Wilkinson & Rogers, 1973), Model 1 equation can be formalised as:

$$\text{outcome}_{ti} \sim 1 + (\text{menstruation}_{ti} + \text{fertility\_probability}_{ti}) * \text{hormonal\_contraceptive\_user}_{i} \\ + (1 + \text{fertility\_probability}_{ti} \mid \text{person})$$

Supplementary Results

Results for Model S1 are shown in Table S1. Replicating results from the main manuscript, neither self-development competitiveness nor competitive behavior were associated with fertility probability, hormonal contraceptive use, or their interaction (Model S1). Further replicating our main analyses, a main effect of hormonal contraceptive use on lack of interest in competition was observed in our primary model (*b* = .30, *SE* = .11, *95% CrI* = .09 – .50).

Table S1. *Bayesian multi-level model output replicating associations between cycle phase, hormonal contraceptive use, and competitive outcomes tested in the main manuscript*

	Self-development competitiveness			**Lack of Interest in competition**[a]			**Competitive behaviors**		
	Est	**SE**	**95%CrI**	**Est**	**SE**	**95%CrI**	**Est**	**SE**	**95%CrI**
Model S1 (Bayesian)									
Intercept	2.16	.04	2.08, 2.23	3.31	.05	3.21, 3.40	2.16	.04	2.08, 2.23
Menstruation (M)[b]	-.01	.02	-.05, .02	.04	.03	-.01, .09	-.01	.02	-.05, .02
Fertility (F)	.03	.05	-.07, .12	.03	.08	-.12, .19	.03	.05	-.07, .12
HC use (HC)[c]	.11	.07	-.04, .25	**.30**	**.11**	**.09, .50**	.11	.07	-.04, .25
M x HC	-.07	.04	-.14, .01	-.04	.05	-.14, .06	-.07	.04	-.14, .01
F x HC	-.09	.10	-.28, .11	<-.01	.16	-.32, .31	-.09	.10	-.28, .11

Note: N = 302, Observations = 5,636. [a] = Three daily observations are missing for Lack of Interest in Competition. [b] Menstruation: 0 = not menstruating, 1 = menstruating. [c] Hormonal contraceptive (HC) use: 0 = naturally cycling participants, 1 = hormonal contraceptive users. Bold indicates confidence intervals that do not cross zero. 95%CrI = 95% Credible Intervals.

Regarding competitive behaviors, no effect of fertility, menstruation or hormonal contraceptive use was observed for gossip, appearance enhancement, taking selfies, engaging in social comparison, or negative evaluations of others (see Table S2). A positive main effect of hormonal contraceptive use was observed for giving advice (*b* = .50, *SE* = .24, *95% CrI* = .03 – .97), suggesting that users are more likely to give advice compared to non-users. A significant interaction between menstruation and hormonal contraceptive use was also observed (*b* = -.39, *SE* = .19, *95% CrI* = -.77, – -.01). This suggests that naturally cycling participants were less likely to take selfies during menstruation, while no effect of menstruation was observed for hormonal contraceptive users.

Table S2. *Bayesian multi-level model output showing associations between cycle phase, hormonal contraceptive use, relationship status and individual competitive behaviors*

	Gossip			**Appearance**			**Advice**		
	Est	**SE**	**95%CrI**	**Est**	**SE**	**95%CrI**	**Est**	**SE**	**95%CrI**
Model S1 (Bayesian)									
Intercept	-.52	.13	-.78, -.26	-1.73	.11	-1.95, -1.51	-1.20	.12	-1.43, -.96
Menstruation (M)[a]	.05	.08	-.11, .22	.07	.08	-.01, .42	-.04	.08	-.19, .12
Fertility (F)	.04	.20	-.36, .44	.30	.20	-.09, .22	.17	.21	-.24, .57
HC use (HC)[b]	.36	.26	-.15, .86	.21	.22	-.21, .65	**.50**	**.24**	**.03, .97**
M x HC	-.26	.17	-.59, .07	-.22	.16	-.53, .10	-.07	.16	-.39, .25
F x HC	-.20	.39	-.98, .57	-.71	.40	-1.51, .08	-.49	.41	-1.30, .34

	Selfies			**Social comparison**			**Negative other evaluations**		
	Est	**SE**	**95%CrI**	**Est**	**SE**	**95%CrI**	**Est**	**SE**	**95%CrI**
Model S1 (Bayesian)									
Intercept	.41	.15	.12, .72	-1.81	.16	-2.11, -1.50	-.83	.14	-1.12, -.55
Menstruation (M)[a]	-.10	.09	-.28, .08	-.03	.08	-.18, .13	-.16	.09	-.33, .02
Fertility (F)	.42	.26	-.11, .94	.15	.22	-.28, .58	-.35	.23	-.80, .10
HC use (HC)[b]	-.05	.30	-.65, .52	.38	.30	-.22, .98	.32	.29	-.23, .91
M x HC	**-.39**	**.19**	**-.77, -.01**	-.25	.17	-.58, .08	.05	.18	-.29, .40
F x HC	.17	.52	-.83, 1.18	-.36	.44	-1.22, .53	.69	.46	-.21, 1.59

Note: *N* = 302, *Observations* = 5,636. [a] Menstruation: 0 = not menstruating, 1 = menstruating. [b] Hormonal contraceptive (HC) use: 0 = naturally cycling participants, 1 = hormonal contraceptive users. Bold indicates confidence intervals that do not cross zero. 95%CrI = 95% Credible Intervals.

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Chapter 5: Women in their mid-follicular phase outcompete hormonal contraceptive users, an effect partially explained by relatively greater progesterone and cortisol reactivity to competition

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Abstract

Early evidence suggests that hormonal contraceptive (HC) use alters psychological functioning and competitive behavior. Yet, there is limited data on endocrine models for explaining how HC use affects these outcomes. In this pre-registered and open-data study, we test if HC users and naturally cycling (NC) females in their low (mid-follicular) and high (mid-luteal) progesterone phase differ in competitive persistence and whether progesterone and cortisol reactivity mediate of this effect. HC users (N = 73) in the active hormone-exposure phase and NC participants in the mid-follicular (N = 69) or mid-luteal (N = 72) phase completed two behavioral measures of competitive persistence, holding up a weight for time followed by attempting to solve an unsolvable anagram. Participants also completed measures of handgrip strength and self-reported competitiveness as well as gave saliva samples before and after the tasks for hormone assay. Results showed that NC-follicular group had greater competitive persistence in the weight-holding task compared to both NC-luteal (d = .38) and HC use (d = .43) groups independent of physical strength and self-reported competitiveness covariates. Although anagram task performance showed similar trends for group differences, analyses for this task were inconclusive. Baseline progesterone did not mediate the effect of cycle phase group on competitive persistence. However, HC users showed relatively blunted cortisol and progesterone reactivity, and this effect partially mediated the difference in competitive persistence between HC users and the NC-follicular group. In sum, results suggest that HC use could downregulate competitive behavior at least partly by dampening cortisol-progesterone reactivity. These findings offer a new endocrine model for understanding HC use and cycle phase effects on motivational and energetic outcomes required for optimal performance in competitive contexts.

Introduction

Hormonal contraceptives (HCs) such as the birth control pill are some of the most commonly used prescription drugs among reproductive age women worldwide (Brynhildsen, 2014; Tinker et al., 2015; United Nations, 2019). Despite their importance for society and women's health, HCs have been regarded as a "worldwide experiment" due to their potential effects on mental health, brain anatomy, and psychological functioning (Beltz et al., 2022; Brønnick et al., 2020; Casto et al., 2022; Pletzer & Kerschbaum, 2014). A recent review and critical analysis of 46 prior studies found that HC users show comparatively worse performance on tasks involving competitive behavior and achievement orientation, with small to medium effect sizes (Arthur et al., 2022). Two of these prior studies specifically showed that women who were naturally-cycling (NC) persisted longer, compared to HC users, in a weight-holding endurance competition (Casto et al., 2020) and in a difficult or unsolvable anagram task (Bradshaw et al., 2020). Because seeking out and succeeding in competitions is necessary for gaining access to valued resources and achieving social status (Casto & Mehta, 2019), HC use may have unintended consequences for women's social advancement.

Progesterone as a mediating mechanism

One hormonal mechanism that may explain the effect of HCs on behavior is progesterone. Regardless of the specific method of delivery or formula, all HCs result in a consistent and often supraphysiological exposure to synthetic progesterone (*progestin*), with combined forms also containing a smaller dose of synthetic estrogen (for review, Hampson, 2020). For those not using an HC, natural levels of progesterone vary depending on menstrual cycle phase; levels are relatively low in the first half of the cycle (i.e., the follicular phase), and then peak midway through the latter half of the cycle (i.e., the luteal phase). High progesterone or cycle phases marked by high progesterone have been previously associated with reduced willingness to engage in social, economic, or physical risks; and increased prosocial behavior towards close relations but not strangers (Eisenbruch & Roney, 2016; Lobmaier et al., 2019; Maner & Miller, 2014; Pearson & Schipper, 2013; for review, Welling & Burris, 2019; but c. f. Ranehill et al., 2018; Sellitto & Kalenscher, 2022). The motivational priorities hypothesis (Roney & Simmons, 2016; 2017) thus proposes that menstrual phases associated with heightened progesterone functions to shift motivation towards low-risk, energetically undemanding activities associated with survival and gestation, and away from competitive activities associated with mating. The implication is that increased progesterone—whether natural or synthetic in origin—may functionally downregulate antisocial, competitive, and risky behavior.

Most studies examining the effects of progesterone on motivational priorities have relied on counting methods to estimate cycle phase as a proxy for hormones levels associated with the menstrual cycle. While this approach is pragmatic, counting methods have validity concerns (for review, Blake at al., 2016; Hampson, 2020) and limit the ability to directly test endocrine levels as explanatory factors for changes in behavior. Of the few studies directly measuring progesterone, several find that neither between-subject nor within-subject progesterone is related to intra-sexual competition (e.g., Hahn et al., 2016; 2020; Stern et al., 2021; 2022). These studies, however, largely measure progesterone and competitiveness during the brief, six-day mid-cycle fertile window, and largely rely on self-reported attitudes. They also focus on competition solely directed at other women and specific to attracting mates or mate-guarding.

Here we propose a model of female competitive behavior beyond the narrow window of fertility, in which peak progesterone suppresses the motivational tendency to compete more generally. Given that HCs expose users to high synthetic progesterone, we further suggest that HC users will have reduced competitive motivation compared to naturally-cycling women in their mid-follicular phase, but not the high-progesterone luteal phase.

Cortisol and progesterone reactivity

Although internally regulated menstrual cycle-shifts in hormone exposure occur over the course of days and weeks, the endocrine system is also rapidly responsive to external stimuli. Short-term hormone reactivity allows for flexible and adaptive responding to environmental demands. For example, rapid and transient shifts in steroid hormones occur during competitive encounters and are thought to aid in meeting the context-based energetic and motivational demands of competition (Casto & Edwards, 2016; 2021; Gleason et al., 2009; Wirth, 2011). One of the most well-studied accounts of context-specific hormone reactivity is the increase in cortisol levels during and immediately following socially evaluative stress (Dickerson et al., 2009; Kemeny, 2009; Kirschbaum et al., 1993). In this context, a blunted cortisol response is positively associated with chronic stress and poorer psycho-social functioning (e.g., Metz et al., 2020; Zorn et al., 2017). It is well-demonstrated that HC users also show blunted cortisol in these tasks (for review, Gervasio et al., 2022). Yet, how this effect mediates performance outcomes or task-based motivation for HC users compared to non-use counterparts has not been well-documented.

Prior research has also shown that individual differences in testosterone reactivity during competition are positively associated with competitive task persistence (Casto et al., 2020). However, this effect was only evident in men; hormonal correlates of competitive and status related behavior in women continues to evade researchers, perhaps due to the primary focus on androgens and a bias against the inclusion of women in this area of research (for review, Casto & Prasad, 2017; Geniole et al., 2017; c.f. Blake, 2022). Comparatively few studies have tested basal or dynamic progesterone in relation to competitive and social-status oriented outcomes (c.f. Blake et al., 2017, Maner et al., 2010; Stanton & Schultheiss, 2007). Exceptions include a relatively small set of studies showing that progesterone levels transiently fluctuate over the course of laboratory-based social tasks (e.g., Herrera et al., 2106; Maner et al., 2010; Schultheiss et al., 2004; Wirth & Schultheiss, 2006; c.f. Gaffey & Wirth, 2014). Whereas progesterone levels associated with the luteal phase of the menstrual cycle are produced within the ovaries, progesterone is also secreted from the adrenal cortex (De Geyter et al., 2002; Genazzani et al., 1998; Wirth et al., 2007), the primary source of progesterone during the follicular phase (Judd et al., 1992). The daily rhythm of both progesterone and cortisol release is pulsatile occurring in episodic bursts every 1-3 hours or so, with progesterone showing greater frequency of pulses in the luteal phase (Bäckström et al., 1982; Trifonova et al., 2013; Young et al., 2004). Thus, event-associated reactivity patterns are conflated by the waxing and waning of these oscillatory patterns. Emergent patterns at the group level most overcome this individual variability in pulse timing.

Despite the well-known effect of HC use on cortisol reactivity during stress, little is known about how HC use impacts event-associated progesterone reactivity. One exception is a study by Oxford et al. (2017) in which HC users showed significantly blunted reactivity associated with a competitive task. This effect could be due to the fact that ethinyl estradiol, contained in all combined oral contraceptives, appears to inhibit the adrenocortical secretion of progesterone (De Geyter et al., 2002). Further, HCs produce a continuous exposure to progestogens compared to the pulsatile nature of endogenous production. Thus, transient increases in both cortisol and progesterone, whether event-induced or pulsatile oscillations, may play a functional role in the physiological responses to social stressors, including competitive contests, but may be suppressed by HC use. It remains unknown whether blunted cortisol and progesterone reactivity mediate HC use effects on performance in competitive tasks or other social stressors.

