Universidad del Desarrollo
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FROM SEX DIFFERENCES IN AGGRESSION TO INTERGROUP CONFLICT AND COOPERATION. THE HISTORY THAT HIDES WOMEN BEHAVIOR

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I. INTRODUCCTION

Sex differences in intrasexual aggression is a phenomenon deeply studied in our specie. These differences are primarily situated in the use of physical versus indirect aggression, being men more prone to express physical aggression and women indirect aggression. Accordingly, we will begin to explain why we could expect sexual differences in the expression of intrasexual aggression and how evolutionary Theory is a conceptual framework that gives a comprehensive group of predictions to sustain these sexual differences.

Intrasexual aggression in humans can be better understood as a compound of mechanisms shaped through our lineage's evolution due to their fitness impact. Accordingly, Trivers' Theory of parental investment in the framework of Sexual Selection (Trivers, 1972) establishes the presence of asymmetries in parental investment between males and females, with males being the sex with a more significant variance in reproductive success, derived from their lower parental investment. In contrast, females' reproductive success would depend on the quality of the partners they select, either as carriers of good genes or providers, since they have to perform more parental investment (e.,g due to lactation, sexual cell production, etc). This difference causes males, in general, to have greater intrasexual competition for access to reproductive mates, while females would be more selective than men competing less intensely among themselves for access to reproductive partners. Applying these predictions to

human beings situates same-sex aggression as a mechanism of intrasexual competition and the sex differences resulting from selective pressures each sex received during evolutionary time. These selective pressures fine-tune the preference for the use of divergent aggressive mechanisms. We will explain the main evidence and theoretical models supporting these sex differences in intrasexual aggression under an evolutionary framework.

Sex Differences in physical aggression.

The first studies about sex differences in the use of physical aggression began with exploring social statistics of violent crime and homicide. Surprisingly, these studies demonstrated that over 90% of violent crimes and homicides are committed between men. The pattern is so robust that for more than 50 years has been constantly replicated, including the UNODCS global study of homicide (2019), which established that 81% of victims of homicide in the world are men, and men committed more than 90% of total world homicides. Accordingly, the seminal work performed by Margo Wilson and Martin Daly (1985) was the first that considered that sex differences in terms of violent crime are attributable to men using aggression as a mechanism for intrasexual competition. Wilson and Daly (1985) support this point by demonstrating that higher victimization rates occur in men near their reproductive peak (around 20 years old), a phenomenon named the young male syndrome. In the last decade, the presence of sex differences in the use of physical aggression has been enriched with new

theoretical models that appointed to understand the use of physical aggression in men as a mechanism of intrasexual competition that primarily operates in two different social contexts: Under intragroup interactions and in the intergroup conflict context.

The use of aggression in Intra and intergroup conflict scenarios.

An individual's position within their social group is essential to maximizing fitness, and human beings are no exception. In our specie, a higher social status predicts better longevity, health, and offspring success. Therefore, it is logical that both sexes compete to increase their social status. Accordingly, although there are no sex differences in the desire to improve social status, both sexes differ in the behavioural mechanisms used to improve it. Consequently, men are prone to be inclined to use contest competition, usually displayed through physical aggression. Contest competition in their behavioural dimension can be defined as a competition mechanism characterized by face-to-face confrontations. These confrontations, typically linked to physical aggression, are usually public, and their resolution heavily impacts the social ranking of individuals involved in the altercation, allowing the winner to gain social status and access to limited resources in the group.

Women and indirect aggression

There’s a common belief that men are more aggressive than women. However, this might be just an observation bias given that male aggression is physical, and

thus, more conspicuous than women's which is indirect. There are high and almost perfect correlations between rates of male and female aggression across the world (Campbell 1999). The use of indirect instead of physical aggression between boys and girls seems to be very small or non-significant in children from young age, which mostly fight about resources such as toys (Campbell 1999). It tends to reach a peak of sex difference between ages 8 and 11 (Archer & Coyne 2005), probably as they reach adolescence and social status become more important, which usually occur a couple of years earlier for girls (Campbell 1999). In adulthood, survival of the mothers is more important for the offspring survival than the father's, women must develop a form of aggression that pose a lesser risk to their integrity than men (Campbell 1999); that is indirect aggression. Unlike physical aggression, a phylogenetic origin of indirect aggression in our close relatives, primates, is very hard to find because it requires language and social skills, which make it unique to humans (Archer & Coyne 2005).

Archer (2004) indicates two theories to explain the sexual differences in aggression: sexual selection theory and social role theory. The first one indicates that men display more physical aggression because they must compete for women, which is the sex that has greater parental investment (Darwin 1871; Trivers 1972). The second theory indicates that sex difference emerges from the division of labor which generates roles with expected gender characteristics associated to different behaviors (Eagly 1987).

Women, contrary to men which use physical aggression, employ mostly indirect aggression (Archer 2004; Arnocky et al. 2019). It is defined as “a type of behavior in which the perpetrator attempts to inflict pain in such a manner that she or he makes it seems as though there is no intention to hurt at all” (Bjoirkqvist et al. 1992 in Archer & Coyne 2005). Indirect aggression, as physical aggression, involve the intention to harm another person, and is expressed in actions such as using or manipulating a third party, gossiping, rumor spreading and ignoring or actively excluding others from a group (Archer & Coyne 2005). Its main consequence is social exclusion of the victim to remove a potential competitor. Usually, the victim is unaware of the perpetrator’s identity; however, ignoring somebody or becoming friends with another person to inflict jealously involves the awareness of the perpetrator’s identity (Archer & Coyne 2005). Women use this type of aggression to avoid the costs of physical damage which might be detrimental for their biological fitness (Benenson & Abadzi 2020) and because it is very effective as a tactic to inflict harm on the victim (Arnocky et al. 2011). Additionally, it requires a social network that are important to the perpetrator and the victim (Archery & Coyne).

Most of the targets of women aggression is another woman (Burbank 1987). Women use aggression to harm same-sex rivals, to increase mating opportunities and to reach and maintain status (Arnocky et al. 2019). Female aggression has evolved since it enhanced biological fitness in ancestral women (Arnocky et al. 2019). Women aggress potential competitors as a form of mate retention strategy,

by aggressing a peer they increase they own fitness and eliminate the threat (Arnocky et al. 2011). For example, women are more aggressive toward sexualized than non-sexualized women. In a study by Vaillancourt & Sharma (2011), participants expressed more derogative language, be less willing to befriend or to introduce her boyfriend when observing the picture of a confederate dressed in a sexualized way than when dressed conventionally. Furthermore, Arnocky et al. (2019) found that women behaved more aggressively towards a sexualized than to non-sexualized confederate using the point subtraction aggression paradigm (PSAP), and that this aggression was mediated by a decreased perception of humanness, regardless of their self-reported intrasexual competitiveness. Further research by Arnocky et al. (2011) indicates that women who made more frequent attractiveness comparisons are the ones that behave more aggressively towards peers, to reduce the mate value of the target or to advance in the social hierarchy. Additionally, they found that women who do not make frequent attractive comparisons are more prone to be victimized by peers, which might indicate that they have a higher mate value that could explain the aggression by other women. Even idealized provocative female models from advertising can trigger women's aggressive behavior as if they were real competitors (Borau & Bonnefon 2017), supporting the mate value hypothesis by Arnocky et al. (2011) They conclude that aggression toward a peer is mediated by jealously, thus suggesting that this emotion might explain indirect aggression among women; probably to maintain access to reproductive opportunities and

parental resources (Borau & Bonnefon 2017), and data about aggression on co-wives seems to support this hypothesis (Burbank 1987).

Intergroup conflict hide women aggression and cooperation

For some scientists, the intergroup conflict represents one of the primary selective pressures our lineage must confront through evolutionary time, and men are specially adapted for this context. In this sense The Male Warrior Hypothesis states that "*humans, particularly men, may possess psychological mechanisms enabling them to form coalitions capable of planning, initiating and executing acts of aggression on members of outgroups, with the ultimate goal of acquiring or protecting reproductive resources"* (McDonald et al., 2012, p.671). There is evidence that under a scenario of intergroup competition, men are more prone than women to be aggressive with men from the other groups (Navarrete et al., 2010), and cooperative with their own group (van Vugt et al., 2007). Therefore, men can exacerbate cooperation and aggression depending on the context and target, being the intergroup menace, probably the more relevant feature that triggers these mechanisms. Both mechanisms produce individual benefits, since they are related to the likelihood of success in a conflict between groups, which in turn, in ancestral environments, was linked to direct fitness benefits and rises in social status. In fact, there is evidence that in traditional societies, the male warriors have a higher social status, and more mates (Chagnon, 1988). In our modern societies for example, high ranking brave military are considered by females as more attractive (Rusch et al., 2015).

