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Evolutionary Approach on Binge Drinking : Meta-Analytic, Experimental and Modeling Investigations of Excessive Alcohol use and Other Risks.

Jordane Boudesseul

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THÈSE

Pour obtenir le grade de

DOCTEUR DE LA COMMUNAUTE UNIVERSITE GRENOBLE ALPES

Spécialité : **Psychologie Sociale Expérimentale**

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Présentée par

Jordane Boudesseul

Thèse dirigée par **Laurent Bègue, Professeur, Univ. Grenoble
Alpes**

préparée au sein du **LIP-PC2S**

dans l'**École Doctorale des Sciences de l'Homme, du Politique et
du Territoire**

**Approche évolutionnaire des alcoolisations
ponctuelles importantes (API):** modélisation, méta-
analyse et recherches expérimentales sur l'usage d'alcool et des
prises de risques

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devant le jury composé de :

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An Evolutionary Approach On Binge Drinking

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An Evolutionary Approach On Binge Drinking

An Evolutionary Approach On Binge Drinking

ABSTRACT OF THE DISSERTATION

An Evolutionary Approach on Binge Drinking: Meta-Analytic, Experimental and Modeling Investigations of Excessive Alcohol use and Other Risks

by

Jordane Boudesseul

Univ. Grenoble Alpes, 2018

Professor Laurent Bègue, Chair

Binge drinking is a worldwide and multi-faceted phenomenon usually defined as having 4 or more alcoholic beverages per occasion for women or 5 or more drinks per occasion for men. Binge drinking also underlies many other risky behaviors (inter- and intra-personal violence, drunk driving, sexual risks, etc.) as well as negative health consequences (cancers, cardiovascular diseases, etc.). The three-fold nature of binge drinking (biological, psychological and sociological) encompasses a wide variety of areas ranging from endocrinology to social and cognitive psychology. Getting an overview of the problem, however, is made difficult by the

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very fact that few evolutionary analysis have been suggested. Here, we propose to frame the problem from a costly signaling perspective. What type of signals do the binge drinkers send? To whom is the signal directed? Are those signals courtship displays or threats to competitors in order to assure reproductive success or maintain social status? How can contextual factors influence drinking rates? Exploring causes, correlates and predictors of binge drinking and its interdisciplinary nature should serve as a relevant starting point to then reveal the necessity of an evolutionary framework.

To address these questions, I first started by shaping an evolutionary-based approach to binge drinking taking into account current data and theories (Chapter 1). I then ran various laboratory studies (eye-tracking) and online experiments aiming at evaluating the mating and intra-sexual signals that binge drinkers send to others (Chapter 2 and 3). Based on those results, I implemented a field prevention program intended at reducing alcohol's attitude and expectancies among French high school students as well as an online replication (Chapter 4). In parallel, I conducted an extensive meta-analysis of women's drinking behaviors and other risks across the menstrual cycle to understand the endocrine influences at play (Chapter 5). Finally, I analyzed the life-history theory of risky drinking at a population level through a hierarchical modeling of binge drinking frequency and intensity from 1997 to 2006 across the United States (Chapter 6). Taken together, those findings can help to build the foundations for an inter-disciplinary approach to binge drinking and create specific micro-targeted prevention programs.

RÉSUMÉ DE LA THESE

Approche évolutionnaire des alcoolisations ponctuelles importantes (API) :
modélisation, méta-analyse et recherches expérimentales sur l'usage d'alcool et des prises de
risques

par

Jordane Boudesseul

Univ. Grenoble Alpes, 2018

L'alcoolisation ponctuelle importante (API) est un phénomène mondial et à multiples facettes généralement défini comme une consommation de 4 boissons alcoolisées ou plus par occasion pour les femmes ou 5 verres ou plus par occasion pour les hommes. Les consommations excessives sous-tendent également de nombreux autres comportements à risque (violence inter et intra-personnelle, conduite en état d'ébriété, risques sexuels, etc.) et ont des effets nocifs avérés sur la santé (cancers, maladies cardiovasculaires, etc.). La triple nature de la consommation excessive d'alcool (biologique, psychologique et sociologique) englobe une grande variété de domaines allant de l'endocrinologie à la psychologie sociale et cognitive. Obtenir une vue d'ensemble du problème, cependant, est rendu difficile par le fait même que peu

d'analyses évolutives ont été suggérées. Ici, nous proposons d'aborder le problème sous l'angle de la théorie du signal coûteux.