The current study

In this preregistered study (https://osf.io/sn9up), we aim to replicate prior research suggesting that HC users show lower competitive or achievement-oriented motivation compared to non-users (Bradshaw et al., 2020; Casto et al., 2020). We extend prior research in several ways: First, we examine whether effects are robust to relevant controls, specifically grip strength and self-report trait competitiveness. Second, we test differences in competitive persistence among three groups: 1) HC users, 2) NC women in their mid-follicular phase (NC-follicular; relatively low progesterone) and 3) NC women in their mid-luteal phase (NC-luteal; relatively high progesterone). We confirm these categories by sampling salivary progesterone levels and test the role of progesterone in mediating the effects of cycle phase on competitive persistence. We hypothesize that NC-follicular women will demonstrate higher competitive persistence than HC users and NC-luteal women in both competitive persistence tasks (H1), and that high progesterone will mediate the negative effect of the luteal phase (versus follicular phase) on competitive persistence (H2).

Third, in an exploratory fashion we assess progesterone and cortisol reactivity during the study session to examine whether HC users differ from non-users in the patterns of change and whether these patterns mediate group differences in competitive persistence. By testing both the basal and dynamic hormones as mediators of HC use and menstrual-phase effects on competitive behavior, we offer initial exploration into short- versus long-term models for hormone exposure effects on status behavior in females. Because prior research suggests that HC users show blunted cortisol and progesterone reactivity as well as lower competitive motivation, we predict that blunted progesterone-cortisol reactivity in HC users (H3) will mediate the negative effect of HC use (versus non-use) on competitive persistence (H4).

Method

This study received ethical approval from the Human Ethics Committee of The University of Melbourne (Ethics ID: 2022-21101-30706-6) and the New College of Florida (Ethics ID: 21-019). Florida data were collected between January 2021 and January 2022, and Melbourne data were collected between February 2022 and September 2022. All participants provided written informed consent.

Procedure

Participants completed an online pre-screening form which automatically determined their eligibility for the study and were then invited to attend a testing session during their mid-follicular or mid-luteal phase (NC women) or on any non-menstruation day (HC users; see "Menstrual Cycle Estimation and Confirmation" for more). The day before their assigned laboratory session they received an email reminding them of their session time and to abstain from eating and drinking anything except water, smoking/vaping, chewing gum, or brushing their teeth within an hour of the session. We also requested they abstain from alcohol or recreational drug use within 12 hours of the session and to reschedule if they had an oral infection, laceration, gum bleeding; or were ill.

All laboratory sessions were conducted between 11:30 am and 5:30 pm. Upon arrival, participants rinsed their mouth with water and completed the handgrip strength measure. They then completed a survey[8] on adherence to the saliva protocol and a trait competitiveness measure. After 10 minutes had elapsed since the mouth rinse, participants provided approximately 2ml of saliva via passive drool. They completed the competitive will task followed by the anagram task, then rinsed their mouth again. Finally, they completed demographics and a menstrual cycle questionnaire, provided a second saliva sample (approximately 5-10 minutes after the mouth rinse), and were debriefed.

The time between the two saliva samples was approximately 20-30 minutes, which may reduce some of the influence of the slightly broader pulsatile oscillations on patterns of progesterone and cortisol reactivity for naturally-cycling participants. While this is the standard

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[8] Measures related to premenstrual dysphoric disorder, mood, motivation and social affiliation (AUS sample only) were collected for exploratory analyses not included in this report.

time frame for detecting cortisol response to social stressors (Goodman et al., 2017), there is no established precedence in the limited prior literature for the appropriate timing to best capture an event-related progesterone response pattern.

Menstrual cycle estimation and confirmation

For our study design, we aimed to capture the broader 5-day windows of mid-follicular and mid-luteal phases. To determine phase day ranges for recruitment, we consulted an analysis of 612,613 menstrual cycles from 124,648 women, which indicated that the average peri-ovulatory period begins on Day 11 and ends on Day 16 (Bull et al., 2019). To account for significant between- and within-women variability in the timing and length of the fertile window, participants were invited to attend laboratory sessions either from day 4 to day 8 of their cycle (categorized as NC-follicular) and were required to have finished menstruating (confirmed via email the night prior to the laboratory session). Although roughly 6% of women may be in the beginning of their fertile window on Day 8 (Blake et al., 2016), it is extremely unlikely that any woman would have ovulated by this time (as ovulation occurs at the end of the fertile window). Thus, our confidence that this window is marked by progesterone quiescence is high.

Luteal phase women were recruited to attend laboratory sessions -8 to -4 days before their predicted next menstrual cycle onset. Bull et al. (2019) found that the average luteal phase lasted 12.9 days, and our more conservative 5-day recruitment window is designed to capture women when progesterone is dominant. It is highly unlikely that women would experience low progesterone (relative to follicular phase levels) during this window, raising confidence in the validity of this cycle phase estimation pattern (e.g., see drastic progesterone level comparisons between ML and MF women in Sharma et al., 2020 using the forward counting method and broader day ranges for these phase windows).

Eligible HC participants were scheduled to participate on any of their active pill days and NC participants were randomly assigned to attend a testing session during either the mid-follicular or mid-luteal window, determined via self-reported recent cycle onset and cycle length. If these windows did not suit participants' schedules, we instructed them to notify us when their next menstrual phase began and the scheduling process was repeated. Following participation, we obtained the date of NC women's next menstrual onset to confirm backward counting cycle days (and thus, luteal phase scheduling accuracy). For luteal participants who did not report their next onset date (25% of cycles), we inferred backwards counted day from the average reported cycle length (as recommended by Welling and Burriss, 2019). We used these dates to confirm the accuracy of our testing windows and report post-hoc exclusions below.

Pre-registration and participants

The method and statistical approach pertaining to H1 and H2 were pre-registered prior to data collection commencement (https://osf.io/sn9up). H3 was exploratory and developed post-hoc. The pre-registered criteria for all participants were: aged 18 to 40 years old; assigned female at birth; physically able to hold a light weight; no medically diagnosed cancer, cardiovascular, metabolic, endocrine, or kidney disorder; no medically diagnosed fertility disorder; and no steroid use in the past three months. Naturally cycling participants had the following additional criteria: no HC use in past three months; average cycle length between 21 and 35 days; and moderate confidence in their average cycle length and date of last menstrual onset. HC users also needed to have used the same HC for at least three months consistently.

Participants were 279 females aged 18-40 years. US participants were New College of Florida students ($N = 73$) and were reimbursed $15 US for participation. Australian participants were University of Melbourne students ($N = 114$), from the University of Melbourne online paid participant pool (*N* = 15), or were members of the general community (*N* = 77). Students received course credit for their participation and paid community participants were reimbursed $20 AUD. The age of first HC use was 16 or younger for 41% of HC users, 86% took the combined oral contraceptive pill (COC), and 14% used a patch or transdermal implant. Thirty-four COCs containing 9 different progestins were reported, with 41% of COCs containing levonorgestrel (Generation 2); 32% containing cyproterone acetate, norethindrone, or norethindrone acetate (Generation 1); 17% containing dienogest, drospirenone, or nomegestrol acetate (Generation 4) and 10% containing desogestrel or norgestimate (Generation 3). Doses ranged from 100-3000 mcg; see Supplementary Materials for further details of the HCs used in the sample.

Due to discrepancies between reported versus actual cycle lengths, not all testing sessions took place during the targeted 5-day window. Participants were excluded from analyses if their testing day was not within or 2 days adjacent to their intended 5-day window (*N* = 16) or if their confirmed menstrual cycle length was not within the 21–35-day range (*N* = 29). We also withdrew hormonal IUD users (*N* = 11) due to the low level or absence of progestin in this method of contraception. Finally, HC users who reported changing HC type between the prescreening and experimental session (*N* = 9) were also excluded. A total of 214 participants (HC = 73, NC-follicular = 69, NC-luteal = 72) remained in the sample for analysis. Following exclusions, the mean and median test day for the NC-follicular (*mean* = day 7.88; *median* = day 8) and NC-luteal (*mean* = day -5.56; *median* = day -5) groups fell within the desired 5-day testing window. See the Supplementary Materials for details of further analyses based on alternative cycle phase criteria.

Measures

Pre-screening survey

The pre-screening survey asked NC participants to report their average cycle length and the start date of their most recent cycle. To improve recall accuracy, participants were encouraged to consult their menstrual cycle tracking app, if they used one. Participants also reported their confidence in the reported date of their last menstrual period and the average cycle length. Additionally, we included the question, “Do you have regular menstrual cycles (i.e., roughly one menstrual period per month?)” with the answer choices “Not at all, my period is completely irregular; Somewhat, my period can sometimes be unpredictable; Pretty much, my period happens mostly once a month with occasional blips; Very much so, my period is quite regular; I'm not sure.” Participants who were confident about their cycle length and last menstrual onset date and answered either “Pretty much, my period happens mostly once a month with occasional blips” or “Very much so, my period is quite regular” were invited to participate.

Handgrip Strength

A digital handheld dynamometer was used to assess individual differences in handgrip force production (kilograms of pressure), a proxy for physical strength. Participants gripped and squeezed the handle of the dynamometer as hard as they could for 3 seconds using their dominant hand. The experimenter recorded the score and asked the participant to repeat the task if the first attempt was not completed correctly.

Trait Competitiveness

Trait competitiveness was measured using the Competitiveness Orientation Measure (COM, Newby & Klein, 2014), a 37-item survey rated on a 5-point Likert scale with subscales for (1) general trait competitiveness, (2) dominant competitiveness, (3) enjoyment or affectivity associated with competitiveness and (4) intrinsic interest in competition for personal enhancement. All four subscales have demonstrated high reliability and validity among large student and community-based samples (Newby & Klein, 2014). Because these subscales produce relatively high inter-correlation (r values .55-.74), we used the mean score as a covariate in relevant analyses (for this and following measures, descriptives are in Table 1).

Competitive Will Task

Competitive persistence was measured by the Competitive Will Task (Casto et al 2020) used to elicit individual differences in the willingness to endure or push through discomfort to out-perform others in competition. This task has been previously validated as measure of mental toughness (Crust & Clough, 2005) and competitive motivation (task performance positively correlates with self-reported competitiveness, dominance motivation, and task-specific desire to win, Casto et al., 2020). Participants held a ~1 lb. dumbbell at arm's length and shoulder height, with arm extended from the body at a 90° angle, for as long as they wanted to in competition with others. The AUS sample used a weight that was 0.1 lb. heavier due to the different metric systems for weights between the US and AUS and resulting availability of only .5 kg weights in AUS.

Participants were told that they were competing against the scores of other participants, and that the five best performers in each academic semester would receive a cash prize ranging from $10 - $50 depending on rank. An index card was placed on the wall to park the participant's shoulder height. Then, the experimenter confirmed the participant understood the task, gave the ready-set-go signal, and started a timer that was out of view to the participant as soon as the participant's arm reach shoulder height. The timer was stopped and time recorded when the participant dropped their arm. Participants were not given any performance feedback during the session; contests winners were contacted at the end of the semester via email to receive their cash prize. Competitive persistence was operationalized as the time in seconds that a participant held up their arm before quitting the contest. The maximum allowed time to compete was 12 minutes.

Competitive Anagram Task

Competitive persistence was also measured by an adapted Anagram Persistence Task (APT, Eisenberger & Leonard, 1980) designed to elicit "the motive to achieve high standards of performance in the face of frustration" (Dudley et al., 2006, cited in and for review, Gignac & Wong, 2018, p.2), and is a validated measure of test-taking effort, persistence, and motivation. To explore differences in persistence between HC users and non-users, Bradshaw et al. (2020) adapted the APT to include a series of three solvable and unsolvable anagram tasks, and found that HC users persisted for less time than non-users on both anagram types. We adapted the APT to a competitive scheme in which participants were told that they could increase their overall rank in the competitive will task performance (by adding 1 minute to their time in that task and therefore, their odds of winning a cash prize). We intended that our adaptation would activate social rank as the goal of competition rather than money, to reduce complications from participants' financial situation influencing their motivation. We also adapted the task by only measuring their performance on one single unsolvable test anagram to reduce the influence of prior experience or verbal fluency.

Participants completed the task in a Qualtrics survey window on a computer in the same testing room as the competitive will task. Participants first read the instructions "Anagrams are a string of letters that can be reordered to make a word. For example, OBKO would be an anagram for BOOK. Your task is to rearrange the letters to make an actual word. Let's practice a few! Feel free to use the scratch paper and pen provided to help solve the anagrams." They then completed two practice solvable anagrams ("NORB" followed by "LABL"). Next, they received the following instructions:

> "Now that you have practiced, we will give you a harder one. BUT this is now a part of the study --> By solving this next one correctly, you will receive 1 min added to your performance time in the weight holding task. This could drastically increase your rank among the other participants. You can take as long as you want, but you are not required to solve it - doing so is for competition, to increase your rank. Click the button below to begin."

An internal timer started when the next screen appeared. This screen contained the anagram (LOIMCPRIS), a blank space to write the answer, and a button with the following instruction written above, "Click the blue button below when you are done attempting to solve (leave the space blank if you exit without figuring it out)." The internal timer stopped when they clicked the button. Competitive persistence in this task was operationalized as the time in seconds that a participant continued attempting to solve the anagram before quitting the contest. The maximum allowed time to compete was 12 minutes.