Women have been usually located within the intergroup conflict, especially in "The Male Warrior Hypothesis," in two positions. First, playing a passive role where women are considered the primary motivating resource for competition between men (Mcdonald et al., 2012). Secondly, and in contrast to this passive role, the experimental results have shown a pattern similar to that of men in rejecting individuals from other groups, estimated from prejudiced behavior towards rivals (Navarrete et al., 2010). This evidence suggests a more active role within the intergroup conflict for women. Still, only at a defensive level because their primary motivation, from a strictly evolutionary point of view, is postulated to be focused on avoiding infanticide and sexual coercion (Mcdonald et al., 2012). Men's participation in intergroup conflicts such as wars is predominant Glowacki et al., (2022), however, women also show a long history of active involvement in this type of conflict that is not anecdotical (for prehistoric evidence see Bengtson & Gorman, 2017). For instance, in the United States, the number of female war veterans has increased to 1.7 million in 2006, according to Murdoch et al. (2006). This trend was already evident during the Gulf War (1991-1992), when women constituted 11% of the allied active-duty personnel, and approximately 4% of those killed in combat were female (Kang et al., 2002). These statistics suggest that women's participation in intergroup conflicts is not a new or marginal phenomenon. Although there is evidence that women play an active and offensive (rather than just defensive) role in conflicts, it is striking that all the burden associated with the motivation to inciting, initiating and maintaining an offensive

position in intergroup conflicts is in general attributed to the male sex (Mcdonald et al., 2012), while women's participation is often dismissed historically (Fussel, 2018). However, considering the available evidence, it is reasonable to propose that women's motives for actively participating in intergroup conflicts extend beyond avoiding sexual coercion and infanticide. For example, food acquisition is fundamental for female reproductive success (Trivers, 1972; Brockman and van Schaik, 2005). In fact, primatological studies show that intergroup competition for resources plays a critical role in shaping female gregariousness (van Schaik, 1989). As a result, women could be motivated to participate in intergroup conflict—in addition to avoid infanticide and sexual coercion—, to access more or better resources which would increase their reproductive success. Moreover, similarly to men (e.g., Rusch et al., 2015), women may gain reputation and prestige from being involved in intergroup conflict, thereby improving their social status, which is a central human motivation (Anderson et al., 2015).

Previous studies have relativized the role of women in the intergroup conflict and overlooked two sex-dependent factors that could be relevant to understanding it: the differences in aggressive mechanisms employed by men and women, and the tendency to cooperate based on group composition. Accordingly, existing research on intergroup conflict (Lahr et al., 2016; Chagnon, 1988) has predominantly focused on direct physical aggression, which is a form of aggression more commonly utilized by men (Archer, 2009). This emphasis on direct physical aggression may have inadvertently limited our understanding of

the diverse ways women contribute to and participate in intergroup conflicts. Furthermore, studies investigating ingroup cooperation often not consider the influence of group sex composition (Stirrat & Perret, 2012; Yuki & Yokota, 2009; for an exception, see van Vugt, 2007). Therefore, this approach falls short in revealing the behavioral architecture of the group outside of typical male behavior. For more than 30 years, both social psychology (e.g., Bandura et al., 1963; Eagly & Wood, 1999) and evolutionary psychology have shown sex differences in the use of aggressive mechanisms (Archer, 2009). According to evolutionary psychology, sex differences in aggression are the product of selective pressures that have changed the psychobiological underpinnings of behavior. As a result, rather than engaging in direct physical aggression, women often choose to use intermediaries to cause harm to a third party (Campbell, 1999; Fisher, 2004; Muñoz-Reyes et al., 2012). This tendency can be attributed to the heightened vulnerability of the female body to the detrimental effects of physical aggression on reproductive capacity (Campbell, 1999, 2004). Concerning cooperation there is evidence indicating that men cooperate more with individuals of the same sex (Colman et al., 2018; Rapoport & Chammah, 1960) even with those of lower status (e.g., Benenson et al., 2014), whereas women exhibit higher rates of cooperation in mixed-sex interactions (Balliet et al., 2011). This pattern indicates that women are skilled at forming tactical partnerships with men. Consequently, the position of women within the intergroup conflict has been delineated without considering the typical aggressive mechanisms of each sex nor the capacity of

women to deploy robust mechanisms of cooperation with men. Thus, addressing these two aspects may shed light on the active and offensive roles women can play in intergroup conflict, aspects that have been largely overlooked to date.

In the first chapter of the present Phd Thesis I will explore the behavioral strategies of the use of aggression and cooperation performed by women in the intergroup conflict scenario. This study constitutes the first evidence against the sex specific theorethical framework of the Male Warrior hypothesis.

On the other hand, in the second chapter I will present the study of the evolutionary basis of cooperation in women. This study constitutes a new approach to the understanding of womens cooperation from the use of an evolutionary focus based on intrasexual competition.

Finally, both studies emphasized the needed of considerate women and their sex specific evolutionary history in the construction of theoretical frameworks that trying to explain human behavior in a wide sense.

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Appendix 1

EVIDENCE OF THE ACTIVE PARTICIPATION OF WOMEN IN THE INTERGROUP CONFLICT BASED ON THE USE OF AGGRESSION AND COOPERATION

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ABSTRACT

Intergroup conflict has been a persistent aspect of human societies since the emergence of our species. Various researchers have proposed that competition between groups has acted as a key selective force throughout human evolutionary history. Such intergroup competition for limited resources

exacerbated the expression of intergroup aggression and intragroup cooperation. Furthermore, it would have a sexual dimorphism, with men demonstrating increased sensitivity to conflict threats—in order to maximize reproductive opportunities—, while women generally reject from active engagement in intergroup conflict. In the present study, we conducted behavioral experiments under controlled laboratory conditions to measure cooperation and aggression from using virtual games, specifically the Public Good Games and the Point Subtraction Aggression Paradigm, in a sample of 541 participants. We created control and experimental intergroup competition scenarios, where aggression and cooperation were necessary to increase monetary rewards. Our results shows that men modulate aggression and cooperation in the presence of intergroup conflict. In addition, our data also reveals that women cooperate more than men and display heightened levels of cooperation and aggression when confronted with intergroup conflict. These findings prompt a reevaluation of current functional theoretical models concerning the role of women in intergroup conflict and suggest that the dynamics of human aggression and cooperation may be more nuanced than previously believed.

Keywords:

Aggression, cooperation, intergroup conflict, sex differences, women

INTRODUCTION

Aggressive conflict between groups of human beings has been ubiquitous in societies dating back to the dawn of our species [1]. Numerous authors have proposed that between-group competition has been one of the main selective forces driven human evolution, even surpassing defense against other predatory species[2–5]. In this sense, the monopolization of physical resources and access to reproductive partners were the main axes on which the motivation to compete between groups was built, despite the devastating effects of being defeated [5]. In fact, from different fields as evolutionary psychology and primatology, it has been suggested that the exacerbated cooperative behavior observed in the human species would be, in large part, the product of a long history of competition between rival groups[4,6,7]. In this regard, functional models have been focused on the central role of men in the intergroup conflict [7], which has been supported in several studies (e.g. [8–10]). However, the role of women in the intergroup conflict has been poorly studied.

Functional perspectives to understand sex differences in intergroup conflict are constructed from Trivers' theory of parental investment within the framework of sexual selection [11], which highlights the asymmetry between male and female in parental investment and reproductive success. Accordingly, males have a greater variance in their reproductive success since they depend on optimizing access to females due their lower mandatory minimal parental investment. In contrast,

females experience less variability in reproductive success, as they are more dependent on their mate's quality, whether they are good providers or bearers of good genes due their higher mandatory minimal parental investment. Consequently, males generally engage in more intensive intrasexual competition to secure access to reproductive partners, while females would be more selective, and engage in less intense intrasexual competition [12]. This has generated many of the physical and behavioral differences that we currently see between both sexes in humans [3]. For example, in upper-body strength men are generally 90% stronger than women [13–15], which is one of the most significant factors driving the differential ability to inflict costs to a rival [16]. According to behavior, differences are present in the tendency to use direct aggression and, especially in physical aggression (e.g., [17,18]) in men. In this context, men would be more inclined to compete, form coalitions, and engage in violent conflict with other groups. This tendency is driven by their heightened emphasis on reproductive success and the need to secure mates (see the Male Warrior Hypothesis in [7,19]). However, evidence from other research domains contradicts Trivers' assumption that females act more selectively and passively [20–22].

Women have been usually located within the intergroup conflict playing a passive role where they are considered the primary motivating resource for competition between men [8]. However, the little experimental evidence about women in intergroup conflict shows a similar behavioral pattern that of men in rejecting individuals from other groups (i.e., estimated from prejudiced behavior

towards rivals [23]). This evidence suggests a more active role within the intergroup conflict for women, which has been interpreted as a defensive strategy to avoid infanticide and sexual coercion [8], although it is obvious that both sexes could be benefited from the monopolization of resources. In this sense, men's participation in intergroup conflicts such as wars is predominant [24], however, studies have shown that women, although in a lesser extent than men, tend to be part in conflicts. For instance, in the United States, the number of female war veterans has increased to 1.7 million in 2006, according to [25]. This trend was already evident during the Gulf War (1991-1992), when women constituted 11% of the allied active-duty personnel, and approximately 4% of those killed in combat were female [26]. These statistics, in addition to archaeological evidence (e.g., [27,28]), suggest that women participation in intergroup conflicts is a real phenomenon, but that has been dismissed historically [29]. Accordingly, considering the available evidence, it is reasonable to propose that women's motives for actively participating in intergroup conflicts could be oriented to obtain limited resources. In this sense, food acquisition is fundamental for female reproductive success [11,30]. In fact, primatological studies show that intergroup competition for resources plays a critical role in shaping female gregariousness [31]. As a result, women could be motivated to participate in intergroup conflict—in addition to avoid infanticide and sexual coercion—, to access more or better resources which would increase their fitness.