Quels types de signaux les buveurs excessifs envoient-ils ? À qui le signal est-il destiné ? Ces signaux sont-ils des parades nuptiales ou des menaces pour les compétiteurs afin d'assurer le succès reproductif ou maintenir un certain statut social ? Comment les facteurs contextuels peuvent-ils influencer les taux de consommation ? Explorer les causes, les corrélats et les prédicteurs de la consommation excessive d'alcool et sa nature interdisciplinaire devrait servir de point de départ pertinent pour ensuite révéler la nécessité d'un cadre évolutif.

Pour répondre à ces questions, j'ai commencé par élaborer une approche évolutive de la consommation excessive d'alcool en tenant compte des données et des théories actuelles (Chapitre 1). J'ai ensuite mené plusieurs études de laboratoire (oculométrique notamment) et des expériences en ligne visant à évaluer les signaux inter- et intra-sexuels que les « binge drinkers » envoient aux autres (Chapitres 2 et 3). Sur la base de ces résultats, j'ai mis en place un programme de prévention sur le terrain visant à réduire l'attitude et les attentes positives de l'alcool chez les lycéens français ainsi qu'une réplique en ligne (Chapitre 4). Parallèlement, j'ai réalisé une large méta-analyse des comportements de consommation d'alcool chez les femmes et d'autres risques au cours du cycle menstruel pour comprendre les influences endocriniennes en jeu (Chapitre 5). Enfin, j'ai analysé la théorie d'histoire de vie de la consommation à risque au niveau populationnel à l'aide d'une modélisation multi-niveaux de la fréquence et de l'intensité des consommations excessives de 1997 à 2006 aux États-Unis (Chapitre 6). Dans leur ensemble, ces résultats s'inscrivent dans la perspective d'une approche évolutive de la consommation excessive d'alcool et permettent d'envisager de créer des programmes de prévention micro-ciblés.

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Chapter 1: Why the Binge Drinkers Survive? A Costly Signal Perspective on Excessive Alcohol Use.

1.1. Introduction

Alcohol abuse is one of the leading causes of mortality worldwide with 3.3 million deaths in 2014, representing 5.9% of all deaths that same year. More than 200 diseases and injuries are causally linked to its harmful effects, through tragic health, socio-economic consequences (WHO, 2014). An important part of alcohol abuse takes place through binge drinking, a worldwide and multi-faceted phenomenon underlying many risky behaviors (inter- and intra-personal violence, drunk driving, sexual risks, etc.) along with high economic cost and lack of productivity (Chikritzhs, Jonas, Stockwell, Heale & Dietze, 2001; Courtney & Polich, 2009; NIAAA, 2004). While countries differ on the exact definition of binge drinking (Beck, Richard, Guignard, Nézet & Spilka, 2014; Haber, Lintzeris, Proude & Lopatko, 2009; NIAAA, 2004), it is generally agreed that consuming more than 4 or 5 drinks (respectively for women and for men) in under 2 hours, equivalent to .08 grams percent of blood alcohol, constitutes a binge drinking episode (CDC, 2012; NIAAA, 2004; WHO, 2014).

For decades now, researchers have sought to examine the cause of binge drinking through a three-fold approach: biological, psychological and sociological (Carrigan et al., 2015; Dudley, 2014). While most epidemiological studies report that men represent the majority of binge drinkers (Courtney & Polich, 2009; Cranford, McCabe & Boyd, 2006), a wide range of cognitive (Stephenson, Hoyle, Palmgreen & Slater, 2003; Zuckerman & Link, 1968) and social factors (Hanson, 1974; Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994; Wechsler & McFadden, 1979) certainly play a role in the emergence and maintenance of risky drinking. Recently, some publications have taken an evolutionary approach to risky drinking through the

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lens of the costly signal (Diamond, 1992; Greitmeyer, Kastenmüller & Fisher, 2013; Kacir, 2010) and life-history theories (Hill & Chow, 2002; Hill, Ross & Low, 1997; Kaplan & Gangestad, 2004). The model proposed in this article claims that Zahavi's handicap principle (Zahavi, 1975; Zahavi & Zahavi 1999) is the best suited at both the local and global levels of analysis integrating the three-level factors (biological, cognitive and sociological). What type of signals do the binge drinkers send? To whom is the signal directed? Are those signals courtship displays or threats to competitors in order to assure reproductive success or maintain social status? How can contextual factors influence drinking frequency and intensity? Exploring causes, correlates and predictors of binge drinking and its interdisciplinary nature should serve as a relevant starting point to then reveal the necessity of an evolutionary framework.