Saliva protocol and assays

To aid consistency in sample collection method, participants watched a video explaining how to provide the saliva sample and reminders for encouraging saliva flow (e.g., lean forward and imagine lemons on the tongue). The video also served as a time-keeper to limit saliva sample collection to 5-7 minutes. AUS saliva samples were frozen at -80 Celsius, then shipped to a professional laboratory in (Stratech; Sydney, Australia) to be assayed for progesterone and cortisol[9]. All samples were analyzed in duplicate and measured using a commercially available

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[9] Saliva samples were also assayed for estradiol and testosterone in the US and AUS samples, respectively. HC users typically have significantly lower basal testosterone levels than NC women. Although not a part of the aims of this study and the pre-registered hypotheses, we include exploratory analyses for testosterone in the smaller subset of AUS participants in the supplementary files. Testosterone levels were indeed lower for HC compared to both NC follicular and NC luteal groups on

ELISA assay, an enzyme immunoassay technique with high sensitivity (Salimetrics, USA), according to the manufacturer's instructions (but c.f. Arslan et al., 2022). Intra- and inter-assay coefficients of variations for progesterone were 3.80% and 4.80%, respectively. Intra- and inter-assay coefficients of variations for cortisol were 4.00% and 4.50%, respectively. US saliva samples were frozen at -20 Celsius, then shipped to a separate professional laboratory (Salimetrics; Calsbad, CA) for assay in duplicate using Salimetrics ELISA kits. Intra- and inter-assay coefficients of variations for progesterone were 6.20% and 7.55%, respectively. Intra- and inter-assay coefficients of variations for cortisol were 5.3% and 6.00%, respectively.

Data Analysis

Power analysis

Previous research comparing competitive persistence between HC users and NC women yielded an average effect size of *Cohen's* $d = .35$ (Casto et al., 2020). However, this effect size, was likely underestimated due to unexplained cycle phase variation in competitive persistence among NC women (Gangestad et al., 2016). For increased accuracy, we based our power calculations on the difference in competitive persistence between NC-follicular phase women and the other two groups (HC users and NC-luteal phase) as having an effect size of $d = .40$. Power analysis indicated our sample of 214 participants yielded 83.3% power with an alpha of .05 to detect an effect size of $f^2 = .04$, equivalent to $d = .40$. A mediation power analysis indicated that our sample size of 141 in the two NC groups yielded 71.9% power to detect the indirect effect of X on Y with $\alpha = .05$, assuming $B = -.25$ for $X \rightarrow M$ (group effect on

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average. However, neither basal nor percent change in testosterone were related to competitive persistence outcomes.

progesterone, estimate from Blake et al., 2017) and $M \rightarrow Y$ (progesterone effect on competitive persistence), and a negligible direct effect of $B = .05$ for X on Y (Kenny, 2017).

Hypothesis tests

Univariate ANOVAs were conducted to determine the extent to which group (HC use, NC-follicular, and NC-luteal) predicted competitive persistence. To test the robustness of our primary models, additional univariate ANOVAs were conducted including relevant covariates, i.e., handgrip strength and trait competitiveness. Mediation analyses were conducted to determine whether, among NC participants, baseline progesterone mediated the effect of cycle phase on competitive will persistence. HC users were excluded from this analysis due to the uncertainty of how synthetic progesterone and the variable doses affect HC users' salivary levels of baseline progesterone as a group. Finally, mediation analyses were conducted to determine whether progesterone or cortisol reactivity, the percentage change across the competition, mediated the effect of group condition on competitive will persistence. Data, analysis code, and all supplementary results are open: https://osf.io/a26sv/.

Results

Descriptive statistics based on raw data were generated for each variable (Table 1). Pearson's correlation coefficients for all continuous variables can be found in the Supplementary Materials. Trait competitiveness and grip strength values were normally distributed and there were no outliers. Competitive will persistence was slightly greater among the AUS sample (M = 223, SD = 68) compared to the US sample (M = 207, SD = 72) possibly due to the slightly higher weight used for the AUS sample (0.5 kg, which is 1.1 lb., compared to 1 lb. for US sample). To adjust for this difference, performance was centered within country. Raw and centered times were abnormally distributed (Kolmogorov-Smirnov $p = .017$ and Shapiro-Wilk tests $p < .001$)

and had three outliers that were more than 3 SDs above the mean. These values were winsorized to 3-*SD*s.

Anagram persistence was abnormally distributed (Kolmogorov-Smirnov and Shapiro-Wilk tests were $p < .001$) as 39% of participants persisted to the maximum cut-off time (12 minutes). Thus, we transformed competitive persistence in the anagram task into a binary variable (0 - time below maximum cut-off, 1 – persisted to ceiling) and conducted logistic regression.

At both timepoints, raw values of progesterone and cortisol were negatively skewed (Kolmogorov-Smirnov and Shapiro-Wilk tests were $p < .001$) and were log-transformed. Transformation normalized progesterone but not cortisol. Three cortisol outliers were winsorized to 3-*SD*s. Whether using the raw or transformed values, progesterone and cortisol levels were significantly and positively correlated at time point 1 (r = .15-.27) and time point 2 (r = .23-.36). These overall positive correlations were carried by the HC participants (Time 1: r = .50-.51; Time 2: r = .60-.71) and NC-follicular participants (Time 1: r = .35-.39; Time 2: r = .50-.51); progesterone and cortisol were not correlated in the NC-luteal participants (Time 1: r = -.01-.06; Time 2: r = .04-.14).

Table 1. *Descriptive Statistics for Sample Characteristics and Study Variables*

Variable	HC n = 73	NC-follicular n = 69	NC-luteal n = 72	Full Sample $N = 214^a$
Age ^{b} – n (%)				
18-22	30 (65.2%)	29 (59.2%)	53 (84.1%)	112 (70.9%)
23-27	11 (23.9%)	13 (26.5%)	3 (4.8%)	27 (17.1%)
28-32	2 (4.3%)	5 (10.2%)	4 (6.3%)	11 (7%)
33-40	3 (6.5%)	2 (4.1%)	3 (4.8%)	8 (5.1%)
Country – n (%)				

Australia	46 (63%)	49 (71%)	63 (87.5%)	158 (73.8%)
United States	27 (37%)	20 (29%)	9 (12.5%)	56 (26.2%)
Trait competitiveness	2.77±.74	3.04±.68	2.82±.71	2.87±.72
Grip strength (kg)	26.51±5.19	24.98±4.89	25.66±5.12	25.73±5.08
Competitive will (sec)	207.05±70.76	237.16±70.44	213.08±63.24	218.79±69.12
Anagram (sec)	503.58±206.10	517.78±232.10	489.72±252.00	503.50±229.90
Progesterone T1 (pg/mL)	119.37±77.48	117.49±51.57	225.54±132.25	154.49±106.21
Progesterone T2 (pg/mL)	109.67±87.20	133.88±65.27	258.70±153.28	166.76±126.24
Cortisol T1 pg/mL	.198±.096	.247±.157	.237±.156	.227±.139
Cortisol T2 pg/mL	.206±.128	.329±.243	.274±.248	.268±.217

Note. Plus-minus values are means ± standard deviation. T1 = Timepoint 1. T2 = Timepoint 2. Raw data is shown for all variables. [a]Missing values for each variable are: gender = 8; trait competitiveness = 5; grip strength = 1, cortisol T1 = 3, progesterone T2 = 2, cortisol T2 = 2. [b]Age data was missing for the Florida participants; however, the age range of the student population is known to be mostly 18-22.

Group differences in competitive persistence (H1)

Competitive will task

A univariate ANOVA indicated that group (HC use, NC-follicular, and NC-luteal) significantly predicted competitive will persistence, $F(2, 214) = 3.835$, $p = .023$, $\eta^2 = .035$. As shown in Figure 1, the NC-follicular group persisted significantly longer in the competition than HC users, $M_{diff} = 27.62$ secs, 95% $CI = 6.17 – 49.06$, $t(140) = 2.54$, $p = .012$, $d = .43$; and the NC luteal group, $M_{diff} = 24.58$ secs, 95% $CI = 3.06 – 46.10$, $t(139) = 2.25$, $p = .025$, $d = .38$, whereas performance between HC users and the NC-luteal group did not differ ($p = .778$). Follow up robustness tests using Tukey HSD indicated that the difference between the two NC phase groups was not robust to multiple comparisons ($CI = -1.19 – 50.34$).

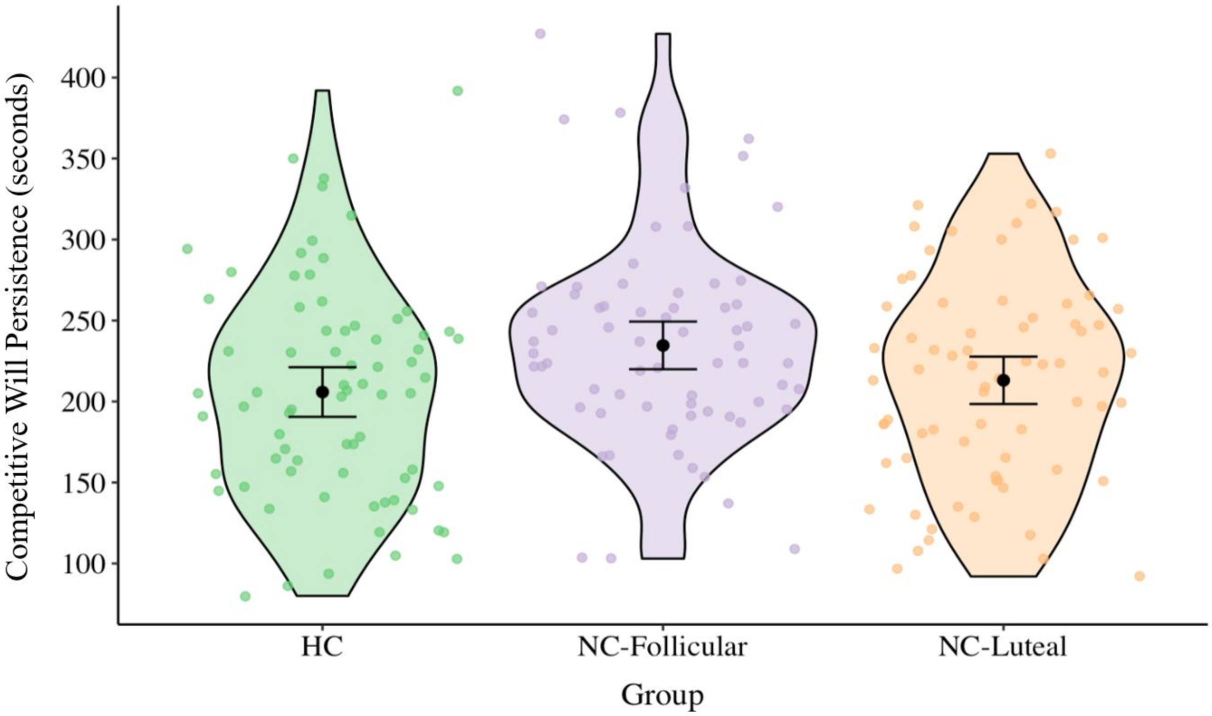
To further test the robustness of this effect, we added handgrip strength and trait competitiveness to the ANOVA model as covariates. Both handgrip strength ($b = 3.90$, 95% $CI = 2.23 – 5.56$, $t(203) = 4.62$, $p < .001$, $\eta^2_{partial} = .10$) and trait competitiveness ($b = 14.72$, 95% $CI = 2.83 – 26.61$, $t(203) = 2.44$, $p = .015$, $\eta^2_{partial} = .03$) were significant positive predictors of competitive will persistence. However, the main effect of group remained significant after accounting for variance explained by these related factors, $F(2, 208) = 4.20$, $p = .016$, $\eta^2_{partial} = .040$. Post-hoc comparisons also remained the same after inclusion of covariates (NC-follicular vs. HC users: $M_{diff} = 29.37$ secs, 95% $CI = 8.56 – 50.18$, $t(137) = 2.78$, $p = .006$, $d = .48$; NC-follicular vs. NC-luteal group: $M_{diff} = 22.61$ secs, 95% $CI = 1.75 – 43.47$, $t(134) = 2.14$, $p = .034$, $d = .37$; NC-luteal vs. HC users: $p = .514$).

Robustness tests using raw values, more conservative menstrual phase window estimates, and less conservative menstrual phase estimates produced similar results in both the size and direction of effects (see Supplementary Materials). Exploratory analysis of competitive will persistence by the generation of the progestin in HC users revealed that HC users whose oral contraceptive contained a 1st generation progestin had lower persistence than those who used a 2nd or 4th generation progestin, but the underpowered analysis was only significant when comparing 1st and 2nd generation HC users. Competitive will persistence was not different based on estimated progestin androgenicity. See Supplementary Materials for plots of exploratory analyses.

Unsolvable anagram task

A univariate ANOVA indicated that group (HC use, NC-follicular, and NC-luteal) did not predict anagram task persistence, $F(2, 214) = .26$, $p = .771$, $\eta^2_{partial} = .002$, although mean times showed a similar trend in group differences as seen for the competitive will task (Table 1). The analysis was repeated with trait competitiveness entered as a covariate. Trait competitiveness was significantly and positively related to anagram task persistence, $b = 48.29$, 95% $CI = 4.21 – 92.37$, $t(204) = 2.16$, $p = .032$, but there was no change in the null result for group, $F(2, 214) = .064$, $p = .938$, $\eta^2_{partial} = .001$. The analysis including covariates was repeated again with only those participants who did not reach the time cap ($N = 126$) and the result was likewise not significant, $F(2, 126) = .90$, $p = .410$, $\eta^2_{partial} = .02$. A logistic regression using the binary outcome variable was also not significant ($p = .407$). Despite these null effects, competitive will persistence and anagram task persistence were positively correlated in a regression analysis controlling for group, $b = 1.25$, 95% $CI = .80 – 1.69$, $t = 5.54$, $p < .001$, $R^2_{change} = .13$.

Figure 1. *Competitive Will Persistence for NC-Follicular, NC-Luteal and HC Group*



Note. N = 214. Raw performance times shown; three upper outliers were winsorized to 3 SDs above the mean (207 seconds). Black circles represent the mean level for each group and the surrounding error bars represent 95% confidence intervals.