There is a lack of studies that, under controlled conditions estimates the role of women in the intergroup conflict. In this sense, there are overlooked two sex-dependent factors that could be relevant to understanding it: the differences in aggressive mechanisms employed by men and women, and the tendency to cooperate based on group composition. Accordingly, existing research on intergroup conflict [32,33] has predominantly focused on direct physical aggression, which is a form of aggression more commonly utilized by men [17]. These studies have demonstrated that men exacerbate aggression when this is directed to outgroup members (e.g.,[9]). However, this emphasis on direct physical aggression may have inadvertently limited our understanding of the diverse ways women contribute to and participate in intergroup conflicts, for example, giving support to their more physical stronger partners. In this sense, studies investigating ingroup cooperation often not consider the influence of group sex composition ([10,34]; for an exception, see [7]). Newly these studies have demonstrated a highly sensitivity of men to intergroup conflict from the increase of ingroup cooperation (e.g., [9 7], etc). These approach falls short in revealing the behavioral architecture of the group outside of typical male behavior. For more than 30 years, both social psychology (e.g., [35,36]) and evolutionary psychology have shown sex differences in the use of aggressive mechanisms [17]. According to evolutionary psychology, sex differences in aggression are the product of selective pressures that have changed the psychobiological underpinnings of behavior. As a result, rather than engaging in direct physical aggression, women often choose to use intermediaries

to cause harm to a third party [18,37,38]. This tendency can be attributed to the heightened vulnerability of the female body to the detrimental effects of physical aggression on reproductive capacity [37,39]. Concerning cooperation there is evidence indicating that men cooperate more with individuals of the same sex [40,41] even with those of lower status (e.g., [42]), whereas women exhibit higher rates of cooperation in mixed-sex interactions [43]. This pattern indicates that women are skilled at forming tactical partnerships with men. Consequently, the position of women within the intergroup conflict must be delineated considering the typical aggressive mechanisms of each sex and the capacity of women to deploy robust mechanisms of cooperation with men, as stated above. Thus, addressing these two aspects may shed light on the active and offensive roles women can play in intergroup conflict, aspects that have been largely overlooked to date.

In the present study, we seek to replicate previous results centered in the modulation of cooperation and aggression under intergroup conflict in men (theorized in the Male Warrior Hypothesis by [7]). But, more interestingly, we want to understand women's role in intergroup conflict from the use of sex specific mechanisms of aggression and cooperation. We expect that as occurs with men, women will increase intragroup cooperation and intergroup aggression in presence of intergroup conflict, probably because women have motivation to use intergroup conflict as a scenario to gaining access to limited resources. We have assessed with an experimental design the ingroup cooperation through public good games and intergroup aggression from the use of a modified version of the

point subtraction aggression paradigm (PSAP), which assessed direct and indirect aggression, taking into account group composition and under two experimental conditions, an intergroup conflict scenario and a control condition.

Concerning aggression, we have two set of predictions: First, we predict sex-based differences in the type of aggression displayed. Specifically, men will exhibit more direct aggression than women, whereas women will display more indirect aggression compared to men. Second, we predict an increase in aggression during intergroup conflict, driven by a heightened level of the more common type of aggression in each sex—direct aggression in men and indirect aggression in women.

In terms of cooperation, our expectations are also twofold: First, we predict sex-based differences in cooperation depending on group composition. That is, men will cooperate more in unisexual groups compared to women, whereas women will cooperate more than men in mixed-sex groups. Second, we predict that in the context of intergroup conflict, men will increase cooperation in unisexual groups, while women will enhance cooperation in mixed-sex groups, as compared to a control scenario (see Behavioral Measurements).

METHODS

Participants

Over a three-year period (2020-2022) we recruited a total of 541 participants aged between 18-45 years old, including 235 men and 306 women (mean ± SD: 25.13 ± 5.70 and 26.67 ± 6.49 years, respectively). Participants were recruited from online advertisements on the laboratory webpage and social media platforms (Instagram and Facebook). Each participant received $15.000 Chilean pesos (around $19 USD) for attending the experimental session. Additionally, they could receive an extra payment of up to another $15.000 Chilean pesos based on their performance in the games. Thus, participants could receive a maximum of $30.000 Chilean pesos. We chose to offer a substantial amount of money ($30.000 pesos represent 7.3 % of the minimum monthly wage in Chile) to ensure participants interest and involvement in the experiments.

Ethics committee authorization and ensuring anonymity.

The Universidad del Desarrollo's Ethics Committee approved the study's protocols and data handling procedures. All processes were performed in conformity with the applicable guidelines and regulations. An informed consent form that explained the protocol and the confidentiality was given to each participant to read and sign. However, before participants signed it, at the beginning of the experimental session, one of the researchers read the consent aloud for them. Prior to taking part in the trial, each participant signed an informed consent form. To protect participant's identities, we followed a conventional coding procedure.

Data availability: Open Practices Statement

Data for the study “Women in the intergroup conflict. Evidence of active participation from the use of aggression and cooperation” are available at Open Science Framework OSF: osf.io/u86zx.

Group formation and the data collection procedure

The experiments took place at the “Laboratorio de Comportamiento Animal y Humano” of the Universidad del Desarrollo, Santiago de Chile. The laboratory has six experimental cabins with computers connected to a local network. These cabins were specifically designed to be isolated from visual and audio stimuli, ensuring that participants could not communicate with one another and could focus on the task at hand. In each experimental session, a group of six participants were assigned to either the intergroup competition scenario or the control scenario. Moreover, participants were also allocated to one of three group compositions: (a) all-male groups (or unisexual), (b) all-female groups, or (c) mixed-sex groups comprising three men and three women (figure 1). We privileged the formation of group of women as they were the main focus of this study.

After signing the informed consent, participants were randomly placed in individual cabins. In mixed-sex groups, men were assigned to one of the first three cabins, while women to the remaining cabins, in order to accommodate their

distinct roles in the PSAP. At the beginning of each session, participants completed a sociodemographic questionnaire (i.e., sexual orientation, age, relationship status, place of origin and socioeconomic status). Subsequently, participants engaged in two economic games: (1) a threshold Public Goods Game (tPGG) and (2) a modified version of the PSAP, played in pairs. The tPGG was designed to elicit cooperative predispositions in the context of a larger group social dilemma, while the PSAP aimed to elicit aggressive inclinations at the individual level in the context of couple against couple interaction. The control scenario gauged both cooperative and aggressive dispositions, whereas the experimental scenario assessed how intergroup conflict modulates intercouple competition and intra-group cooperation respectively (Muñoz-Reyes et al. 2020). In the intergroup scenario, participants were informed that they were playing with another group with the same characteristics in terms of group composition, though in reality, they competed against a fictitious opponent (i.e., the game software). The same occurs for the control condition of the PSAP where participants must compete against fictitious couples located in another university.

Behavioral measurements (see figure 1)

Threshold public good game (tPPG): We applied the protocol used by [9]Muñoz-Reyes et al. (2020), to measure individual cooperation within a group context. Participants played the tPGG on computers using the z-Tree software [44]. At the beginning of the game, each participant received $5,000 Chilean pesos and had

the option to decide how much to contribute for the benefit of the group. They were informed that a bonus of $7,000 Chilean pesos would be awarded if the total group contribution surpassed $18,000 Chilean pesos, regardless of their individual contributions. However, if the group did not meet the threshold amount, no bonuses would be awarded, and participants would only retain the money they chose not to contribute.

In the control scenario, participants received no additional instructions beyond these basic rules. However, in the experimental scenario, they were informed that were playing with another group simultaneously and that the bonus would be given to the group that exceeded $18,000 Chilean pesos. Participants also were informed that in the event that both groups exceeded the threshold only the first group to make the decision would be granted the bonus. Since the competing group was fictitious the participants were rewarded with the bonus if they surpassed the threshold. This setup created a context of competition for a monopolizable resource. To ensure participants fully understood the game and scenario, an animated video was shown prior to the start of the game. Consistent with previous research [7,9] participants played a practice round before the actual game commenced. The outcomes of the games were communicated at the end of all the experimental procedures to avoid any potential impact on subsequent games. Cooperation levels were measured based on each participant's individual contribution to the group.

The Point subtraction aggression paradigm (PSAP): This is a widely recognized and reliable tool for measuring aggression, particularly in men and was first used by Cherek in the 1980s [9,45]. It is a computer game where participants play/compete against a fictitious opponent (but they did not know this information). The main objective is to get as many points as possible, which then are converted into real money at the end of the game. The participant's score is displayed on the computer screen, and they are given three behavioral options that cannot be executed simultaneously. For our study, we employed a modified version of the game, in which individuals played in pairs against other fictional pairs (but did not handle this information). Each pair was composed of a " front-line attacker" and a "supporter". Only in mixed-sex groups, women were always assigned the supporter role (figure 1). As in the original game, individuals had three behavioral options that cannot be taken simultaneously, but one of the options (button B) differed for front-line attacker and supporters. Table1 shows the main differences between the original version of the PSAP and the modified version that we used in this study.