General health theories, like the Theories of Reasoned Action and Planned Behaviour (Johnston & White, 2003), consider that the intention to perform an action is influenced by an attitudinal and a normative component (Fishbein & Ajzen, 1975). While attitude evaluates the valence of the behavior (positive or negative), the subjective norm is conceptualized through the perception of general social pressure from important peers (later additional features included volitional control, see Johnston & White, 2003). However, such models are mainly correlational (as they observe consequences, they cannot distinguish the causes from the symptoms) and static (they are unable to describe the dynamic aspect of the maintenance or not of risky drinking). On the other hand, those explanations focus on an individual level and may not give a larger picture of the binge drinking phenomenon such as those taking place on US college campuses (Syre & McAllister, 1997).

Our model proposes to analyze binge drinking as a signal of resistance and high genetic quality. It can serve as a direct threat to potential same-sex competitors for resources or as a

display of genetic quality to available mates. Binge drinking games can be viewed as a way to reproduce intrasexual competition without any form of direct aggression as it is frequent in the animal world (Smith & Harper, 2003; Smith & Price, 1973). That theory can produce precise experimental predictions as well as modeling key factors. An additional feature of such an approach is its interdisciplinary perspective reconciling the three fold-nature of binge drinking.

1.1.1. Defining Binge Drinking

The original definition of binge drinking simply stated that an individual needed to consume at least five alcoholic beverages during the same session (Cahalan, Cisin, & Crossley 1969). Decades later, the Harvard School of Public Health updated this definition by adding a gender distinction with five drinks for men and four for women in the same sitting in a 2-hour period (Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994) essentially due to the lower rate of gastric metabolism in women (Wechsler, Dowdall, Davenport, & Rimm, 1995). The 2-hour timeframe has since become the general definition in experimental design of binge drinking (Oei & Morawaska, 2004; Syre & McAllister, 1997; Weschler, Dowdall, Maenner, Hill-Hoyt, & Lee, 1998). A physiological characterization of binge drinking logically accompanies this definition through a blood alcohol concentration (BAC) level of 0.08 percent in a single sitting (NIAAA, 2004; Rolland et al., 2017).

Still, the World Health Organization defines binge drinking as 6 standard drinks (60 grams of alcohol) per sitting without specifying the drinking speed, in contrast to the NIAAA (WHO, 2014). To compare the sociodemographic and drinking characteristics of subjects of those two sets of criteria, Rolland et al. (2017) found that the NIAAA combined criteria included higher frequency of regular drinkers, family drinking troubles and hospitalization. NIAAA criteria also revealed that participants were more likely to be male, single and unemployed.

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Pearson, Bravo, Kirouac & Witkiewitz (2017) have recently broadened the limits of the monotonic/non-dynamic validity of the 4+/5+ binge drinking criteria and urge the use of speed as the critical component to encompassing this risky phenomenon.

All in all, the use of such a definition in health and psychological studies has been fairly widespread (King, Houle, Wit, Holdstock & Schuster, 2002; Read, Beattie, Chamberlain & Merrill, 2008; Wechsler et al., 1994; Wechsler, Dowdall, Davenport, & Rimm, 1995) allowing uniform reviews and comparisons across time and space (Courtney & Polich, 2009; Zeigler et al., 2005). Beyond the threshold of at least 4 or 5 drinks in a 2 hour window, the social risk to the binge drinker substantially increases (e.g., fights, drunk driving, confrontation with authorities, etc.), as do his or her health (e.g., sexual risks or dysfunction, suicide attempts, stroke, etc.) and economic hazards (lack of productivity) among others (Courtney & Polich, 2009; Miller, Naimi, Brewer & Jones, 2007; Wechsler, Davenport, Dowdall, Moeykens & Castillo, 1994).