Mediation via basal progesterone (H2)

Among only the NC participants, an examination of the effect of cycle phase on progesterone ($X \rightarrow M$) indicated that phase significantly predicted basal progesterone level (β = 0.25, $p < .001$), with mean progesterone +108 pg/ml greater on average in the NC-luteal than NC-follicular phase (Table 1). However, basal progesterone was not associated competitive will performance (M→Y; $\beta = 23.55$, $p = .318$). This null effect persisted after accounting for trait competitiveness and grip strength as covariates. Given that no group differences were observed for anagram task persistence, we did not run a follow-up mediation analyses.

Group differences in hormone reactivity (H3)

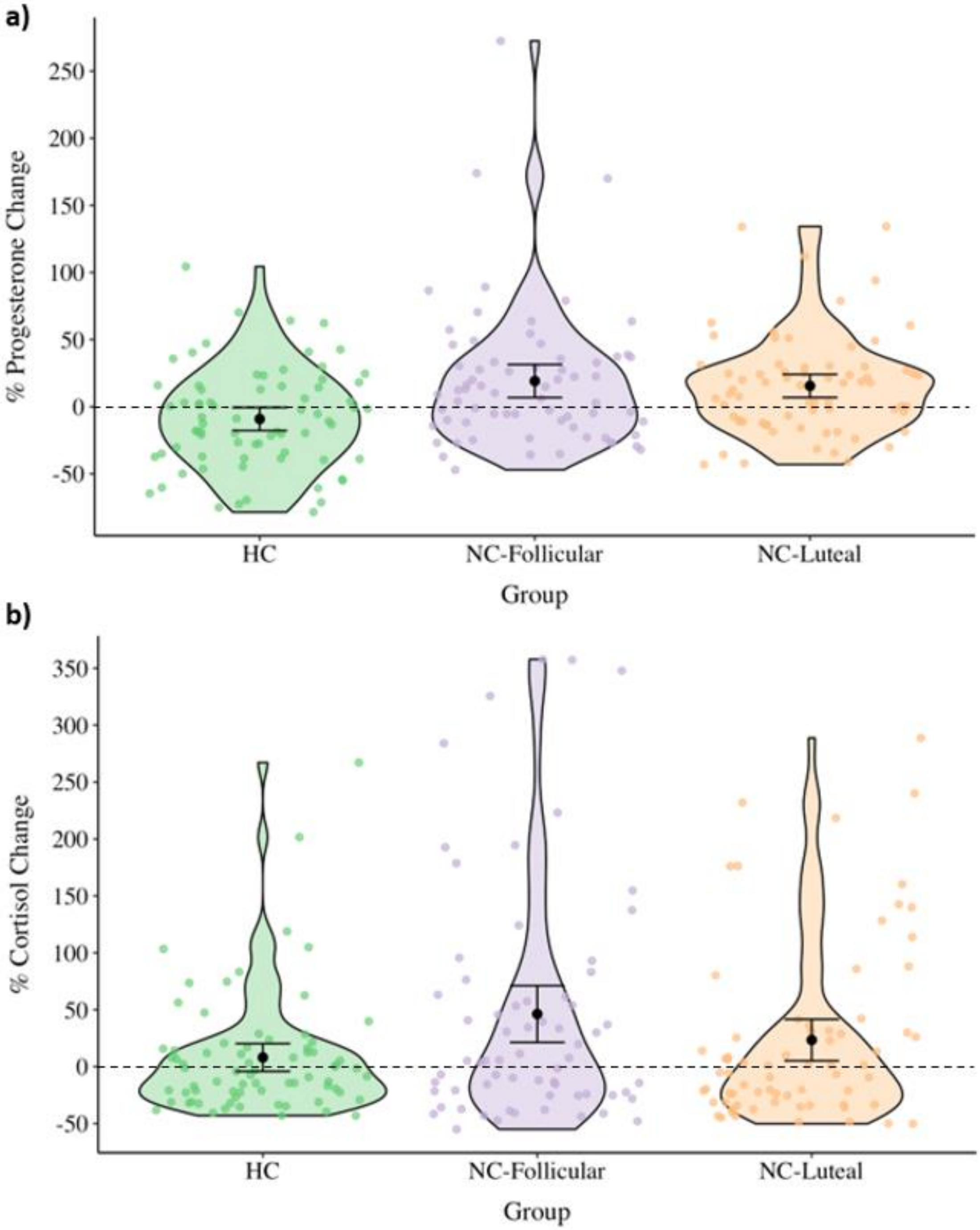
To estimate the relative change in progesterone and cortisol levels over the testing period, we calculated the percentage change in progesterone and cortisol levels between samples, with higher scores indicating an increase from first to second sample. The percentage change in progesterone and cortisol were significantly and positively correlated in all three conditions (HC users, $r = .48$, $p <.001$; NC-follicular, $r = .48$, $p <.001$; NC-luteal, $r = .37$, $p = .002$).

Separate univariate ANOVAs indicated that HC users, NC-follicular, and NC-luteal groups differed in hormone reactivity, see Figure 2. For progesterone (HC users, $M = -9.17\%$; $SD = 37.49$; NC-follicular $M = +19.11\%$; $SD = 52.11$; NC-luteal, $M = +15.49\%$; $SD = 37.34$), the group effect was significant, $F(2, 212) = 9.27$, $p < .001$, $\eta^2 = .08$. Post hoc tests indicated that HC users showed blunted progesterone reactivity compared to both the NC-follicular group, $M_{diff} = 28.28\%$, 95% $CI = 14.11 – 42.44$, $t(140) = 3.94$, $p < .001$, $d = .67$; and the NC-luteal group, $M_{diff} = 24.66\%$, 95% $CI = 10.55 – 38.77$, $t(141) = 3.44$, $p = .001$, $d = .58$. The NC-follicular and NC-luteal groups were not different in their pattern of progesterone reactivity ($p = .619$).

For cortisol (HC users, *M* = +8.07%; *SD* = 53.15; NC-follicular *M* = +46.28%; *SD* = 105.53; NC-luteal, *M* = +23.42%; *SD* = 78.86), the group difference was significant: *F*(2, 209) = 3.87, *p* = .022, η^2 = .04. Post hoc tests indicated that HC users showed blunted cortisol reactivity compared to the NC-follicular group, M_{diff} = 38.19%, 95% *CI* = 11.02 – 65.37, *t*(137) = 2.77, *p* = .006, *d* = .47; but not the NC luteal group, M_{diff} = 15.35%, 95% *CI* = -11.41 – 42.12, *t*(141) = 1.13, *p* = .259, *d* = .22. NC-follicular and luteal groups were not significantly different in cortisol reactivity (*p* = .102).

Exploratory analysis of hormone reactivity by the generation of the progestin in HC users revealed that HC users whose oral contraceptive contained a 1st generation progestin decreased in progesterone and cortisol over the course of competition, while those who used a 2nd or 4th generation progestin remained relatively unchanged over the course of the testing period, but the underpowered statistical comparison was not significant between the progestin generation groups. Neither progesterone nor cortisol reactivity differed based on estimated progestin androgenicity. See Supplementary Materials for plots of exploratory analyses.

Figure 2. *Group Progesterone and Cortisol Reactivity from Pre- to Post-Competition*



Note. N = 214. Percentage of hormone change from pre- to post competition for a) progesterone and b) cortisol. Black circles represent the mean levels for each group and the surrounding error bars represent 95% confidence intervals. High scores indicate an increase in hormone from the first to the second sample. Dashed line indicates $y = 0$.

Mediation via hormone reactivity (H4)

Given that the differences between the NC-luteal and NC-follicular groups in both competitive will persistence and hormone change were not robust and the most robust comparisons occurred between the NC-follicular and HC use groups, we effect coded the three conditions for mediation analysis as -1 for HC users, 1 for NC-follicular, and 0 for NC-luteal. Thus, results of the mediation analyses focus on explaining the differences in competitive will persistence between HC-users and NC-follicular groups. Results are displayed in Table 2.

An examination of the effect of group on progesterone reactivity indicated that group significantly predicted progesterone reactivity (*X*→*M*), with mean progesterone reactivity greater in the NC-follicular (*M* = +19.11%, *SD* = 52.21) than HC-user group (*M* = -9.17%, *SD* = 37.49). Progesterone reactivity was not associated with competitive will persistence (*M*→*Y)* nor was the indirect effect of progesterone reactivity. Repeating the same analyses with cortisol reactivity indicated that group significantly predicted cortisol reactivity (*X*→*M*), with mean cortisol reactivity greater in the NC-follicular (*M* = +46.26%, *SD* = 105.53) than HC-user group (*M* = +8.07%, *SD* = 53.15). Cortisol reactivity was positively associated with competitive will persistence (*M*→*Y)* and the indirect effect of cortisol reactivity on competitive will persistence was also positive and significant.

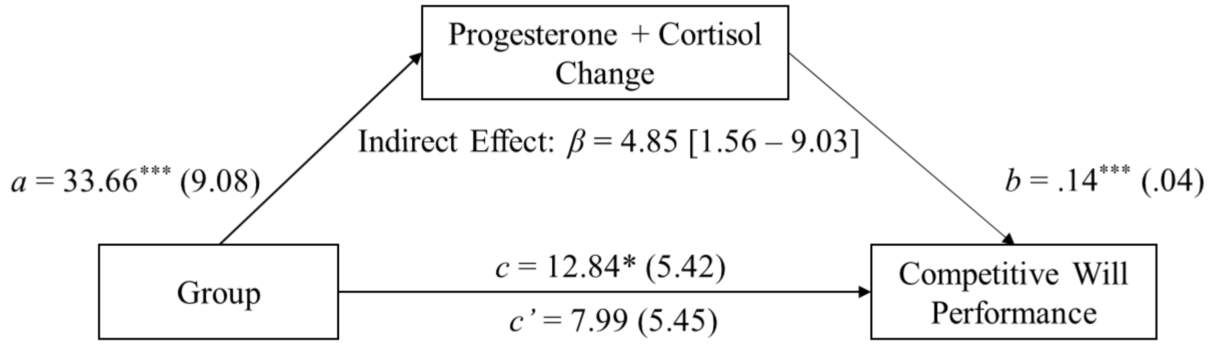
To test the combined explanatory power of blunted reactivity in HC users, we summed the reactivity scores for both progesterone and cortisol; model results are shown in Figure 3. The effect of group on combined reactivity indicated that group significantly predicted combined hormone reactivity (*X*→*M*), with mean reactivity greater in the NC-follicular than HC-user group. Combined reactivity was positively associated with competitive will persistence (*M*→*Y)* and the indirect effect of combined reactivity on competitive will persistence was also positive and significant. Effect sizes were small across all analyses and the inclusion of handgrip strength and trait competitiveness as covariates on *Y* produced similar results (see Supplementary Materials).

Table 2. *Mediation Analysis Results for Progesterone, Cortisol and Summed Reactivity*

	B	*b*(SE)	*CI*	*t*	*p*	R^2
Progesterone Reactivity						
Path A (*X*→*M*)	.26	14.24 (3.61)	7.12 – 21.35	3.95	<.001	.07
Path B (*M*→*Y*)	.12	.18 (.10)	-.03 – .38	1.71	.089	.04
Indirect Effect*	.03	2.53 (1.94)	-1.03 – 6.56			
Cortisol Reactivity						
Path A (*X*→*M*)	.19	19.03 (6.87)	5.48 – 32.58	2.77	.006	.04
Path B (*M*→*Y*)	.26	.20 (.05)	.10 – .31	3.85	<.001	.09
Indirect Effect*	.05	3.89 (1.59)	1.03 – 7.27			
Progesterone + Cortisol Reactivity						
Path A (*X*→*M*)	.25	33.66 (9.08)	15.76 – 51.55	3.71	<.001	.06
Path B (*M*→*Y*)	.25	.14 (.04)	.06 – .22	3.57	<.001	.08
Indirect Effect*	.06	4.85 (1.92)	1.56 – 9.03			

Notes. Path A = Group condition effect coded as -1 for HC users, 1 for NC-follicular, and 0 for NC-luteal to hormone reactivity value; Path B = hormone reactivity value to competitive will persistence; *Indirect effect is based on 5,000 bootstrapped samples.

Figure 3. *Mediation of the effect of group condition on competitive persistence mediated by combined progesterone and cortisol reactivity*



Note. Group condition effect coded as -1 for HC users, 1 for NC-follicular, and 0 for NC-luteal to hormone reactivity value. Process Model 4. *** p <.001, ** p< .01, * p <.05.

Discussion

The purpose of this study was to replicate and extend prior research on the relationship between HC use, menstrual-cycle phase, and competitive behavior. Results of our pre-registered analysis replicated prior work showing that HC users have lower persistence in a weight-holding competition compared to naturally-cycling participants (Casto et al., 2020). We add to this research by showing that this effect is significant only when compared to naturally-cycling participants in their follicular phase, who outperformed both HC users and naturally-cycling participants in their luteal phase. The effect remained unaffected by the inclusion of covariates for grip strength and trait competitiveness, and effect sizes were relatively small to medium overall. The difference between NC-follicular and NC-luteal phase participants was particularly small and not robust.

These results add to a growing body of literature that suggests HC use impacts psychological outcomes. For instance, studies have shown that HC users, compared to naturally-cycling individuals, may have dysregulated social reward mechanisms, increased emotional reactivity to aversive stimuli, and altered stress reactivity (Hertel et al., 2017; Sharma et al., 2020; for review, Montoya & Bos, 2017). However, studies of HCs effects on cognition reveal potential advantages for verbal memory and visuospatial skills, depending on the specific hormone formula (Beltz, 2022; Beltz & Moser, 2020). Studies of social and economic outcomes have also shown that HC users, compared to non-users, may behave differently, both less pro-social and less advantageous, in economic bargaining games (e.g., Strojny et al., 2021; but see, Ranehill et al. 2018; for review, Arthur et al., 2022). The current study contributes new evidence that the lack of accounting for cycle phase of the naturally-cycling comparison group could explain mixed effects and small effect sizes in some prior literature (for review, Arthur et al., 2022; Cobey & Hahn, 2018).