Gaining points (button A): Participants gain 1 point by pressing the "A" button 100 times. One point was equal to $1,000 Chilean pesos.

Aggression (button B): In this option, " front-line attacker" were informed that they could "destroy" points from the rival pair, but without gaining those points to their own score (i.e., destroying decreases the other player's score without increasing

one's own). Participants were told that, by pressing the B button 10 times, they would destroy 1 point from the opponent pair's score. Additionally, they were informed that their rivals would receive the points that were taken from them, when the "front-line attackers" pressed the B button to destroy their points. Therefore, participants were in an asymmetrical condition with their rivals, what represents a constituent element of the game. The only effect of destroying points was to harm the opponent pair, without benefiting the player who pressed the button [9]. On the other hand, "supporters" were informed that they would not have the ability to directly destroy points from the rival pair. Instead, their role was to support potential attacks from the " front-line attacker. More specifically, they were told that if they pressed the B key 10 times the next time their partner attacked (if it attacked at all) they would destroy the opponent's two points instead of one.

Protection (button C): Particints were informed that their rivals could steal their points, so they were provided with an option to protect themselves by pressing the "C" button 10 times—which would protect them from possible attacks that could lead to the subtraction of their points during a fixed period.

A single 10-minute round was conducted in both the control and experimental conditions. During these 10 minutes, the individuals could choose any of the three behaviors sequentially but not simultaneously. In other words, once a button was pressed, they needed to finish the sequence (i.e., the number of times that the selected button must be pressed to activate the different options

of the PSAP) after choosing the same or other option (i.e., protection, aggression, gaining points). In the control condition, participants were informed that the points obtained by the pair would be added up and divided equally at the end of the game. In contrast, participants in the experimental scenario were told that they were part of a group competing against another group in a laboratory at another university (but it was a fictional couple). They were informed that each couple was going to be paired with another couple from the competing group (fictional group), and the winner would be the group that gained more points. The winning group would receive a bonus, equal to the points obtained by the losing group, which would be split evenly between the members of the winning group. The losing group would only receive the points obtained by each pair. As the competing group was fictitious, participants were always informed that they had won the match and were given a bonus equal to 50% of the points they obtained [9](Muñoz-Reyes et al., 2020). To achieve greater ecological validity and consider the relevance of aggression in intergroup competition and intragroup status, we followed a strategy used by Geniole et al. (2017), in which participants are intensely provoked, that is, the (fictitious) rival attacked them very intensely, taking away points. Aggression was estimated by calculating the percentage of times the “B” button was pressed in relation to the total number of times all the buttons were pressed (see [9,45]). The aggression measured from first liners was interpreted as direct aggression whereas aggression measured from the supporters was interpreted as indirect aggression. The experimental scenario involves a conflict with an

outgroup threat, with real potential consequences in terms of monetary payoffs, which the members of the group can collect by outcompeting the fictitious outgroup.

Data analysis

To test our predictions regarding aggressive behavior, a full factorial general linear model was used with three factors: condition (intergroup conflict *vs*. control), sex (man *vs*. woman), and type of aggression (direct *vs*. indirect). Age was included as a control covariate, and the dependent variable was the aggression displayed by each participant in the PSAP. The two-way interaction between sex and type of aggression was used to test the first prediction, while the three-way interaction between sex, type of aggression, and condition, was used to test the second prediction. To avoid the possible confounding effect of mixed-sex group (in this configuration, we only have men performing direct aggression and women performing indirect aggression), we have repeated this analysis using only unisexual groups, (i.e., men and women performing direct and indirect aggression in same-sex groups). To test the two predictions concerning cooperative behavior, we fitted a full factorial general lineal model with three factors: condition (intergroup conflict *vs*. control), sex (man *vs*. woman), and group composition (unisexual vs. mixed). Age was also included as a control covariate, and the dependent variable was the contribution made by each participant in the public good game. The two-way interaction between sex and group composition

was used to test the first prediction, while the three-way interaction between sex, group composition, and condition was used to test the second prediction.

For both models, we conducted pairwise comparisons with Bonferroni corrections when significant two-way or three-way interactions were present. We performed a sensitivity analysis that indicated we had 80% power to detect an effect size of $\eta^2 = 0.014$, which is considered small. All analyses were carried out using IBM SPSS Statistics v25 software, and sensitivity analysis was conducted with G*Power 3.1.9.7. All analysis were two-tailed and our level of significance was set at $\alpha = 0.05$.

RESULTS

Table 2 shows the mean, standard deviation, and sample size for cooperation in the tPGG, direct aggression and indirect aggression according to sex, condition, and group composition, the last only for cooperation measures.

Table 3 shows the model related to aggression. In relation to our first prediction, we did not find sex differences in the type of aggression employed since the two-way interaction between sex and type of aggression was not significant ($F_{1,540} = 1.142$, $p = .286$, $\eta^2 = .002$). We found, instead, a main effect of the type of aggression ($F_{1,540} = 15.152$, $p < .001$, $\eta^2 = .028$). Both men and women displayed more indirect aggression ($M = .068$, $SE = .004$) than direct aggression ($M = .046$, $SE = .004$). Regarding our second prediction, we did not find that men displayed more direct aggression and women more indirect

aggression during intergroup conflict condition compared to control context since the three-way interaction was not significant ($F_{1,540} = 0.028$, $p = .868$, $\eta^2 < .001$). However, we found a main effect of the condition ($F_{1,540} = 12.667$, $p < .001$, $\eta^2 = .023$). Men and women display more aggression, both direct and indirect, during the intergroup conflict condition ($M = .067$, $SE = .004$) compared to the control condition ($M = .047$, $SE = .004$). When excluding mixed-sex groups, we obtained similar results. First, we did not find sex differences in the type of aggression employed since the two-way interaction between sex and type of aggression was not significant ($F_{1,304} = 2.325$, $p = .128$, $\eta^2 = .008$). We found a main effect of the type of aggression ($F_{1,304} = 9.461$, $p = .002$, $\eta^2 = .031$). Both men and women displayed more indirect aggression ($M = .069$, $SE = .005$) than direct aggression ($M = .049$, $SE = .005$) when playing with same-sex partners. Second, regarding our second prediction, we did not find that men displayed more direct aggression and women more indirect aggression during intergroup conflict condition compared to control context since the three-way interaction was not significant ($F_{1,304} = 0.187$, $p = .666$, $\eta^2 = .001$). But similarly to the first analysis, we found a main effect of the condition ($F_{1,304} = 12.514$, $p < .001$, $\eta^2 = .041$). Men and women display more aggression, both direct and indirect, during the intergroup conflict condition ($M = .071$, $SE = .004$) compared to the control condition ($M = .047$, $SE = .005$) when playing with same-sex partners.

Table 4 shows the model related to cooperation. First, we did not find sex differences according group composition since the two-way interaction between

sex and group composition was not significant ($F_{1,541} = 0.870$, $p = .351$, $\eta^2 = .002$), but we found a sex differences as a main effect ($F_{1,541} = 4.237$, $p = .040$, $\eta^2 = .008$). Women contributed more to the public good ($M = 3558.492$, $SE = 53.30$) than men did ($M = 3394.21$, $SE = 59.06$) regardless of group composition. Considering the presence of intergroup conflict, we only found a statistical trend in the three-way interaction between sex, group composition and context ($F_{1,541} = 2.724$, $p = .099$, $\eta^2 = .005$). Alternatively, if we focus in the two-ways interactions, we found a significant interaction between group composition and context ($F_{1,541} = 4.674$, $p = .031$, $\eta^2 = .009$). Post-hoc analysis with Bonferroni correction (figure 2) showed that individuals contribute more in the intergroup conflict condition ($M = 3609.21$, $SE = 71.18$) compared to control condition ($M = 3251.46$, $SE = 80.11$) in the unisexual group composition (mean differences = 357.75, $SE = 107.167$, $p = .001$) but not in the mixed-sex group composition (mean differences = 14.86, $SE = 116.91$, $p = .899$). In addition, individuals contribute more in mixed-sex groups ($M = 3514.94$, $SE = 83.17$) compared to unisexual groups ($M = 3251.46$, $SE = 80.11$) but only in the control condition (mean differences = 263.47, $SE = 115.47$, $p = .023$) since in the intergroup conflict condition no differences were found (mean differences = -79.41, $SE = 108.71$, $p = .465$).

Discussion

In the present study, we seek to understand how intergroup conflict modulates the expression of aggression and cooperation in both sexes. While we

obtained partial support for our predictions, our results indicate that intergroup conflict exacerbates the expression of direct and indirect aggression in both sexes. Furthermore, women tend to be more cooperative than men, and cooperation was exacerbated in intergroup conflict but only in unisexual groups of men and women. Overall, our study contributes to a better understanding of the roles of men and women in intergroup conflict.