1.1.2. Epidemiology

The starting age of regular (at least twice a month) binge drinking ranges between 15 and 16 years old depending of the risk level of the children (Hill, Shen, Lowers, & Locke, 2000). While the age of onset of excessive alcohol use is relatively low, the age group with the most binge drinkers extends from 18 to 34 years old with even some 65 years and older reporting binge drinking five to six times a month on average (CDC, 2010). The gender difference in reported binge drinking episodes is another important factor with the prevalence of men being twice that of women (CDC, 2012). Approximately 50% of male students report binge drinking versus 39% of female students (BRFSS, 2016; Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994). Social status is another important variable since binge drinking is more common among richer households in the U.S. (incomes of \$75,000 or more, see CDC, 2012). Finally,

racial differences were also important predictors of binge drinking, with Caucasians involved in 78% of all binge-drinking episodes in the U.S. while African and Asian Americans groups reported the lowest levels (Cranford et al., 2006; Naimi et al., 2003).

1.1.3. Clinical Diagnosis

Recently, the health community has shifted its determination if alcohol abuse and alcohol dependence fall in a common substance disorders spectrum (DSM-IV, 1995; DSM-5; 2013). Originally, chronic drinking or alcoholism was defined as a prolonged disease including strong craving for alcohol, continued use despite regular interpersonal problems and inability to limit drinking (DSM-IV, 1995). Excessive alcohol use, a form of binge drinking, was conceptually diagnosed as “alcohol abuse” where “school and job performance may suffer either from the aftereffects of drinking or from actual intoxication on the job or at school; child care or household responsibilities may be neglected; and alcohol-related absences may occur from school or job” (DSM-IV, p. 196, 1995). The person may use alcohol in dangerous situations (e.g., driving) and suffer legal consequences (e.g., intoxicated behavior, driving under the influence). “Finally, individuals with Alcohol Abuse may continue to consume alcohol despite the knowledge that continued consumption poses significant social or interpersonal problems for them (e.g., violent arguments with spouse while intoxicated, child abuse)” (DSM-IV, p.196, 1995).

Surprisingly, no mention is made of data showing that most early age binge drinkers are not dependent on alcohol (Esser et al., 2014). Despite being an aggravating risk factor (Englund et al., 2013), the transition from binge drinking to chronic drinking is far from automatic and clear comorbidity between binge drinking and long-term alcohol dependence is uncertain (Hussong, Hicks, Levy & Curran, 2001). While we recognize that such approach might have

clear applicable values for practitioners, we think that this conceptualization prevents us from drawing an interdisciplinary picture of the phenomenon. Evolutionary psychology and medicine can respectively serve as theoretical tools to make predictions and framework to build specific and more targeted alcohol prevention programs, particularly among youth¹.

1.1.4. Distinguishable effects

Binge and chronic drinking also display different patterns of effects. On a lower level, for instance, alcohol consumption acutely impairs functions of the pre-frontal cortex (in particular, planning, information processing, inhibitory control response flexibility, attention and set-shifting) but increases dopamine release in the ventral striatum, facilitating the onset of risky behaviors and aggressive attacks (Heinz, Beck, Meyer-Linderberg, Sterzer & Heinz, 2011). Chronic alcohol consumption acts differently by impairing serotonergic transmissions in the prefrontal cortex and the amygdala triggering greater emotional responses to threatening stimuli eventually leading to more aggressive behaviors (see Figure 1).

Another main differences between binge drinkers and alcoholics is the dependence level. While various mechanisms (e.g. self-efficacy, self-esteem, etc.) can make the binge drinker resistant to alcohol outside a social context, the alcoholic may continuously crave alcohol, eventually being unable to resist the temptation. The social acceptance of binge drinking is widespread, especially among college students where playing drinking games can be a way to integrate to a group (Borsari & Carey, 2003) whereas isolation, shame and hiding are more

¹ As Berridge, Herring and Thom (2009) noticed, binge drinking has been used recently to describe two quite distinct phenomena. The first one, as the DSM-IV stated, described a pattern of extended abuse alcohol across time and which is included in the term “alcoholism”. The second definition, the one used nowadays for public policy outcomes in particular, refers to the number of single events leading to intoxication after a certain number of drinks. As we outlined before, analyzing binge drinking through an evolutionary lens like incompatibility between current environment and ancestral selection processes might be a way to resolve the tension between those two concepts.

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characteristic of chronic drinkers (whether binge drinking alone or not, see Dearing, Stuewig & Tangney, 2005).