We were unable to replicate the original study design and results from Bradshaw et al. (2020) regarding differences between HC users and non-users in the unsolvable anagram task. Several methodological disparities between our design and theirs likely explain the different results. These differences include the competitive and monetary incentive structure present in the current study and differences in the design (e.g., one vs multiple anagrams, short vs long time cap). Additionally, 39% of our participants persisted for the longest time possible, resulting in ceiling effects. Although effects were in a similar direction as the competitive will task, neither HC users nor naturally-cycling women in the follicular or luteal phase significantly differed in their likelihood of persisting in the unsolvable anagram task, suggesting HC use and cycle phase did not affect competitive persistence as measured with this task.

Menstrual-cycle phase, progesterone, and competitive behavior

Prior research on menstrual cycle shifts in competitive behavior has focused on the *late* follicular phase, marked by peak estradiol and corresponding ovulation (i.e., the fertile window). The premise of this area of research is that fertility is associated with increased intrasexual competition and behavioral assertiveness, presumably to support women in their acquisition of high-quality mates (e.g., Blake, 2016; Blake et al., 2022; Cobey et al., 2013; Durante et al., 2008; Stern et al., 2022). Studies examining competitive behavior outside of mating contexts have also shown that competitive behavior in economic games may increase during the fertile window, although effect sizes are small (e.g., Eisenbruch and Roney, 2016; Pearson and Schipper, 2013; but see, Ranehill et al. 2018; for review, Arthur et al., 2022).

In contrast, the focus of the current study was to test whether competitive behavior differs between the mid-follicular phase – where progesterone is quiescent – and mid-luteal phase – where progesterone is dominant. Contrary to our predictions, there was no compelling evidence that the drastically higher basal levels in progesterone for luteal phase group explained their relatively lower competitive persistence, compared to the follicular phase group. That is, individual differences in basal progesterone were unrelated to competitive behavior. This result contrasts with Schipper (2015), who found that basal progesterone showed a slight positive correlation with bidding amount in a competitive auction game and a negative correlation with profit, interpreted as reduced competitiveness, although the effects were small. The current study required persistence in a weight-holding competition rather than financial risk/benefit decisions, but our null results are consistent with at least one other study on progesterone and social risk (Strojny et al., 2021).

The difference in results between Schipper (2015) and ours could also have to do with the fact that participants in the present study competed during a restricted mid-follicular and mid-luteal window whereas, in Schipper (2015), cycle phase was not accounted for and presumably represented a broader range of the cycle. Null findings in the present study and other prior research may also be due to between- rather than within-subject analysis. Our results showed broad individual variability in levels of progesterone within the follicular and luteal phases. If daily circulating levels of progesterone mediate competitive behavior, then this effect would be best assessed by measuring the relative change across these two phases within an individual. Further research into basal progesterone and competitive behavior is needed to understand the relationship between these variables, with attention to within-subject analysis.

Cortisol and progesterone reactivity and competitive behavior

An exploratory aim of this study was to explore how transient shifts in progesterone and cortisol differ based on HC use and cycle phase, and subsequently, how these shifts relate to competitive persistence outcomes. Results showed new evidence that the relative changes in progesterone and cortisol over the course of a competitive encounter were significantly blunted in HC users compared to naturally-cycling participants. Further, progesterone and cortisol change scores were strongly positively correlated in all participant groups suggesting a shared adrenal source. The HC effects on blunted progesterone and cortisol reactivity may be physiologically mediated by the ability of progestin and estrogen compounds in HCs to produce an inhibitory effect on context-dependent adrenocortical secretion of endogenous progesterone and cortisol (De Geyter et al., 2002).

Blunted progesterone and cortisol responses could also be due to HC suppression of context-independent, spontaneous pulsatile patterns of progesterone release (their effect on pulsatile cortisol patterns is not well understood). However, the strong positive correlation between progesterone and cortisol change in HC users suggest that HCs suppress event-related responsivity from a shared source (adrenals). Alternatively, if pulsatile oscillation patterns are responsible for the observed responses, the blunted responses and positive correlation between progesterone and cortisol change could suggest that the underlying mechanism has to do with HCs somehow affecting pulse generation dynamics in the hypothalamic–pituitary–adrenal axis. In any case, the attenuation of adrenal hormone response by HCs highlights the importance of subsequent research testing the dosage effects of HCs and specific hormone composition on the magnitude of adrenal hormone reactivity suppression. Further, future research should explore how other adrenal hormones are affected by HC use and its impact on behavior.

The significance of the blunting of adrenal steroid hormone reactivity for adaptive behavior responses is not well-understood. Results from this study show that the change in these hormones – particularly cortisol – was positively related to task performance, with higher increases predicting longer persistence. Indeed, the collective hormone change mediated the finding that HC users performed poorly compared to the naturally-cycling participants in their follicular phase. Although the overall effect size was small, this finding remained significant after accounting for variance in the outcome due to physical strength and trait competitiveness.

Studies of hormonal reactivity associated with competition have focused primarily on testosterone and cortisol (Casto & Edwards, 2016). There is limited evidence from prior research on the transient reactivity of progesterone associated with competition. Initial evidence has shown that progesterone levels can change during socially-oriented video stimuli or during competitive tasks with fixed outcomes, and that these changes correlate positively with measures of implicit motivation for social affiliation (Oxford et al., 2017; Schultheiss et al., 2004; Wirth & Schultheiss, 2006). These changes could function to alter sensitivity to social signals through the selective activation of areas of the brain associated with emotion processing (van Wingen et al., 2008).

Previous research has demonstrated a consistent effect of HCs on blunted cortisol reactivity over the course of a social-evaluative stressor (i.e., the TSST; for recent meta-analysis, Gervasio et al., 2022). The current study extends this finding to a task that is not explicitly stressful, but one that nonetheless requires participants to invest mental and physical energy to achieve personal success. Results also showed that the blunted cortisol reactivity in HC users was only significant in comparison to naturally-cycling individuals in their mid-follicular phase. Naturally cycling participants in the mid-follicular phase were not different in their average cortisol change compared to those in the mid-luteal phase. This finding contrasts with some prior research suggesting that—although results are somewhat mixed—the luteal phase is associated with larger changes in cortisol relative to the follicular phase, at least in response to psychosocial stress (e.g., Duchesne & Pruessner, 2013; Stephens et al. 2016).

Previous research on the cortisol reactivity in HC users compared to non-use counterparts has generally neglected to test the impact of the relatively blunted cortisol on behavioral outcomes (except for self-reported variables such as mood and anxiety; e.g., Villada et al., 2014). Rather, discussion surrounding this phenomenon appears centered on simply whether HC users should be excluded as participants. Here we provide new evidence that blunted cortisol response in HC users over the course of a goal-oriented competitive task – with a small contribution of blunted progesterone – partly explains their comparatively lower task performance. Thus, future research on cortisol reactivity to social and stressful encounters should include HC use and test for effects on the outcomes of interest. And finally, given evidence that hormone-behavior relationships may be implicit (Casto, Prasad, et al., 2023) and that the effects here emerged above and beyond self-reported competitiveness, we recommend that future studies focus on the relationship between cortisol or progesterone reactivity in relation to behavior, rather than self-reports.

HC type and progestin compound heterogeneity

For main analyses in this study, HC users were treated as a homogenous group. However, variations in the route of administration, hormone combination, and dose may produce important differences in cognition and behavior that are not captured in our analyses. Recent reviews of existing animal studies highlight the many differences in pharmacokinetics and pharmacodynamics of the variety of progestins available in HC formulas (Griksiene et al., 2022;

Pletzer et al., 2023). Thus, the specific progestin compound in HCs will vary in its interaction with basic physiology and brain processes, its ability to effectively mimic natural progesterone, and its interaction with the binding and action of other hormones (e.g., estrogens and androgens).

For example, some progestins used in common HC formulas are androgenic, meaning that they facilitate the action of androgen binding or action, whereas others are anti-androgenic, meaning that they inhibit the action of androgen binding or action (Darney, 1995; Stanczyk, 2003). There is growing evidence that variation in androgenic and anti-androgenic profiles of progestins produce important variation regarding central nervous system structure, function, and connectivity (e.g.,(Pletzer et al., 2015); for review, Beltz & Mozer, 2020; Hampson, 2023). Thus, depending on the formula, progestogenic effects could be conflated with their indirect effects on androgen action in the brain.

Our own exploratory, albeit underpowered, analyses showed that 1st generation progestins had the lowest competitive persistence and reduced hormone reactivity patterns compared to the other generations (2nd and 4th; the 3rd generation group was two small to test), although effects were small. Study outcomes were not different based on whether the progestin is known to be androgenic or anti-androgenic. Our open dataset includes variables for HC type, progestin name, generation, and androgenicity which may be combined with other datasets for future, adequately-powered analyses. Future research that tests outcomes by aspects of the progestin type will aid in determining the underlying mechanism for HC effects on brain and behavior. Additionally, future studies should report, at minimum, the brand and dose information of HC users and consider sharing data openly for larger-scale collaborative analysis of effects related to specific progestin formulas.

Additional limitations and future directions

The research presented here has several limitations. Due to the between-subject, quasi-experimental and correlational nature of our design, we cannot speak to the causality of the relationships between variables. HC users may systematically differ from non-users in social factors such as social-economic or relationship status, variables unaccounted for in this study. Further, within -subjects designs typically provide higher power and greater validity for menstrual cycle-phase related hypotheses. However, the behavioral tasks used here were not suitable for repeated-measures designs.

The methods for salivary immunoassays may also introduce unexplained error that limits the conclusions of this research. Immunoassays tend to have poor hormone sensitivity at low concentrations and recent reports have shown a weak association between expected and measured steroid hormone levels across cycle phase (Arslan et al., 2023; Ghazal et al., 2022; Handelsman, 2017). Future studies may consider more precise hormone measurements such as liquid chromatography–tandem mass spectrometry and serum blood samples, while balancing practicality and cost (Taylor et al., 2015). Another factor that could aid precision in hormone measurements would be to increase the number of samples taken, particularly when attempting to estimate individuals' relative baseline. Our interpretations of baseline progesterone and its role in mediating menstrual-cycle based effects on competitive behavior based on a single pre-task measure could be influenced by random variations in the timing of its pulsatile release. An increased number of samples at shorter intervals within the task period could also better account for pulsatile versus event-based reactivity patterns.

Conclusion

Originally developed for the prevention of pregnancy, HCs are now commonly prescribed for a variety of conditions, including acne, irregular or painful cycles, and as a primary treatment for endocrine conditions such as polycystic ovarian syndrome and endometriosis (Vannuccini et al., 2022; Prior, 2016). These critical medicines also afford individuals the autonomy to regulate the timing, frequency, and severity of the menstrual period. Adding to a growing body of research showing that HCs alter female psychology, and consistent with prior research on competition outcomes, our results show that naturally-cycling women in the mid-follicular phase show greater competitive persistence compared to HC users. Women in the mid-follicular phase also showed greater competitive persistence than those in the mid-luteal phase, but this difference was not robust and requires further investigation.

Results from this study also show that HC users display a blunted cortisol and progesterone response over the course of a competition. Exploratory mediation analysis further showed that the relatively worse performance of HC users compared to mid-follicular phase participants is partially explained by this dampened adrenal-hormone reactivity. These results provide new insight into the mechanism by which HC use may alter the motivational and energetic demands required for optimal performance in competition and other social contexts. By better understanding the effects of HCs on competitive motivation and persistence, women and others who rely on this critical medicine can be empowered to make informed decisions about what medical interventions are appropriate for them.

Data Availability

Complete data and analysis code are posted on the Open Science Framework: https://osf.io/a26sv/

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Appendix: Supplementary Materials

Hormonal Contraceptive Type Used by Participants

Table S.1 contains information regarding the specific hormonal contraceptives used by participants.

Table S.1. *Descriptive Details of Hormonal Contraceptive Users*

HC Type	Progestin Generation	Progestin Type	Brand Name	P dose (mcg)	E dose (mcg)	Brand N
Combined Oral Contraceptive	**1 (*n* = 20)**	cyproterone acetate	Brenda	2000	35	1
			Estelle	2000	30	1
				2000	35	5
		norethindrone	Nortrel	500	35	1
			Sharobel	250	35	1
		norethindrone acetate	Blisovi	1000	20	2
				1500	30	1
			Hailey	1500	30	1
			Junel	1000	20	3
			Lo Loestrin	1000	10	1
				1000	20	2
			Norethrindrone	1000	20	1
	2 (*n* = 26)	levonorgestrel	Daysee	150	30	1
			Eleanor	150	30	1
			Evelyn	150	30	5
			Femikadin	100	20	1
			Femme-Tab	100	20	3
				150	30	1
			Introvale	150	30	1
			Levlen	150	30	6

HC Type	Progestin Generation	Progestin Type	Brand Name	P dose (mcg)	E dose (mcg)	Brand N
			Levlen ED	150	30	1
			Loette	100	20	1
			Microgynon	100	20	1
				150	30	1
			Micronelle	100	20	1
			Mycrogynon	125	50	1
			Vienva	100	20	1
	3 (*n* = 6)	desogestrel	Marvelon	150	30	1
		norgestimate	Estarylla	250	35	1
			Lupin	250	35	1
			Mono-Linyah	250	35	1
			Tri-Sprintec	215	35	1
				250	35	1
	4 (*n* = 11)	dienogest	Oedien	2000	30	1
		drospirenone	Drospirenone	3000	20	1
			Gianvi	3000	20	1
			Lupin	3000	30	1
			Mylan	3000	30	1
			Yaz	3000	20	2
		nomegestrol acetate	Zoely	2500	1500	4
Transdermal Implant	**3 (*n* = 9)**	etonogestrel	Implanon	-	-	7
			Nexplanon	-	-	2
Patch	**3 (*n* = 1)**	norelgestromin	Xulane	150	35	1

Additional Descriptive Results

Correlations

Pearson's correlation coefficients for all continuous variables can be found in Table S.2. There was a significant, positive correlation between the two measures of competitive persistence, the competitive will performance and the unsolvable anagram task. Trait competitiveness had small but significant positive correlation with the competitive will performance and the impossible anagram task. There was a significant, moderate positive correlation between CW performance and grip strength. Progesterone was not significantly correlated with any of the continuous variables.