Our first set of prediction focused on aggression and was divided into two parts. In line with prior research (e.g., [17,46]), we expected sex differences in the utilization of aggression. Observations in natural settings have revealed distinctions in type of aggression employed, with men consistently exhibiting a greater propensity for physical aggression [47]. This can be attributed to the higher costs associated with engaging in physical aggression for women [48]. However, contrary to our expectations, we did not observe any differences in the types of aggression exhibited by men and women, as there was no interaction between sex and aggression type. Given that sex differences in aggression have been consistently reported in previous research (e.g., [18,49–51]), we can speculate that the expression of sexual dimorphism we anticipated need additional elements that were not incorporated into our experimental design that are present in natural contexts. For instance, our design did not allow participants to choose between first-liners (direct attack) and supporters roles; instead, they were forced to engage in a specific type of aggression due to their assigned role within the experiment. Moreover, in our experiment, men were only assigned to display

indirect aggression in unisexual groups, while women assumed this role in both unisexual and mixed-sex groups. However, when we analyzed only unisexual groups, the pattern of results was maintained. Thus, it is possible that sex differences in the use of indirect aggression may only emerge if men reduce their employment specifically when interacting with women or if both sexes can choose between using direct or indirect aggression. Another explanation is based on the magnitude of the perceived threat and the inability to assess rivals in our experimental setup. Sex differences in aggression have been found to vary in magnitude depending on the level of threat [48]. However, in our study, participants could not observe their rivals, and the controlled laboratory environment lacked the contextual cues present in natural settings. This absence of contextual information could influence the types of aggression exhibited by both sexes under the experimental conditions. The relevance of this observation relies in the fact that specific signals, such as upper trunk strength or formidability, play a crucial role in determining whether (or not) to initiate direct aggressive interactions [52]. In our study, individuals were unable to assess their rivals in terms of physical strength, which could have influenced the expression of direct aggression for both sexes. Consequently, to further examine this intriguing finding, it is essential to employ new methodologies that can validate the absence of sexual dimorphism in aggression, at least in the context of virtual games conducted under controlled laboratory conditions.

In the second part of our prediction, we expected an increase in aggression in both sexes within the intergroup conflict scenario. Specifically, we expected more direct aggression in men and increased indirect aggression in women. As previously noted, we did not find sex differences in the expression of aggression. However, we did observe a context effect on aggression, i.e., both sexes exacerbate their direct and indirect aggressive strategies during intergroup conflict, illustrating that they are sensitive to intergroup conflict situations. Furthermore, this finding is consistent with previous evidence of women participating in conflicts (e.g., [26,53,54]). In this regard, our results suggest that it is probable that both sexes would pursue the acquisition of resources, which is interesting because although the participation of women in conflicts such as war is lesser than men, our results indicate that when women have to confront to another group, they can assume an active role. In our game, women were not suffering the risk of infanticide or sexual coercion; the incentive consisted of a relevant monetary reward. We conclude that, as occurs with men, the possibility to obtain a valuable limited resource is an incentive for increasing aggression. These results contribute to reevaluating the roles and motivations underlying women's expression of aggression in intergroup conflict situations.

Our set of predictions regarding cooperation, were also divided into two parts. In the first one, we expected sex differences in cooperation according to the group composition. In this sense, women were expected to be more cooperative than men in mixed-sex groups while men were expected to be more cooperative

than women in unisexual groups. From a functional approach, it is expectable that men will be more prone to cooperate with same-sex group members since the conformation of coalitions of men has been proposed as a critical factor for the success of the group [5,7,19,55]. In contrast, previous evidence demonstrates that women cooperate more than men in mixed groups [43], and actively compete to form bonds with higher-status men [56]. However, although there were theoretical reasons to expect this dimorphic pattern of behavior, our results indicate that group composition is irrelevant to explaining cooperation in both sexes, as women were consistently more cooperative than men, regardless of group composition. These results align with a recent meta-analysis that found no effect of sex composition on cooperation rates, but contrast with it since we found overall differences in cooperation between sexes [57]. Therefore, our results suggest that factors other than group composition likely explain the tendency to cooperate in men and women, with women being more cooperative overall.

In the second part of this prediction, we assessed cooperation considering sex differences but now in the presence of intergroup conflict. Unexpectedly, we found that, independently of sex, unisexual groups increased cooperation under intergroup conflict. In addition, mixed-sex groups were not sensible to intergroup conflict. Although there were no sex differences in this behavior, different functional explanations can explain it for each sex. For men, our results confirm the previous research of men in the functional approach, specifically under the theoretical framework of the male warrior hypothesis (see van [9,58]), i.e., men

increase intragroup cooperation in the presence of intergroup conflict, to be compared with the control condition, probably because men are seeking to robustness alliances with other men in the presence of an external menace. In contrast, for women our explanation is quite different. In this sense, women are known to be more fearful than men of being socially excluded by other women [59,60], this is a very effective and typical intrasexual competitive mechanism of this sex. As noted by [56], in situations where women are surrounded by unrelated same-sex peers, as occurred in our experimental design, they may be more likely to form coalitions quickly to avoid the potential threat of social exclusion, which could be devastating in a context of intergroup conflict. Therefore, we propose they are sensible to intergroup conflict where cooperation is needed to construct internal alliances in the confrontation with the exogenous group.

Following with prediction two and regarding mixed-sex groups, as we have mentioned, no differences between control and intergroup scenario were found. However, in the control condition mixed-sex groups cooperate more than unisexual groups, and in the intergroup conflict condition there were no differences between unisexual and mixed-sex groups. This suggests that, irrespective of the scenario, mixed-sex groups seem to cooperate at a similar rate as unisexual groups during intergroup conflict situations. One plausible explanation for those relatively high levels of cooperation observed in the mixed-sex groups could be attributed to the presence of an intragroup mating scenario. It is known that the presence of women tends to enhance competitive altruism in

men [61,62]. Despite the fact that contributions were anonymously, group performance was informed at the end of the experimental procedure, allowing participants to exchange details about their donations. Consequently, it is conceivable that mating motives for men may overshadow the effects of the intergroup competition context, resulting in high levels of cooperation in both control and intergroup conflict scenarios. The concept of competitive altruism among women has been discussed in the literature, but studies predominantly focus on men [61,63–65] but this factor may contribute as well to the pattern found. However, further studies would be required to better explain and understand why groups composed by men and women seem not to be sensitive to the presence of an intergroup conflict scenario. Nevertheless, it is noteworthy that our study detected a strong sensitivity to intergroup conflict in same-sex groups for both men and women. Surprisingly, and contrary to our initial predictions, this was also observed in groups of women. Future studies are needed to reply to these findings.

Within the limitations of this study, we can mention that participants could not choose their role within the game, as they were assigned to one or another condition. In addition, the result obtained in our study i.e., a lack of sex differences in the use of aggressive behavior, indicate that it could be relevant for future studies to include mixed groups where women occupy the role of the front-line attack. We have not considered this condition in the current study since, as we stated before, the objective was to observe if women were sensitive to

intergroup conflict in their aggressive behavioral mechanism, beyond the composition of the group (mixed or unisexual). Another elements for future studies could be to include psychological measures such as risk aversion or dark triad assessments. These additions could shed light on other aspects of the psychology of men and women in intergroup conflict situations. Additionally, it would be beneficial to allow participants the possibility of evaluating their rivals. While incorporating such a feature might be challenging in terms of experimental design, it could yield valuable insights into the strategies employed by individuals during intergroup conflicts. It is relevant to highlight a group of studies [66–68] which proposed that ingroup love over outgroup menace is the real motivation that could explain sex differences in cooperation, with men preferring ingroup cooperation versus outgroup cooperation beyond of the presence of intergroup conflict. These studies applied a treatment to encourage group identity from the minimal group paradigm [68]. We propose that future studies integrate this methodological tool to discuss the possibility that our results could be explained by a weaker ingroup love in men's participants due to the lack of this treatment. Ultimately, our findings emphasize the need to increase the complexity of experimental design to fully understand how intergroup conflict modulates human behavior.

Our study has uncovered new evidence suggesting that women exacerbate aggression in intergroup conflict scenarios. In the case of cooperation, we found it to be higher in women than men, with both sexes increasing cooperation in same-sex groups in intergroup conflict scenarios. Concerning

aggression, both sexes increase direct and indirect aggression in the intergroup conflict scenario at least when interacting with same-sex partners. These results are interesting since they open the possibility that women will be sensible to conflict beyond the view of men being primarily interested and sensitive to participate in intergroup conflict actively. In the same sense, recent studies have proposed a change in the expected pattern of behavior for other resource acquisition behavior in traditional societies, such as hunting (e.g., [69,70]). This study invites to enrich the current theoretical models by looking for new evidence about the roles of both sexes in intergroup conflict.