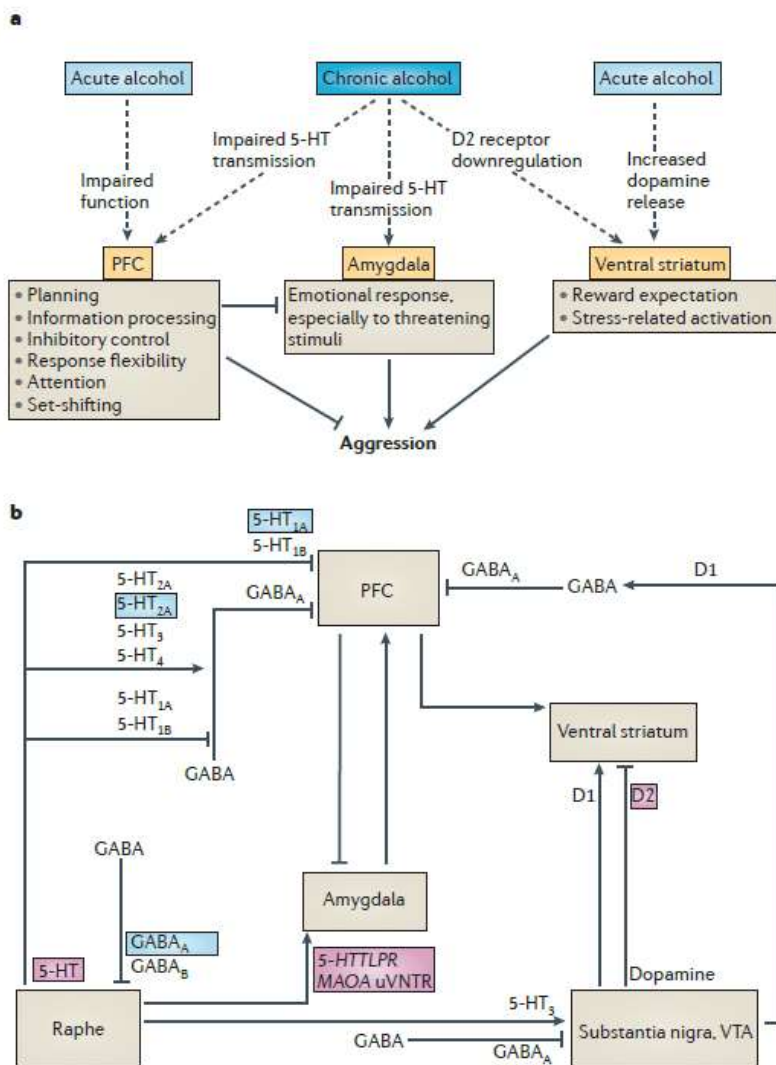


Figure 1. Example of the differential acute vs. chronic effects of alcohol on aggressive behaviors. a | Brain areas involved in alcohol-induced aggression. b | Neurotransmitter system variations in alcohol-associated aggression cascades are in blue while, in purple, are pathways affected by genetic and environmental influences.

Reprinted from Heinz et al. (2011).

1.2. Binge Drinking as a Multi-faceted Phenomenon

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Empirical studies on binge drinking started more than 20 years ago and have shed light on the variety of factors that might play an important role. From cognitive genetics to sociology, the correlates and experimental results pass through different levels of organization that I summarized here, for the sake of the argument, as biological, cognitive and social. I synthesized it graphically (as seen as figure 2) and we will go through the different levels one by one. Then, we will present the different theories of binge drinking and how they integrate those different factors. Finally, we will evaluate their limitations before arguing for an evolutionary approach of binge drinking through the costly signal and the life-history theories that had been fruitful in evolutionary biology.