Table S.2. *Bivariate Correlations with Confidence Intervals for Continuous Variables for Participants with a Testing Day Less Than Two Days Outside the Target Testing Window*

Variable	1	2	3	4	5	6
1. Competitive will	—					
2. Anagram	.34**	—				
3. Baseline Progesterone	.01	.10	—			
4. Baseline Cortisol	.15*	.17*	.15*	—		
5. Grip strength	.26**	.08	.07	.14*	—	
6. Trait competitiveness	.17*	.15*	-.06	.08	-.04	—

Note. *N* = 214. All variables use raw values. Pearson's method was used. *p < .05. **p < .01.

Additional Robustness Tests

Competitive will task

A series of univariate ANOVAs were conducted using other metrics of the competitive will task to determine the robustness of the effect of group (HC use, NC-follicular, and NC-luteal) on competitive will persistence. Results are listed below.

Effects when competitive will times were raw and not winsorized

Replicating the primary analysis, group condition was a significant overall predictor of competitive will persistence, $F(2, 214) = 3.83$, $p = .023$, $\eta^2_{partial} = .035$. Post hoc parameter estimates revealed that the NC-follicular group persisted significantly longer in the competition than HC users, $M_{diff} = 30.11$ secs, 95% $CI = 7.53 – 52.68$, $t(140) = 2.63$, $p = .009$, $d = .44$; and the NC-luteal group, $M_{diff} = 24.08$ secs, 95% $CI = 1.42 – 46.73$, $t(139) = 2.10$, $p = .037$, $d = .36$. HC users and the NC-luteal group were not different in their mean competitive will persistence ($p = .595$). Post-hoc contrasts revealed that the difference between the two NC phase groups was not significant when assessing the effect using Tukey HSD multiple comparisons with the lower portion of the mean difference is overlapping with zero (95% $CI = -3.05 – 51.20$).

To account for individual differences in physical strength and competitiveness, an ANCOVA was conducted using the same variables as above with the addition of handgrip strength and trait competitiveness entered as covariates (sample size $N = 208$ due to missing data on one of these two variables for 6 participants). Both handgrip strength ($b = 4.10$, 95% $CI = 2.34 – 5.86$, $t(203) = 4.59$, $p < .001$, $\eta^2_{partial} = .09$) and trait competitiveness ($b = 14.98$, 95% $CI = 2.41 – 27.55$, $t(203) =2.35$, $p = .020$, $\eta^2_{partial} = .03$) were significantly and positively related to competitive will persistence. The main effect of group condition (HC use, NC-follicular, and NC-luteal) remained significant above and beyond variance accounted for by these factors, $F(2, 208) = 4.34$, $p = .014$, $\eta^2_{partial} = .04$. Replicating the analysis excluding covariates, post hoc parameter estimates revealed that the NC-follicular group persisted significantly longer in the competition than HC users, $M_{diff} = 32.30$ secs, 95% $CI = 10.30 – 54.31$, $t(137) = 2.89$, $p = .004$, $d = .49$; and the NC-luteal group, $M_{diff} = 22.19$ secs, 95% $CI = .13 – 44.25$, $t(134) = 1.98$, $p = .049$, $d = .34$. HC users and the NC-luteal group were not different in their mean competitive will persistence (p = .356). Post-hoc contrasts revealed that the difference between the two NC phase groups was not significant when assessing the effect using Tukey HSD multiple comparisons with the lower portion of the mean difference overlapping with zero (95% *CI* = -4.82 – 49.19).

Effects when using a more conservative menstrual phase window estimate.

To test the robustness of our main analysis we re-ran analyses using a smaller subset of participants*,* including HC users and only NC participants with a testing day within the target 5-day testing window (HC = 73; NC-follicular = 43; NC-luteal = 56). This narrower window was a more conservative estimate of menstrual cycle phase. However, post-hoc power analysis indicated that the 19.63% reduction in sample size (N = 172) yields just 74.16% power with an alpha of .05 to detect an effect size of f^2 = .04, equivalent to d = .40. Thus, although the results below replicate our primary analysis in direction and effect size, the sample is underpowered to detect significant effects.

Although the overall pattern and effect size remains similar to the primary analysis, group condition was not a significant overall predictor of competitive will persistence, $F(2, 172)$ = 2.82, p = .062, $\eta^2_{partial}$ = .032. Post hoc parameter estimates revealed that the NC-follicular group persisted significantly longer in the competition than HC users, M_{diff} = 27.39 secs, 95% *CI* = 3.29 – 51.48, $t(114)$ = 2.24, p = .026, d = .42; while comparison with the NC-luteal group did not reach conventional significance levels, M_{diff} = 25.34 secs, 95% *CI* = -.08 – 50.76, $t(97)$ = 1.97, p = .051, d = .40. HC users and the NC-luteal group were not different in their mean competitive will persistence (p = .856). Post-hoc contrasts revealed that the difference between the two NC phase groups was not significant when assessing the effect using Tukey HSD multiple comparisons with the lower portion of the mean difference overlapping with zero (95% *CI* = -5.11 – 55.79).

To account for individual differences in physical strength and competitiveness, an ANCOVA was conducted using the same variables as above with the addition of handgrip strength and trait competitiveness entered as covariates (sample size $N = 167$ due to missing data on one of these two variables for 5 participants). Both handgrip strength ($b = 4.09$, *95% CI* = 2.38 – 5.81, $t(162) = 4.71$, $p < .001$, $\eta^2_{partial} = .12$) and competitiveness ($b = 16.41$, *95% CI* = 3.85 – 28.97, $t(162) =2.58$, $p = .011$, $\eta^2_{partial} = .04$) were significantly and positively related to competitive will persistence. The main effect of group condition (HC use, NC-follicular, and NC-luteal) was significant above and beyond variance accounted for by these factors, $F(2, 167) = 4.30$, p = .015, $\eta^2_{partial} = .05$. In contrast to the analysis excluding covariates, post hoc parameter estimates revealed that the NC-follicular group persisted significantly longer in the competition than both HC users, $M_{diff} = 33.48$ secs, *95% CI* = 10.50 – 56.45, $t(112) = 2.88$, $p = .005$, $d = .54$; and the NC-luteal group, $M_{diff} = 26.62$ secs, *95% CI* = 2.47 – 50.78, $t(93) = 2.18$, $p = .031$, $d = .45$. HC users and the NC-luteal group were not different in their mean competitive will persistence ($p = .524$). Thus, despite the reduced power when using more conservative cycle phase estimates, when relevant covariates are controlled for, we replicate the finding that NC-follicular participants display higher competitive will performance compared to NC-luteal and HC user participants.

Effects when using less conservative menstrual phase exclusion criteria.

To test the robustness of our results, we re-ran analyses including participants ($N = 16$) who met inclusion criteria but were excluded due to their testing day falling more than two days outside the target 5-day testing window (HC = 73; NC-follicular = 73; NC-luteal = 84).

Group condition was a significant overall predictor of competitive will persistence, $F(2, 230) = 3.99$, $p = .020$, $\eta^2_{partial} = .034$. Post hoc parameter estimates revealed that the NC-follicular group persisted significantly longer in the competition than HC users, $M_{diff} = 27.32$ secs, 95% $CI = 5.91 – 48.72$, $t(144) = 2.51$, $p = .013$, $d = .42$; and NC-luteal group, $M_{diff} = 25.26$ secs, 95% $CI = 4.56 – 45.95$, $t(155) = 2.41$, $p = .017$, $d = .39$. HC users and the NC-luteal group were not different in their mean competitive will persistence. With the increased sample size, post-hoc contrasts revealed that the difference between the two NC phase groups was significant when assessing the effect using Tukey HSD multiple comparisons (95% $CI = .48 – 50.04$).

To account for individual differences in physical strength and competitiveness, an ANCOVA was conducted using the same variables as above with the addition of handgrip strength and trait competitiveness entered as covariates (sample size $N = 224$ due to missing data on one of these two variables for 6 participants). Both handgrip strength ($b = 4.31$, 95% $CI = 2.73 – 5.89$, $t(219) = 5.37$, $p < .001$, $\eta^2_{partial} = .12$) and trait competitiveness ($b = 13.56$, 95% $CI = 2.37 – 24.76$, $t(219) = 2.39$, $p = .018$, $\eta^2_{partial} = .03$) were significantly and positively related to competitive will persistence. The main effect of group condition (HC use, NC-follicular, and NC-luteal) was significant above and beyond variance accounted for by these factors, $F(2, 167) = 4.43$, $p = .013$, $\eta^2_{partial} = .04$. Post hoc parameter estimates replicated, with the NC-follicular group persisting significantly longer in the competition than HC users, $M_{diff} = 29.40$ secs, 95% $CI = 8.82 – 49.99$, $t(141) = 2.82$, $p = .005$, $d = .47$; and the NC-luteal group, $M_{diff} = 23.16$ secs, 95% $CI = 3.35 – 42.98$, $t(150) = 2.30$, $p = .022$, $d = .38$. HC users and the NC-luteal group were not different in their mean competitive will persistence. Post-hoc contrasts revealed that the difference between the two NC phase groups was not significant when assessing the effect using Tukey HSD multiple comparisons with the lower portion of the mean difference overlapping with zero (95% $CI = -2.97 – 56.22$).

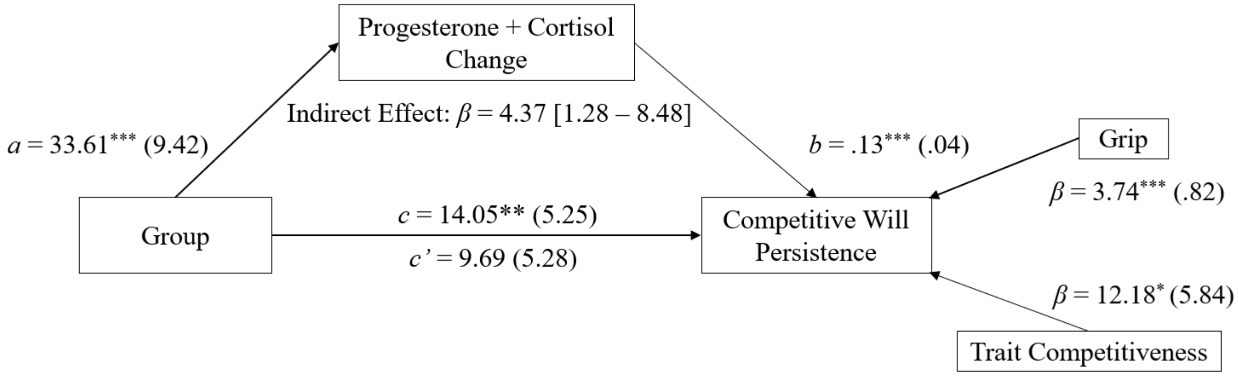
Additional hormone reactivity analyses

Mediation of competitive will performance, controlling for covariates.

To test the robustness of the significant and positive predictor effect of combined progesterone and cortisol reactivity on competitive will performance, handgrip strength and trait competitiveness were added as covariates. As in the main analysis, we effect coded the three conditions as -1 for HC users, 1 for NC-follicular, and 0 for NC-luteal given that the difference between the NC-luteal and NC-follicular in both competitive behavior and hormone change was not robust. Results of the robustness test below focus on explaining differences in competitive will performance between the HC-users and NC-follicular phase participants.

Replicating our primary analysis, results showed that the combined reactivity of progesterone and cortisol remained a significant and positive predictor of competitive will and significantly explain the effect of group condition (HC users vs. for NC-follicular) on this outcome (see Figure S.1). Grip strength and trait competitiveness were also significant and positive predictors of competitive will task performance.

Figure S.1. *Competitive Will Task Performance, Mediated by Combined Progesterone and Cortisol Reactivity, Grip Strength and Trait Competitiveness Added as Covariates*



Note. Group condition effect coded as -1 for HC users, 1 for NC-follicular, and 0 for NC-luteal to hormone reactivity value. *** p <.001, ** p< .01, * p <.05.

Chapter 6: General Discussion

The research presented in this thesis investigated the relationships between fertility, ovarian hormone concentrations, and competitive motivation and behavior. Informed by previous research, this thesis aimed to (1) review and synthesize existing research regarding the effect of ovarian hormones and hormonal contraceptives on competitive outcomes, (2) use methodologically robust methods to determine whether naturally cycling women experience variation in competitiveness across the menstrual cycle, and (3) establish the effect of hormonal contraceptive use on competitive outcomes.

My general introduction (Chapter 1) provided theoretical, mechanistic, and methodological background that was intended to support understanding for the remainder of this thesis. In Chapter 2, I systematically reviewed existing research into the effects of ovarian hormones and hormonal contraceptives on competition for mates, status, and financial resources. I also proposed a novel 'hormonal contraceptives as disruptors' framework (Arthur et al., 2022), arguing that hormonal contraceptives attenuate cycle-related variation in competitiveness by disrupting underlying hormonal mechanisms. Chapters 3 and 4 used a sophisticated longitudinal diary design to measure competitive motivation and behavior across the menstrual cycle, allowing me to test for pattern variation between naturally cycling participants and hormonal contraceptive users. Chapter 5 concluded my novel empirical contribution with a lab-based quasi-experimental design, measuring the effects of progesterone and cortisol reactivity on competitive behavior.