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Figure 1. Group composition design

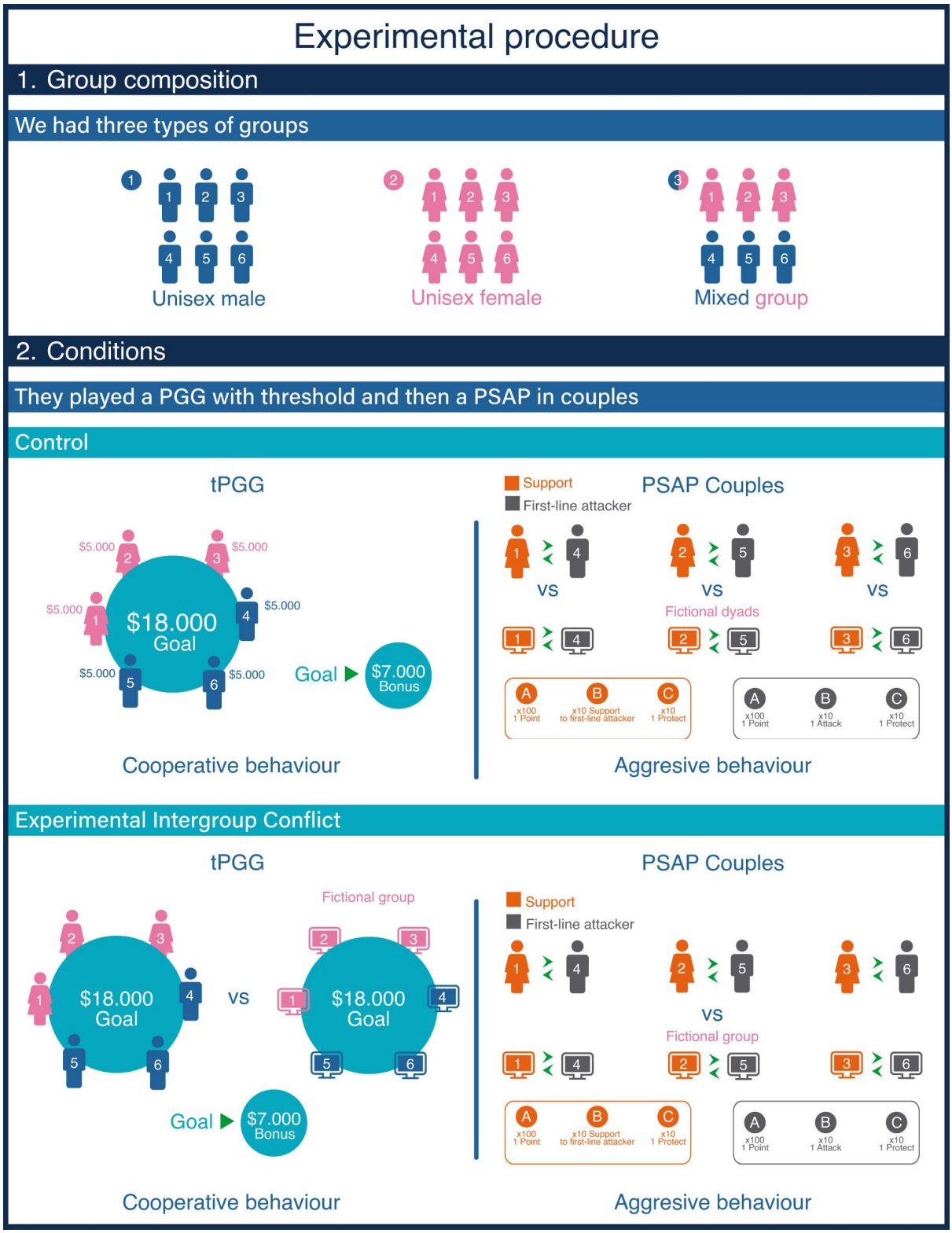
Experimental procedure
1. Group composition
We had three types of groups
Unisex male
Unisex female
Mixed group
2. Conditions
They played a PGG with threshold and then a PSAP in couples
Control
tPGG
$18.000 Goal
$5.000
Goal
$7.000 Bonus
Cooperative behaviour
PSAP Couples
Support
First-line attacker
vs
Fictional dyads
A x100 1 Point
B x10 Support to first-line attacker
C x10 1 Protect
A x100 1 Point
B x10 1 Attack
C x10 1 Protect
Aggresive behaviour
Experimental Intergroup Conflict
tPGG
Fictional group
$18.000 Goal
vs
Goal
$7.000 Bonus
Cooperative behaviour
PSAP Couples
Support
First-line attacker
vs
Fictional group
Aggresive behaviour

Figure 2. Contributions in the public good game according to group composition and treatment

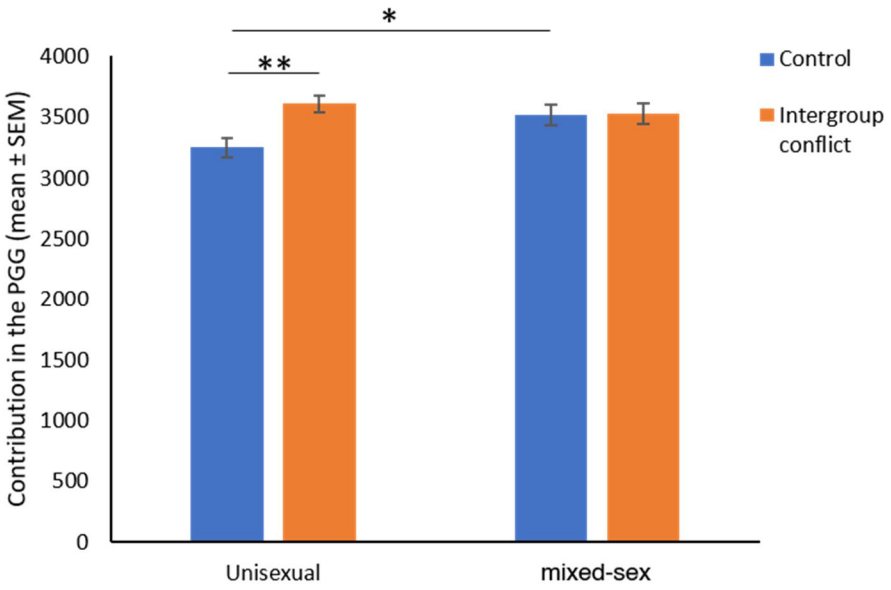

Table 1: Shows the differences between the traditional PSAP and the modified PSAP.

Traditional PSAP	PSAP couples
Gaining points (button A): To obtain 1 gain point you must press the letter A 100 times. 1 profit point equals 1000 Chilean pesos	Gaining points (button A): To obtain 1 gain point you must press the letter A 100 times. 1 profit point equals 1000 Chilean pesos
Aggression (B button): To attack the opponent (fictitious) you must press the	Aggression (B button):

B key 10 times, which destroys one point of the opponent but does not accumulate them for your gain.	Role 1: Front line attacker: this player can destroy points of the rival pair by pressing the letter B 10 times. Role 2: Support: this player can boost the attack towards the rivals by pressing the letter B 10 times but as support for the attack role and not autonomously, that is, they were informed that they could not destroy rival points individually but only in pairs.
Protection (C button): Individuals can protect themselves from the attack of rivals for a fixed period.	Protection (C button): Individuals can protect themselves from the attack of rivals for a fixed period.

Table 2: Mean, standard deviation (in parenthesis) and sample size for cooperation, direct aggression and indirect aggression according to sex, condition and group composition.

	Control				Intergroup competition			
	Men		Women		Men		Women	
	Unisexual	Mixed sex	Unisexual	Mixed sex	Unisexual	Mixed sex	Unisexual	Mixed sex
Cooperation	3027.04 (1195.02) N = 52	3492.33 (783.87) N = 58	3474.56 (803.06) N = 80	3534.81 (816.99) N = 59	3585.44 (1088.36) N = 63	3452.42 (926.94) N = 62	3631.22 (852.19) N = 109	3608.62 (717.34) N = 58
	Men		Women		Men		Women	
Direct aggression	.0381 (.0503) N = 84		.0247 (.0359) N = 43		.0639 (.0589) N = 95		.0568 (.0409) N = 58	
Indirect aggression	.0621 (.0468) N = 25		.0623 (.0645) N = 96		.0718 (.0597) N = 30		.0747 (.0661) N = 109	

Table 3: General lineal model of aggression in the PSAP according to sex, type of aggression and condition.

	F-value	**p-value**	**η^2**
Intercept	25.791	< .001	.046
Sex	0.642	.423	.001
Type of aggression	15.152	< .001	.028
Condition	12.667	< .001	.023
Age	0.036	.849	< .001
Sex * Type of aggression	1.142	.286	.002
Sex*Condition	0.151	.698	< .001
Type of aggression * Condition	2.455	.118	.005
Sex * Type of aggression * Condition	0.028	.868	< .001
Corrected model	4.758	< .001	.067 (R^2)/.053 (R^2_{adj})

Table 4: General lineal model of contributions in the public good game according to sex, group composition and condition.