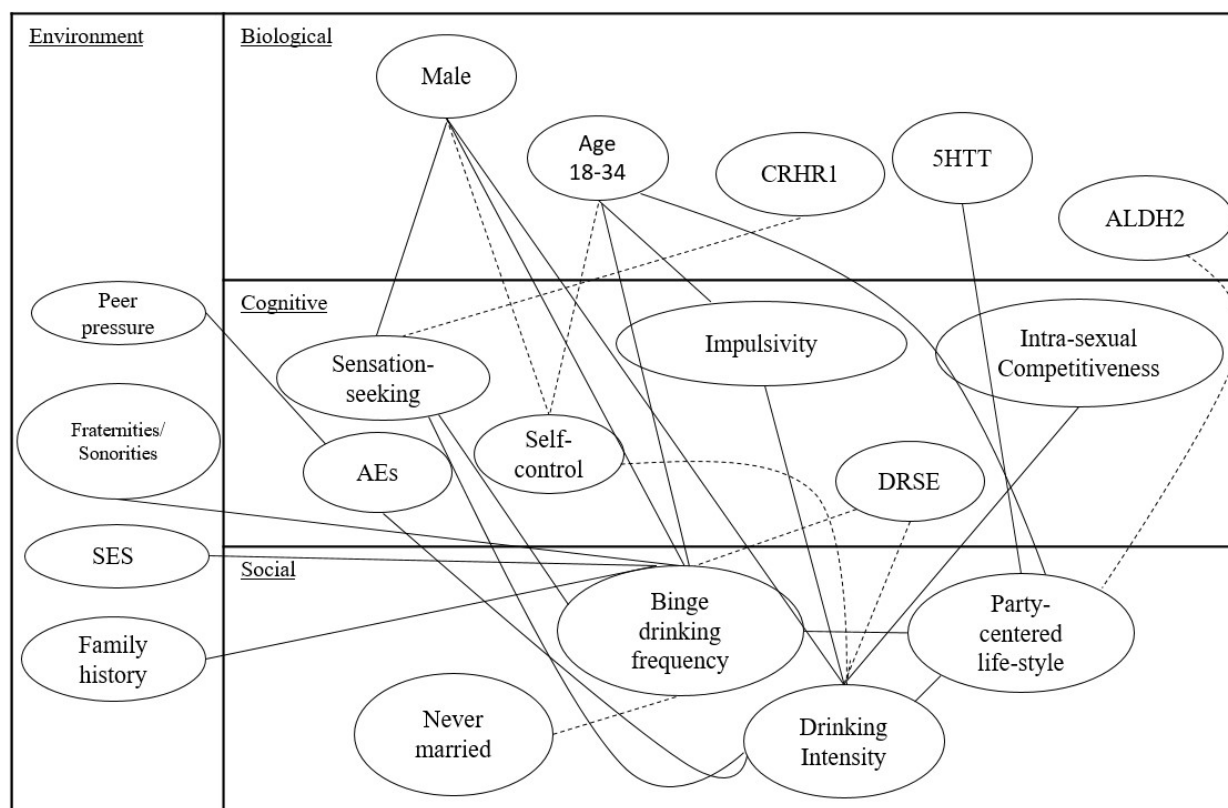


Fig. 2. The three-fold components of binge drinking. Solid lines indicate a positive relationship whereas dashed ones indicates a negative one (e.g. being male increases the probability of having higher sensation-seeking level compare to women but lower self-control).

1.2.1. Social determinants

In 1949, Straus and Bacon conducted a 3-year study in 27 US colleges and universities of 15,000 men and women reported in their book *Drinking in college* (Strauss & Bacon, 1953). Their work, confirmed by later studies (Wechsler, Davenport, Dowdall, Moeykens, & Castillo, 1994; Wechsler & McFadden, 1979), showed that a particularly high percentage of freshmen were binge drinkers. As expected, high-school binge drinking pattern was a very strong predictor of later binge-drinking in college (Wechsler & McFadden, 1979). Along with more (subtle-not the best adjective here) studies, a myriad of social factors correlated with binge drinking emerged: involvement in fraternities, party-centered life-style among men (Weschler, Dowdall, Davenport, and Castillo, 1995) but also among young women (Dowdall, Crawford & Wechsler, 1998). Fraternities, for instance, are famous for widespread participation in drinking games and 81.1% of fraternity or sorority residents in the US are binge drinkers (Wechsler et al., 1998; Wechsler, Davenport, Dowdall, Moeykens & Castillo, 1994). Another explanation could be that high school men planning to join a fraternity were already frequently heavy drinkers and that individuals at high-risk of behavior such as drinking (but also unsafe sex, risky driving, etc.) in general are more likely to be part of a fraternity (Canterbury et al., 1992).