Summary of Key Findings

Key findings from this PhD relate to the effects of fertility, progesterone, and hormonal contraceptive use on competitive motivation and behavior. Below I review the findings of each study and consider how these results fit together. Later in my general discussion I consider theoretical implications based on how these results fit within the broader literature.

Mixed effects of cycle phase on self-reported competitive motivation and behavior

Fertility effects

The purpose of both longitudinal diary studies (Chapters 3 and 4) was to test for fertility effects on competitiveness, while controlling for menstruation. Aligning with the broader literature, the effects of fertility were mixed across outcomes and studies. In Chapter 3, I collected data on self-report competitive motivation across four distinct competitive orientations: self-developmental competition, hyper-competitiveness, competition avoidance, and disinterest in competition. For naturally cycling participants, I observed a mid-cycle increase in self-developmental competitiveness, suggesting that achievement motivation increases in association with high fertility. Conversely, no effects of fertility or menstruation were observed for hyper-competitiveness, competition avoidance, or disinterest in competition, suggesting that fertility does not increase competition uniformly and may be limited to elevated achievement motivation.

In Chapter 4, I extended my research question to test for variation in self-report competitive behavior, in addition to competitive motivation. I added a composite measure of self-report competitive behavior to the daily survey and included behaviors relevant to mate attraction and status-seeking (e.g., daily reports of gossip, social comparison, negative evaluations of others, appearance enhancement, giving advice, and taking selfies). I also retained two of the four competitive orientations used in Chapter 3 (self-development competitiveness and disinterest in competition). Contrary to my predictions, I found no robust association between fertility or menstruation and self-development competitiveness, disinterest in competition, or competitive behavior.

Luteal phase effects

Previous research on menstrual cycle-related shifts in competitive behavior has concentrated on fertility effects, with less attention paid to non-fertile phases of the cycle. To address this gap, Chapter 5 was designed to determine whether competitive behavior differs between the mid-follicular phase, when progesterone levels are low, and the mid-luteal phase, when progesterone is dominant. In a quasi-experimental, lab-based study, I showed that participants in the mid-luteal phase displayed less competitive persistence on a physically challenging task compared to participants in the mid-follicular phase. Baseline progesterone levels were tested as a potential mediator of competitive persistence, though baseline progesterone did not explain variation between mid-follicular and mid-luteal groups. Even so, this result suggests that competition may be suppressed during the luteal phase, relative to the mid-follicular phase.

Hormonal contraceptives associated with reduced competitiveness

Across two longitudinal diary studies, I observed that hormonal contraceptive users reported less competitive motivation compared to naturally cycling participants. In Chapter 3, hormonal contraceptive users did not display a mid-cycle peak in self-development competitiveness, signifying a departure from patterns observed in naturally cycling participants. I also found evidence that hormonal contraceptive use was associated with lower hyper-competitiveness and more disinterest in competition compared to naturally cycling participants. Replicating this effect in Chapter 4, hormonal contraceptive users also reported a greater disinterest in competition compared to participants not using these drugs. Taken together, this work suggests that hormonal contraceptive use is associated with lower competitive motivation overall.

In contrast to effects of hormonal contraceptives on competitive motivation, effects on competitive behavior were mixed. Counter to my expectations, self-report competitive behavior did not vary between hormonal contraceptive users and naturally cycling participants in Chapter 4. Critically, the self-report behavioral questions were worded such that social desirability likely influenced participant responding. In contrast, when participants came into the lab to compete in a physically demanding task in Chapter 5, hormonal contraceptive users participated for a significantly shorter duration compared to naturally cycling participants in the mid-follicular phase. Hormonal contraceptive users participated for a similar amount of time compared to participants in the mid-luteal phase, suggesting that high synthetic progestins may induce similar effects to elevated endogenous progesterone during the mid-luteal phase.

In addition to establishing whether hormonal contraceptives were associated with reduced competitiveness, an important goal of my research was to establish *how* hormonal contraceptives influence competition. Previous research has been largely unable to provide causal relationships between hormonal contraceptives and competitive outcomes due to reliance on quasi-experimental designs and diary studies (Botzet et al., 2021). My thesis addressed this gap by testing the underlying hormonal mechanisms expected to respond to a competitive task. Chapter 5 revealed that lower competitive task persistence by hormonal contraceptive users, compared to mid-follicular phase participants, was fully mediated by blunted progesterone and cortisol reactivity in response to competition. This study therefore offers the first mechanistic explanation for why hormonal contraceptive users display less competitiveness compared to naturally cycling participants. Below I consider the theoretical and practical implications of this and other findings from this thesis.

Theoretical Implications

Taken together, the results from this thesis have several important theoretical implications. Below I consider how these results contribute to the already mixed results in the menstrual cycle literature. I also consider how these results provide preliminary support for my theory of hormonal contraceptives as endocrine level disruptors of competitive motivation and behavior. Finally, I reflect on the ongoing methodological limitations that constrain theory development in the menstrual cycle literature.

Continued uncertainty regarding cycle phase effects on competitive outcomes

One aim of this thesis was to use methodologically robust methods to determine whether naturally cycling women experience variation in competitiveness across the menstrual cycle. As described previously, existing research investigating associations between ovarian hormones and competitive outcomes are mixed, with some studies suggesting variation in competitiveness across the cycle (e.g., Blake, 2022; Durante et al., 2008, 2011; Fisher, 2004; Grammer et al., 2004; Saad & Stenstrom, 2012), and others reporting null effects (e.g., Ranehill et al., 2018; Schleifenbaum et al., 2021; Stern et al., 2023). Although I used the most robust methods available to test my hypotheses, it remains unclear whether different phases of the cycle are associated with reduced competitive motivation and behavior. Below I propose three possible explanations for mixed results in my research and the broader literature.

The first possible explanation for repeated contradictory results throughout the literature is flexible methods and analysis strategies: perhaps researchers are simply selectively reporting results which support their hypotheses and adjusting their methods and analysis to suit. A critique of menstrual cycle research generally is that researchers have too much flexibility when designing these studies (i.e., high researcher degrees of freedom; Wood & Carden, 2014). For instance, researchers must determine how to estimate cycle phase (counting methods vs hormone tests), whether to use continuous or discrete fertility estimates, and what exclusion criteria to apply. Applying different decisions to the same dataset can lead to vastly contradictory results (e.g., Gangestad et al., 2019; Jünger et al., 2018; Stern et al., 2019). Methodological flexibility, however, cannot explain contradictory effects of fertility on self-development competitiveness observed between my two longitudinal diary studies, as these studies used one consistent method and analysis technique. Although it remains possible that the fertility effects that I observed in Chapter 3 could represent a false positive (or Type 1 error), given that my mixed results reflect the broader context of contradictory findings, it is prudent to consider other explanations.

A second possible explanation for mixed effects is that some women are more likely to experience variation across the cycle compared to others, potentially leading to biased samples. Preliminary support for this proposition can be found in research demonstrating that some women are more sensitive to mood changes across the cycle than others (Pope et al., 2017; Soares & Zitek, 2008), suggesting that hormonal fluctuations do not affect all women equally. In my research, the sample of intrinsically motivated volunteers (Chapter 3) reported more cycle phase effects compared to a sample of reimbursed participants (Chapter 4), suggesting that those experiencing cycle related effects may be more likely to volunteer for a menstrual cycle study. To address this possibility, future research should investigate what characteristics predict an individual’s sensitivity to changes across their cycle and how this is related to competitive motivation and behavior.

The third possibility is that different phases of the cycle may influence different types of competition and behavior. For example, mating competition may be heightened during the fertile phase, when attracting a high-quality mate may produce optimal reproductive outcomes (Arthur

& Blake, 2022; Nikiforidis et al., 2017). Women may also avoid physically demanding competitive tasks during the luteal phase compared to all other phases, when conception may have occurred, and energy is theoretically being allocated towards non-competitive goals (Casto et al., 2023). The data collected throughout this thesis does not allow me to determine whether different forms of competition may be influenced by different hormones because my research did not compare different forms of competition. Even so, the literature reviewed in my systematic review (Chapter 2) suggests that variation in ovarian hormones appear more likely to influence competition for mates compared to competition for financial resources, indicating varying effects of hormones on a range of competitive outcomes. Future research would benefit from research further disentangling different types of competition at different times during the cycle.

It is likely that all three explanations — high researcher degrees of freedom, biased samples, and outcome disparity — contribute to mixed results in the menstrual cycle literature. The implication is that theories regarding endocrine mediated outcomes continue to receive mixed support. In my thesis, elevated competitiveness associated with fertility and the mid-follicular phase was observed in Chapters 3 and 5, respectively. These results provide partial support for the ovulatory competition hypothesis, which argues that fertility boosts a woman's desire for positional advantage when the potential gains are elevated, relative to other periods of the cycle (Durante et al., 2014; Nikiforidis et al., 2017). However, these same results also provide partial support for an endocrine mediated trade-off between periods of high and low competitiveness, thus aligning theoretically with the motivational shift hypothesis (Roney & Simmons, 2017). Finally, several null effects observed in Chapters 3 and 4 suggest inconsistent impacts of fertility on competition. Determining the fit of these and other hypotheses therefore requires further research.

Hormonal contraceptives as disruptors of competitive motivation and behavior

In addition to determining the effect of ovarian hormones and cycle phase on competitiveness, a core aim of this thesis was to determine the effect of hormonal contraceptive use on competitive outcomes. In particular, I aimed to test my novel theory that hormonal contraceptives disrupt steroid hormone modulation of socially competitive attitudes and behavior (Arthur et al., 2022). Several studies from this thesis provide support for this theory. Chapter 3 demonstrated that hormonal contraceptive users do not experience a peak in self-developmental competitiveness that is observed around ovulation in naturally cycling participants. Similarly, in Chapter 5, hormonal contraceptive users displayed less competitive behavior compared to naturally cycling participants in the mid-follicular phase. Lower performance by hormonal contraceptive users was fully mediated by blunted cortisol and progesterone reactivity in response to competition. Therefore, this thesis provides initial empirical and mechanistic support for my theory of hormonal contraceptives as disruptors of competitive motivation and behavior.

It is also important, however, to highlight several results from this thesis which do not ostensibly support the hypothesis that hormonal contraceptives disrupt natural fluctuation in competitive outcomes. My theory is grounded in the assumption that ovarian hormones are associated with variation in competitive motivation and behavior, and that the use of synthetic hormones disrupts these patterns. Yet as outlined above, it remains unclear whether ovarian hormones are reliably associated with competition. For example, Chapter 4 found no effects of fertility on self-development competitiveness, lack of interest in competition, or a composite measure of competitive behavior (Arthur et al., 2024). Similarly, Chapter 5 reported no effects of cycle phase or progesterone concentrations on competitive persistence in a cognitively challenging anagram task (Casto et al., 2023). When null effects are observed for cycle phase and hormone concentrations, the capacity for hormonal contraceptives to disrupt natural variation in competitiveness is essentially eliminated.

To further improve my theory, it may be necessary to establish boundary conditions by reducing its scope to a subset of competitive outcomes, such as those associated with competition for mates and reproductive opportunities. The current state of the literature suggests that fertility effects may be strongest for competitive attitudes and behaviors in this domain. For example, some research suggests that fertility is associated with elevated beautification and sexual desire (Arslan et al., 2021; Saad & Stenstrom, 2012; Schleifenbaum et al., 2021; cf. Stern et al., 2024). Other forms of intrasexual competition, such as self-promotion and competitor derogation, also appear to be associated with fertility in some studies (Arthur & Blake, 2022; Blake, 2022; Piccoli et al., 2013; cf. Arthur et al., 2024; Stern et al., 2023). Conversely, general measures of competitiveness and competition for financial resources show negligible associations with fertility and hormone concentrations (Ranehill et al., 2018; Stern et al., 2023). While I acknowledge that the literature remains mixed, a revised theory of hormonal contraceptives may therefore propose that hormonal contraceptives disrupt hormone mediated competition for mates and reproductive opportunities.

Methodological limitations continue to constrain theory development

In recent years, time and resources have been spent on improving the methods and analysis techniques used in the menstrual cycle literature, including improved fertility and hormone estimation. For example, Blake et al. (2016) provided advice about how to combine counting methods with luteinizing hormone tests to determine whether participants were in the fertile phase. Gangestad et al. (2016) and Arslan et al. (2021) made recommendations for the use of continuous fertility estimates in place of discrete fertility windows. Regarding hormone estimation, emerging research suggests that the accuracy of salivary hormone assays is limited compared to blood-based estimation (Schultheiss & Stanton, 2009; Stern et al., 2022). In response to this work, Arslan et al. (2023) recommended that researchers avoid salivary assays and instead conduct analyses with imputed population-average serum hormone levels based on cycle day. Although diary designs have vastly improved fertility estimation in within-subject studies, they cannot provide insight regarding hormone reactivity, nor can they measure changes in behavior in response to changing social and physical contexts.

My research demonstrates that menstrual cycle research progress will accelerate when theory development and testing is conducted with methodological constraints in mind. As previously described, behavioral endocrinologists argue that circulating hormone concentrations increase the likelihood of certain outcomes occurring in response to the environment, they do not suggest that hormones control behavior directly (Oliveira, 2009; Roney, 2016, 2023). Therefore, to determine whether hormones mediate behavior, it is necessary to manufacture (or at least monitor) changes in the environment and measure corresponding behavior change. To test theories of hormone effects on competitive outcomes, researchers need to employ designs where women are given an opportunity to compete with others. If behavioral responding varies at different times in the cycle or when women use hormonal contraceptives, this would suggest a mediating role of hormone concentrations on competitiveness. Until more research utilizes designs measuring competitive behavior across a range of contexts, the true effect of hormones and hormonal contraceptives will remain unclear.