	F-value	**p-value**	**η^2**
Intercept	391.664	< .001	.424
Sex	4.237	.040	.008
Group composition	1.347	.246	.003
Condition	5.520	.019	.010
Age	0.920	.338	.002
Sex * Group composition	0.870	.351	.002
Sex*Condition	0.792	.374	.001
Group composition * Condition	4.674	.031	.009
Sex * Group composition * Condition	2.724	.099	.005
Corrected model	2.419	.014	.035 (R^2)/.021 (R^2_{adj})

Appendix 2

Women's prosocial behavior in groups: effects of sex composition of the group, maternity and relationship status

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INTRODUCTION

Prosocial behavior is defined as voluntary actions that benefit others and include behaviors such as helping, , cooperating, , etc. (Olsson et al. 2021). Humans are a highly social species that has even been defined as an ultrasocial species (Jensen et al. 2014). Human prosocial behavior evolved because it provides fitness (survival and reproductive) benefits. In this sense, prosocial behavior is thought to have played a key role during human evolution enabling humans to thrive in all types of environments (van Vugt & Schaller 2008) and providing benefits such as: protection from conspecifics and predators, labor division,

alloparental care, territorial and resources access and defense, etc. (McDonald et al. 2012). Despite its importance, prosocial behavior has been extensively studied in men but has been rarely explored in women (Engel 2011; Muñoz-Reyes et al. 2014; Tognetti et al. 2016; Kramer 2022). In addition, few studies exploed the effect of the sex composition of the group, maternity, and relationship status within prosocial behavior in women.

Cooperation in men has been mainly linked to alliance formation in the context of contest competition and direct aggression toward other men to gain or maintain social status (Benenson & Abadzi 2020). Social status is also important for women since, as for men, it is positively associated with longevity, physical and psychological health, and access to reproduction (Anderson et al. 2015; Fournier 2020; von Rueden et al. 2010). However, rather than using contest competition, women are prone to express scramble competition, which is characterized by using solitary tactics that avoid both direct contest situations (which can imply physical damage) and the formation of great alliances (Benenson & Abadzi 2020) leading to the question of why women cooperate and behave prosocially. Under an evolutionary perspective, women mainly cooperate with a selected group of individuals to gain and reinforce social status in their social groups (Benenson & Abadzi 2020; Kramer 2022). Accordingly, cooperation is selectively used to gain or reinforce social bonds with some individuals of the group to increase the offspring caring support (alloparental care) (Stenstrom et al. 2018; Wang et al. 2021; Kramer 2022), or with a possible mate, by displaying prosocial behavior as

a sexually attractive signal (Stenstrom et al. 2018; Bhogal et al. 2019). The last aspect might explain why higher levels of cooperation in women can be found in mixed-sex arrangements rather than arrangements where only women participate (Croson & Gneezy 2009; Balliet et al. 2011; Muñoz-Reyes et al. 2014; Olsson et al. 2021). In addition, women may be prone to establish cooperative alliances, abandoning scramble competition with other women for different reasons, i.e., when they interact with unrelated same-sex peers or need social protection to avoid derogation (i.e., social exclusion) or perform derogation on other high social status women (Benenson 2013; Benenson et al. 2008, 2011, 2013; Benenson & Abadzi 2020). However, importantly these motives that might explain women's cooperation have not been formally studied in laboratory-controlled conditions. In addition, relevant variables that clarity previous arguments that sustain female cooperation as sex composition of the group, maternity, and relationship status have not been integrated.

Sex composition of the group is an often overlooked factor that significantly affects human behavior such as social interactions and cooperation dynamics in both sexes (Tognetti et al. 2016; Barrero-Amortegui & Maldonado 2021). It affects financial decisions (Griskevicius et al. 2012), natural resources exploitation (Barrero-Amortegui & Maldonado 2021), and prosocial behavior (Tognetti et al. 2016; Farmer & Farelly 2021). However, this evidence comes primarily from men because research typically focuses on men's behavior and considers women merely as experimental observers (van Vugt & Iridale 2013; Tognetti et al. 2012,

2016). As stated before, men and women can display cooperative strategies, but with different characteristics, especially when social status is at stake. A real-life example of the effect of the sex composition of the group has been observed in university professors of the same department, where high ranking male professors co-published more with same-sex lower rank professors than high rank female professors (Benenson et al. 2014). There were no differences in co-publication rates with members of the opposite-sex despite rank level differences (Benenson et al. 2014). These examples show how men and, particularly, women adjust their behavior and strategies depending on the sex of the interactor. Another study that focused on the sex composition of the group (Tognetti et al. 2016) selectively manipulated it in a four players-group Public Good Game (PGG) and found that it affected men's behavior. Single men contributed more when they were aware of the presence of at least one woman and one man in the group (Tognetti et al. 2016). This study did not find a competitive effect induced by the sex composition of the group on women's behavior. However, the study was not focused on women's behavior (Tognetti et al. 2016), which could explain the negative results since they did not consider the effect of women's biological conditions to affect these results (i.e., maternity, hormonal state, etc.; Benenson & Abadzi 2020). Finally, men's and women's behavior can be also affected by the sex of the observers. In one of the few studies that considered women's behavior, Tognetti et al. (2012) found that women in rural Senegal were more prosocial in the presence of other young unrelated women (from a distant village), perhaps as

a mechanism to increase social status (or gain social support) from cooperation. These results might be explained since unrelated women or older women, who must no longer raise children, may abandon scramble competition strategies and use cooperation as a strategy for direct competition (Benenson & Abadzi 2020).

Women employ cooperation as a strategy to increase their status, either for improving their chances of getting a high-status partner or for improving their offspring rearing conditions, which might be affected by individual differences such as maternity and relationship status that can alter their motivations (Tognetti et al. 2016; Benenson & Abadzi 2020). None of the previous studies have considered these individual differences, even though they may affect female behavior (Lucas & Koff 2013; Eisenbuch & Roney 2016), and are crucial motivators in group-context interactions. In this sense, maternity can change a women's motivation for socialization and cooperation, since mothers need or seek social allies who can provide resources and help in offspring care (Benenson 2013; Rucas 2017; Spake et al. 2021; Kramer 2022). Human offspring rearing is very resource consuming and among the costliest in the animal kingdom (Rucas 2017). Mothers are the primary care givers in almost all hunter gatherer human societies (Jaeggi et al. 2017; Kramer & Veile 2018); consequently, maternity itself can affect foraging and production activities because mothers must lactate and take care of their offspring (Jaeggi et al. 2017; Kramer 2022). Thus, mothers may have a net deficit of food production (Rucas 2017) and incur in a huge need for resources for themselves and their offspring (Benenson 2013; Jaeggi et al. 2017;

Kramer 2022). Mothers heavily rely on social bonds to obtain food and resources (Rucas 2017; Kramer & Veile 2018) and, although networking and social interactions are very costly and time consuming, mothers invest in them because they greatly benefit from social allies who can help them gain status, resources, and offspring care and rearing (Benenson 2013; Rucas 2017; Spake et al. 2021; Hruschka et al. 2022), thus maximizing their biological fitness. Females with high status will also benefit from having high quality helpers, which can also provide them with more time for other activities such as foraging and socializing (Benenson & Markovits 2014; Kramer 2022).

On the other hand, relationship status (single vs. partnered) can also change a women's motivation since single women might display cooperative behavior as a sexually attractive signal (Stenstrom et al. 2018; Bhogal et al. 2019) to attain a partner or gain status in the group while partnered women may display cooperative behavior as a mean to improve alloparental care from other women (Benenson, 2013). Accordingly, single men and women consumed more alcohol (Pedersen et al. 2009), spent more time in Facebook (McAndrew & Jeong 2012) and were more likely to display a revealing photograph as their Facebook profile picture (Hetsroni & Guldin 2017) than people in a relationship. These examples highlight how women can change their social strategies to maximize their success depending on their relationship status. Additionally, relationship status affects women's attractiveness preferences on faces of both potential mates and same-sex competitors (Little et al. 2002; Sacco et al. 2021), thus highlighting its

importance in social behavior. Despite a higher interest on women's relationship status on mating behavior, to the best of our knowledge its impact on prosocial behavior has not been studied.

In the present work, we studied in a sample of 306 young participants (between 18-45 years old, N = 183 women; N = 123 men) the effect of the sex composition of the group (same-sex and mixed groups), maternity (mother and non-mother) and relationship status (single and partnered) over women's prosocial behavior from the use of a public good game in laboratory-controlled conditions. We proposed the following hypothesis: i) single mothers cooperate more than all other groups of women in both group contexts because they must establish and form social alliances for the provision of resources, and they must also minimize the damage to themselves and their offspring by not having a partner who can protect them or provide resources. ii) Partnered mothers are more cooperative in same-sex groups than in mixed groups because they seek to establish links with other women who can help them in alloparental care without representing a risk while also reducing the damage risks towards themselves or their offspring or avoid problems with their partner when interacting with other men, who pose a greater threat than women. iii) Non-mother single women cooperate more in the context of mixed groups than in same-sex groups because they exhibit prosocial behavior as a sexually attractiveness signal. Despite our focus is on women's behavior, men's prosocial behavior will also be described in this work since they are part of

the experimental design (mixed groups) and sexual differences will be analyzed for further understanding of the phenomenon.

METHODS

Participants

Over two years we recruited a total of 306 participants between 18-45 years old (183 women and 123 men; mean ± sd age: 27.30 ± 6.74 and 25.70 ± 5.74 years respectively). Participants were recruited from online ads on social networks (Facebook and Instagram) and the laboratory web page. From the 183 female participants, 14 were single mothers, 76 were partnered mothers, 42 were single non-mothers and 51 were partnered non-mothers. Only mothers with dependent children (under 7 years old) were considered. All male participants were non-fathers. Each participant received $15,000 Chilean pesos (CLP, around $19 USD) after the experiments. Additionally, they could receive an additional payment of up to another $15,000 CLP according to their performance in the games. Thus, participants could receive a maximum of $30,000 pesos. We decided to give a significant amount of money ($30,000 pesos represent 7.3 % of the minimum monthly wage in Chile) to ensure interest and involvement in the experiments.