When controlling for other demographic variables, the status of “never married” was also a strong predictor of binge drinking (see Weschler, Dowdall, Davenport, and Castillo, 1995; Schulenberg et al., 1996). Other studies are more nuanced and tend to show that the prevalence of binge drinking among single students is not remarkably higher than that among married students their freshmen year of college, but the big difference lies in the change in behavior between the freshman year and subsequent years of their college career: students self-described as “never married” tend to drink more and more in the course of their studies when compared to

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married students (Wechsler, Lee, Kuo & Lee, 2000). This could indicate that a relationship serves as a protective barrier against binge drinking through less exposure to drinking games, peer pressure or to single friends who engage in risky drinking. On the other hand, single students can use group gatherings and parties as a way to socialize (particularly during the freshman year when students do not know each other) and thus are exposed to drinking games and peer pressure, in particular through fraternities.

In contrast to what could be considered as a “healthy life-style”, student-athletes actually participate in binge drinking more often than their non-athletic counterparts (Wechsler, Davenport, Dowdall, Grossman, & Zanakos, 1997). Taking part in athletics can trigger pressure, stress, injuries and social isolation. However, the strongest predictor among students involved in athletics was actually whether the athlete was living in a fraternity or sorority. In his book *College Drinking: Reframing a Social Problem / Changing the Culture* (2008), George Dowdall goes further by referencing a case of irresponsible and violent behavior among college athletes such as in the Duke Lacrosse team. This led to an ad hoc committee that recommended, in particular, a code of conduct for athletes, a need for improved communication between student affairs and athletics and an enforced alcohol policy. While still maintaining excellent scholastic or athletic achievements, sports team members in colleges might find themselves in a pro-drug, pro-binge drinking environment and project their high competitiveness into drinking games leading to disastrous consequences.

Other sociodemographic factors emerge when studying binge drinking patterns. In particular, precollege and family drinking patterns are good predictors of risky drinking. In a 2003 study, Weitzman, Nelson & Wechsler found that students who started drinking before age 16 were more likely to end up binge drinking when compared to their peers who started later in

their adolescence. The early onset of drinking among teenagers might be due to their parents' alcohol use and attitude toward drinking since two thirds of the group in Weitzman's study reported that their parents used to drink during their childhood. Chassin, Pitts and Prost (2002) evaluated the binge drinking trajectories from adolescence to emerging adulthood in a high-risk sample. They found that family structure was a good predictor in particular for early heavy drinkers: adolescents from disrupted families (where one or more biological parent is absent) were more likely to be involved in risky drinking activities than their counterparts from unified families (where both biological parents are present). Children of alcoholics ("COA"s) were particularly vulnerable to heavy drinking from the ages of 12 to 23 (Chassin, Curran, Hussong, & Colder, 1996; Chassin, Pitts, DeLucia, & Todd, 1999). The early heavy drinkers exhibited all those characteristics ranging from parental alcoholism and antisociality to peer drinking, drug use and, for men, low levels of depression (Chassin, Pitts & Prost, 2002).

1.2.2. Cognitive Aspects

One of the cognitive aspects regularly and robustly linked to binge drinking is the seeking of sensation (Zuckerman, Bone, Neary, Mangelsdorff & Brustman, 1972). A person's general attitude towards risk, measured through different short- or-long version questionnaires (Stephenson, Hoyle, Palmgreen & Slater, 2003; Zuckerman, 1968), can indicate how much they crave or are willing to be involved in risky activities that are not necessarily related to drinking (e.g. skydiving) but can sometimes be highly correlated to it (e.g. wild parties). These personality variables have long been linked to substance use (Donohew, Hoyle & Clayton, 1999; Schwarz, Burkhart & Green, 1978; Zuckerman & Neeb, 1979). A study of an Australian adolescent male population, led by Andrew and Cronin (1997) explored the link between sensation seeking and alcohol use among 318 ninth, tenth and eleventh graders, thus permitting an evaluation before

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the freshman year of college. Using Arnett's Inventory of Sensation Seeking (Arnett 1994), they found that desire for intensity was a stronger predictor of alcohol use and binge drinking episodes than desire for novelty.

Another construct known to be linked to binge drinking, although generally related to substance use, is impulsivity (Balodis, Potenza & Olmstead, 2009). Generally considered as a personality trait, it promotes rapid and unplanned responses to stimuli with a lower focus on the negative counterparts (Moeller et al., 2001; Potenza 2007). However, it is difficult to understand the causal direction since impulsivity as a personality trait may predispose young adolescents toward risky drinking but also excessive alcohol use that can impair self-control and inhibition, leading to behavior that could be characterized as impulsive. There is a debate in the literature as to whether gender differences exist regarding the link between impulsivity and binge drinking (Balodis, Potenza & Olmstead, 2009). While some studies reported notable gender differences regarding this relationship (Zuckermann & Kuhlmann, 2000), the gender difference for binge drinking itself is well established (Wechsler et al., 1994). A study of over 428 Queen's University students between 2002 and 2007 revealed that while impulsivity did not correlate directly to binge drinking per se, it did to drinking habits in general and in particular to number of drinks per drinking occasion (Balodis, Potenza & Olmstead, 2009).