Practical Implications

In addition to theoretical implications, the findings from this thesis have practical implications for both naturally cycling participants and hormonal contraceptive users. For naturally cycling participants, understanding how psychosocial motivation may change across different menstrual cycle phases can lead to improved decision making and self-advocacy. For hormonal contraceptive users and anyone considering using these drugs, understanding the non-clinical implications is of critical importance. One implication is that unintended reduced competitive motivation and behavior among hormonal contraceptive users may lead to poorer performance in a range of settings. To conclude this section, I consider why this research is important for public health.

Empowering women through improved menstrual cycle research and knowledge

Recognizing the influence of hormonal fluctuations on motivation and behavior can provide women with valuable insights regarding the relationship between their menstrual cycle and psychosocial outcomes. Harnessing this knowledge allows for a more nuanced understanding of one's own psychology, potentially leading to improved self-awareness and personal growth. By understanding that increased achievement motivation may be associated with fertility, women can harness this phase to undertake difficult tasks. Conversely, awareness that the luteal phase may be associated with reduced competitive behavior can help women make informed decisions about when to engage in certain activities or how to approach particular situations. Rather than viewing hormone fluctuation as a limitation, this view considers them as providing an opportunity to engage in activities that align with one’s current psychological state. It's crucial to emphasize that these hormonal influences do not determine a woman's capabilities or limit her potential. Instead, this information should be viewed as a tool for self-optimization and self-compassion, by understanding that certain feelings or behaviors may be influenced or enhanced by one’s current hormonal context.

While these implications may seem unrealistic to some, many women are already using menstrual cycle research to engage in ‘menstrual cycle biohacking’. Biohacking is a form of human enhancement where individuals attempt to modify or monitor physiological processes to improve their wellbeing, health, or performance (Gangadharbatla, 2020). Menstrual cycle biohacking has gained traction among women seeking to optimize their physical and mental performance (Carlson, 2024). This trend involves strategically aligning activities and goals with different phases of the menstrual cycle to leverage hormonal fluctuations. Women are using cycle tracking apps and wearable devices to monitor their cycles and gain insights into how hormones affect their energy levels, mood, and cognitive function (Carlson, 2024). Books, podcasts, and online resources advise women about how to adjust their workout routines, sleep, and even their communication within romantic relationships, based on their cycle phase (e.g., Estima, 2024; Peach, 2020; Sovijarvi, 2023). Given the increasing popularity of these practices, it is important that research continue to investigate the legitimacy of these claims and, where appropriate, validate women’s anecdotal experiences.

Cycle tracking, hormonal contraceptives and athletic competition

Another practical implication of this research is the potential for ovarian hormone fluctuation and hormonal contraceptive use to influence sports and athletic performance. Similar to menstrual cycle biohacking among the general population, some coaches and sports scientists are using menstrual cycle data to enhance individual and team success (Carmichael et al., 2024; Kleyn, 2020; Loudin, 2019; Saner, 2019). Variation in ovarian hormone levels can influence performance related physiology, such as hydration, glucose metabolism, and ligament pliability (Herzberg et al., 2017; Lebrun et al., 2013), though effect sizes are small (Rael et al., 2021). Poorer performance and reduced motivation may also be associated with menstruation

(Carmichael et al., 2021; McNulty et al., 2020; cf. Paludo et al., 2022). My research adds to the empirical data which coaches and athletes can use to maximize performance by suggesting that fertility may be associated with peak competitive motivation. Conversely, hormonal contraceptives may unintentionally reduce an athletes drive to compete.

Critically, there are several ethical considerations that should be considered in relation to the use of menstrual cycle tracking in sport (Casto, 2022). The primary concern relates to issues of privacy, such as who will have access to the data and whether it can be sold (Howe, 2024; Osborne & Cunningham, 2017). Another concern is who will make decisions about the most appropriate contraceptive for an athlete. Young athletes and those in high pressure sporting environments may be particularly vulnerable to data misuse due to power discrepancies between coaches and athletes (Rylander, 2015). Several review papers also fail to observe meaningful differences in performance across a range of outcomes, including strength, power, and fatigue (Blagrove et al., 2020; Dasa et al., 2021; McNulty et al., 2020), suggesting that cycle tracking in sport may be of limited utility. Continuing to research the effects of endogenous and synthetic hormones on real-world competitive motivation and performance will provide more reliable information for sports professionals to make ethical decisions.

Hormonal contraceptives and public health

The association between hormonal contraceptives and reduced competitive motivation highlights a need for a more comprehensive approach to reproductive health education and counseling. Beyond competitiveness, research suggests that hormonal contraceptive use may influence cognition, sexual motivation, and mood (Burrows et al., 2012; Casado-Espada et al., 2019; Gurvich et al., 2023; Robakis et al., 2019). Healthcare providers, including gynecologists, general practitioners, and family planning clinics, should be equipped to discuss non-clinical effects of hormonal contraceptives with their patients. Patients should be informed about how hormonal contraceptives may influence not only their physical health but also psychological and behavioral characteristics, including competitiveness. It is not my intention to argue that women should not use hormonal contraceptives, simply that improved public health communication would facilitate more informed decision-making, enabling individuals to weigh meaningful costs against the many benefits of hormonal contraception.

Strengths, Limitations, and Future Directions

Strengths

The current thesis has several methodological strengths, including the use of both within- and between-person designs to achieve different research aims. The longitudinal diary designs provided rich within-person data, allowing me to establish whether patterns of competitive motivation differed between naturally cycling participants and hormonal contraceptive users. However, without a measure of hormone reactivity, these studies were unable to make a case for *why* hormonal contraceptive use is associated with reduced competitiveness. Filling this gap, direct hormone measurement in Chapter 5 allowed me to test predictions about why hormonal contraceptive users display less competitiveness compared to non-users. My research thus injects new insights into this debate by demonstrating that hormonal contraceptive use disrupts the upregulation of progesterone and cortisol reactivity in response to a competition.

Another important strength of this research was the cross-cultural nature of the sample. Both longitudinal diary studies included participants located in 22 countries and six continents. Collecting a geographically diverse sample was possible because the survey platform used in my thesis (FormR; Arslan et al., 2020) was programmed to send daily survey notifications based on each participant's local time zone. Previous research in this field has focused on WEIRD samples, predominantly located in the United States and Western European countries (e.g., Arslan et al., 2021; Schleifenbaum et al., 2021; Stern et al., 2023). Life history theory predicts that evolutionary adaptations should be present at the species level. Therefore, it was important to test my predictions in a geographically and culturally diverse sample.

Limitations

Beyond the limitations outlined in each empirical Chapter, this thesis is limited by the broad conceptualization of competition. Competition can vary across multiple dimensions, including the purpose (e.g., self-improvement, beating others, learning) and target of competition (e.g., the self, other individuals, or groups; Fülöp & Orosz, 2015). Although I used validated self-report and behavioral measures of competition (Casto et al., 2020; Orosz et al., 2018), the self-report questions were relatively general and it remains unclear whether performance on my behavioral measure (the competitive will task) generalizes to other competitive situations. This implication is important because Chapter 2 showed that ovarian hormones influence competition in domain specific ways. Namely, Chapter 2 revealed that although hormone or cycle phase effects were observed regarding competition for mates and status, no robust effects were observed for competition for financial resources. Therefore, by using measures which were domain general, I may have unintentionally diluted proposed competitive effects by attempting to capture too wide an array of motivations and behaviors.

Another limitation is the correlational and quasi-experimental nature of the research presented in this PhD. Quasi-experimental designs, while valuable in settings where random assignment is not feasible, are generally considered less robust than randomized controlled trials (RCTs) for establishing causal relationships (Bhide et al., 2018). This limitation is particularly salient in research on hormonal contraceptive use, where individual differences in participants' baseline characteristics — such as reproductive health, socioeconomic status, or psychological traits — may influence both the choice to use hormonal contraceptives and the outcomes of interest (Arousell et al., 2019; Botzet et al., 2021; S. S. Brown & Eisenberg, 1995; Metcalfe et al., 2016). RCTs allow for greater control over confounding variables by randomly assigning participants to conditions, which minimizes bias and strengthens the internal validity. However, within the time and resource constraints of this PhD, the use of RCTs was not feasible and therefore could not be implemented.

Future Directions

Several future directions have been mentioned throughout this thesis, so in this section I will focus on one theoretical question that remains unanswered: what psychological outcomes increase during periods of low competitive motivation and behavior? Said another way, this thesis argues that hormones help coordinate trade-offs between periods of high and low competitiveness, and future research should therefore investigate what competition ‘trades-off’ with. I will draw on the motivational shift hypothesis to illustrate this point. This theory argues that sexual motivation increases around ovulation, while feeding behavior increases post ovulation (Roney & Simmons, 2017). Energy is allegedly allocated (or traded) between reproductive and survival needs. Following a similar logic, during non-ovulatory phases (i.e., when competitive motivation is low), it reasons that energy may be allocated towards behaviors that enhance other survival goals.

One possibility is that when competition is low then affiliative motivation and behavior may increase. This outcome may be especially likely during the luteal phase, when progesterone is elevated relative to other times in the cycle. Although research into progesterone effects is relatively sparse, some research suggests that progesterone may be linked to affiliation and social bonding. For example, some animal research suggests that progesterone promotes social and affiliative behavior (Koonce & Frye, 2013; Miyamoto & Schams, 1991). In humans, progesterone appears to increase in response to social closeness and social affiliation tasks (Brown et al., 2009; Schultheiss et al., 2004). Other work reports that higher relative progesterone levels predict increased attention to social information (Fleischman et al., 2015; Maner & Miller, 2014). Based on previous work, there is a reasonable empirical basis to continue the pursuit of a hypothetical link between progesterone and social affiliation.

Assuming that social affiliation and progesterone are associated, it is important to consider the evolutionary benefit of this relationship. Social affiliation and support have important implications for health, wellbeing, and cognition, such that stronger social networks are associated with better outcomes for individuals (Costa-Cordella et al., 2021; Schwarzer & Leppin, 1991; Uchino et al., 2018). Throughout human history, women have often relied on social networks for protection, sharing resources, and mutual aid, especially during vulnerable times like pregnancy and early motherhood (Baheiraei et al., 2012; Bedrov & Gable, 2022; Reynolds, 2022). It is possible that during the luteal phase, when conception may have occurred, that women are particularly attuned to social support which may be critical in the maintenance of current or future pregnancies. Research investigating affiliation across the menstrual cycle is currently limited, presenting an opportunity for future research.

When designing a study to test for variation in affiliation across the menstrual cycle, there are several things a researcher must consider. For instance, if the luteal phase is associated with elevated affiliation motivation, it should be limited to affiliation with individuals most likely to provide social support, such as romantic partners, close friends, or family (e.g., Gangestad &

Grebe, 2017). There is no theoretical reason to expect cycle-related changes in a woman's desire to affiliate with people who do not form part of their support network, such as acquaintances or strangers. Therefore, researchers planning to use surveys to measure affiliation should design questions specifying the target person and activities. For example, a survey could ask participants how motivated they are to spend time with their romantic partner engaging in a range of activities, including recreation, sexual intimacy, or emotional connection. Improving details about the kinds of affiliation women want to engage in across the cycle would create a more nuanced understanding of how affiliation motivation changes in association with ovarian hormone change.

In addition to testing affiliation motivation through self-report measures, researchers should also test for variation in affiliative behavior across the cycle. In an experimental lab-based setting, this could include designs where participants must choose to complete an activity alone or with others. Importantly, as explained above, I would not expect individuals to want to affiliate equally with anyone, so it would be important to control for characteristics of their potential partner. For example, participants may be asked to attend the lab with a friend, or an online study may require them to nominate someone they would like to work with. Outside the lab, researchers could also collect data about participants' social behavior, such as the frequency and length of social activities. Note, however, that social behavior is likely to be subject to individual differences (e.g., personality types) and contextual factors (e.g., the weekend, friend availability) that may significantly bias results.

Finally, in order to test for trade-offs, experimental designs should encourage participants to choose between options that are competitive or affiliative, rather than testing these possibilities separately. A trade-off assessment could be achieved through a partner selection paradigm, where participants are told they must choose between working alone (competitive option) or with a partner (affiliation option) in order to perform a task and obtain a reward. In the competitive option, participants would be told they will compete against another player and the better performer takes the reward for themselves. In the affiliative option, participants would be told they will work with another partner towards a joint goal. Although the specific task may vary across experiments, researchers could compare whether individuals are more likely to choose the competitive or affiliative option at different times in the cycle. Critically, social pressure for women to appear prosocial may bias the data such that the majority of women may choose the affiliative option, regardless of their true preference (Cassar & Rigdon, 2021; Rudman et al., 2012). Future researchers will have to overcome these and other methodological challenges while attempting to understand true relationships between ovarian hormones and psycho-social outcomes.

Conclusions

This thesis provides a robust investigation into the effects of ovarian hormones and hormonal contraceptives on competitive motivation and behavior. A growing body of work has investigated whether different phases of the menstrual cycle, or the use of synthetic hormones, influence competition for mates, status, or financial resources. However, much of this work has been limited by small samples or inappropriate research methods. In this thesis, I demonstrate across one review and three methodologically robust empirical studies that some competitive attitudes and behaviors vary across the menstrual cycle and that hormonal contraceptives attenuate these effects. My results also suggest that hormonal contraceptive use may be associated with reduced competitive motivation and behavior overall. This thesis illustrates the importance of using the best available methods to test for small effects that are likely to be influenced by the physical and social environment. Findings from this thesis can provide women with valuable insights about how their menstrual cycle may influence their psychology and behavior. Finally, this thesis should be viewed as one contribution to a larger body committed to advancing women's health, physiology, and psychology. It has been a great honor and privilege to contribute to this important endeavor.

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