Ethics committee authorization and ensuring anonymity

The research, including protocols and data treatment, was approved by The Institutional Ethics Committee of the Universidad del Desarrollo. All methods were performed in accordance with the relevant guidelines and regulations.

Participants were asked to read and sign an informed consent form that detailed the procedure and the confidentiality. One of the researchers read the consent aloud for the participants before signing. All the participants signed the informed consent prior to their participation in the study. We used a standard coding process to preserve the anonymity of the participants.

Group formation and the data collection procedure

The experiment was conducted between December 2020 and January 2023 at the Laboratorio de Comportamiento Animal y Humano (www.labcah.cl) of the Universidad del Desarrollo, Chile. These laboratories have six experimental cabins with computers connected in a local network. The cabins are isolated from visual and audio stimuli, preventing communication among participants and enhancing their concentration. Groups of six participants were recruited for a single session in which all data was taken. After signing the informed consent, each participant was randomly assigned to a single cabin. At the beginning of each session, participants had to complete a sociodemographic questionnaire (i.e. sexual orientation, age, relationship status, etc.) and then went to a common room for the Public Good Game (PGG) instructions.

The PGG consists of a social dilemma where cooperating (any positive contribution) is a dominant strategy where non-cooperation leads to an inefficient social outcome (Muñoz-Reyes et al. 2020). We applied the protocol used by Muñoz-Reyes et al. (2020) to measure individual cooperation in a group context.

PGG was played on computers using the z-Tree software. Participants had $5,000 CLP at the start of the game and they could decide how much to contribute for the benefit of the group. They were told that they would receive a bonus of $11,000 CLP if the total group contribution exceeded $18,000 CLP regardless of their individual contribution. No bonuses would be given of they failed to exceed the group amount and each participant would only gain the amount of money they decided not to contribute on the game.

Participants were provided with a complete description of the game through an animated video and then returned to their original cabin. Following previous research (van Vugt et al. 2007; Muñoz-Reyes et al. 2020) they played a practice round before the actual game. After the game, prosocial behavior was measured as the individual contribution made by a participant to the group.

Data analyses

The individual contribution made by a participant to the group (i.e. prosocial behavior) was compared using General Linear Models (GLM) on R 4.2.2 (R Core Team, 2022). Factors considered in the analyses were the sex composition of the group (same-sex and mixed groups), maternity (mother and non-mother) and relationship status (single and partnered). Interactions were evaluated in accordance with the hypotheses. Additionally, the prosocial behavior was compared between sexes using a Mann Whitney test.

Results

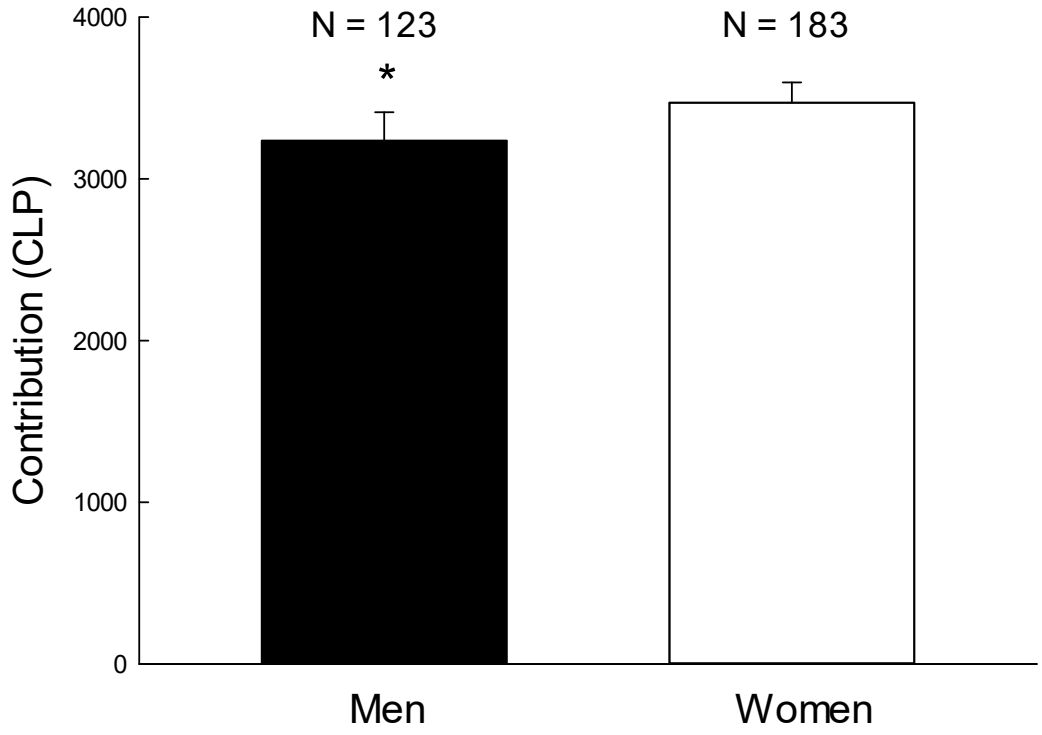
None of the factors considered affected the individual contribution made by a participant to the group (Table 1).

Table 1. Results for the Generalized Linear Model for the individual contribution made by a participant to the group (prosocial behavior), under different treatments. AIC= Akaike information criterion = 5050.5; * indicates significance at $P < 0.05$.

	Estimate	**SE**	***t*-value**	***P*-value**
Intercept	2829.7	944.3	2.997	0.00296*
Maternity (mat)	951.8	800.1	1.190	0.23517
Group sex composition (comp)	322.4	615.1	0.524	0.60062
Relationship status (rel)	1184.9	1152.4	1.028	0.30466
Mat*comp	-1434.1	930.4	-1.541	0.12430
Mat*rel	-652.8	526.5	-1.240	0.21593
Comp*rel	-754.7	737.2	-1.024	0.30677
Mat*comp*rel	994.0	597.1	1.665	0.09703

Comparisons between sexes indicate that prosocial behavior differ between sexes ($U = 9466$; $P = 0.016$), being the average contribution made by women higher than that of men (mean ± SD, women: 3471.14 ± 861.26; men: 3236.43 ± 985.58, Figure 1).

Figure 1. Individual contribution made by a participant to the group (prosocial behavior) of men and women. * Indicates significant differences between treatments at $P < 0.05$.



Discussion

In this study, none of the hypothesis were confirmed. We did not find an effect of the sex composition of the group (same-sex and mixed groups), maternity (mother and non-mother) and relationship status (single and partnered) over women's prosocial behavior from the use of a PGG in laboratory-controlled conditions. We

did not find that single mothers cooperated more than other women, we did not find that partnered mothers are more cooperative in same-sex groups than in mixed groups, and we did no find that non-mother single women cooperate more in the context of mixed groups. The only significant result is the difference in the prosocial behavior between men and women.

We found sex differences in the prosocial behavior of men and women, being higher in the latter. Although a meta-analysis revealed that there is no significant difference between men and women across 20 societies (Spadaro et al. 2022), not even through children and adolescents' development (House et al. 2022), our results could be explained since the same meta-analysis indicates that there is higher cooperation in studies with a higher prevalence of women, as in the case of this study (59.6 % of the participants are women). Furthermore, the present study focuses on the effects of maternity; as such, this study has a total of 90 female participants who were mothers (49.18 % of the female sample). Women may cooperate more than men in this study because the maternity situation involves a stronger conflict of interests, suggesting that women may opt for the "tend and befriend" strategy as an adaptive response to maximize the offspring survival or benefit (Taylor et al. 2000; Spadaro et al. 2022), and thus could explain the higher levels of cooperation observed in women than in men in this study.

We found no significant differences in the cooperative behavior of partnered mothers considering the sex composition of the group. Other studies obtained similar results, Berge et al. (2016) did not find differences in women's contributions to a PGG between mixed or only-women groups. This could be explained because women, and especially mothers, may have motivations to cooperate with either men or women because they need to obtain social support for their daily lives; for example, in the study made by Wang et al. (2021) women allocated more resources to female recipients, probably to get more help on offspring-rearing. Although none of the mentioned studies considered maternity, we did not find an interaction of it with sex composition of the group, which might be explained because women interact more dyadically than in groups while men interact in groups (Benenson & Markovits 2014; Benenson 2019; Benenson & Abadzi 2020). This is one of the limitations of the study, which might also explain the lack of results of the sex composition of the group observed in this study and by Tognetti et al. (2016). We suggest studying the effects of maternity, relationship status and sex of the partner considering dyadic games such as the trust game (Berg et al. 1995) instead of group games such as the PGG.

Other possible limitation in this study might be the type of incentive (experimental reward) used. In this study it was monetary but other studies that used benefits for the offspring have observed that the motivations of women change, at least in competitive behavior (Cassar et al. 2016). Future studies might consider providing

and incentive for the children instead of a general one (money) like we used in this study to evaluate the effect of maternity.

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