Drinking games are also an interesting platform to analyze behaviors and personality traits among players. Moreover, drinking games are one of the main channels to risky drinking among university students and their participation is a good predictor of heavy episodic drinking (Clapp et al., 2003; Clapp, Won Min, Shillington, Reed, & Ketchie Croff, 2008). Their main reasons or justification for participating in drinking games is competitiveness (i.e., "because I want to win") and reproductive success ("in order to have sex with someone"; Borsari, 2004).

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The beginning of college is often a novel period of relative leisure time without parental supervision and a sudden access to a multitude of potential mates but also competitors, making the first few semesters of college determinants for engagement in binge drinking. For instance, a study on 263 students from the University of Miami, not only showed important gender differences in the frequency of drinking game participation, but also that both social competitiveness and competitive drinking game enthusiasm were good mediators to predict the frequency of participation in drinking games in two-phase studies, confirming other previous studies (Hone & McCullough, 2015).

Alcohol expectancies (AE) and drinking-refusal self-efficacy (DRSE) are also two important predictors of risky drinking. The concept of AE states that the physiological effect of alcohol not only influences our reaction to but also the expectations we have of it (Oei & Morawska, 2004). Participants receiving a placebo while believing it to be alcohol behave in accordance with their expectations of the latter's effects (Marlatt & Rohsenow, 1980). According to Bandura (1977, 1986) two classes of expectations can be distinguished: the efficacy expectancy – the capacity to resist alcohol in particular situations – and the outcome expectancy – that evaluates the consequences of a particular activity such as binge drinking. Alcohol expectancy seems to be a construct that develops before contact with alcohol and tends to crystalize later in life (Miller, Smith & Goldman, 1990). We are regularly exposed to alcohol through ads, family, peers, and events during childhood and progressively construct specific expectations toward the product stored in long-term memory. Those expectancies might be reinforced when one tends to selectively focus on specific positive outcomes resulting from alcohol consumption rather negatives ones (e.g. sociability vs. negative consequences). Through global positive, social and physical pleasures, AEs have been shown to explain a much larger

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share of adult and adolescent drinking when compared to other sociodemographic variables (10-19% of the variance observed in adults while peer influence and environment explained only 5% and 8% respectively; Oei & Morawska, 2004; Martin & Hoffman 1993).

However, while AEs might be reliable predictors for the amount of alcohol consumed on a given occasion, they are less efficient for predicting the frequency of drinking (Mooney, Fromme, Kivlahan, & Marlatt, 1987). Drinking-refusal self-efficacy (DRSE) on the other hand, which indicates the capacity to refuse to drink alcohol in particular situation, is related to the frequency of drinking. An individual with low DRSE would be more willing to drink more when given the opportunity to drink. In that sense, Vogel-Sprott (1974) described those aspects of drinking as being influenced by different factor types: the amount of drinking would be an aspect under an individual's control while the frequency of drinking occasions will be more influenced by social factors. Thus, the dynamic might be that social pressure, or a party-centered life-style in a particular ecology would trigger the opportunity to drink and DRSE will be the switch to participate or not. AEs' base level will then determine the quantity of alcohol drunk in that particular event. Again, alcohol dependent and binge drinkers are interesting examples of how those two particular factors (AE vs. DRSE) might interact. Chronic dependent drinkers have both positive expectations toward alcohol (high AE) and difficulty resisting it when offered (low DRSE; Cooney, Gillespie, Baker, and Kaplan, 1987). On the other hand, binge drinkers would tend to have higher DRSE and exhibit more willingness to refuse to participate when presented with an opportunity to drink (even though they could end up drinking more when they do agree to attend).

1.2.3. Biological components

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Integrating the three-fold nature of binge drinking naturally leads us to evaluate how predisposed biological factors might influence the emergence and maintenance of binge drinking (figure 2). Robert Dudley proposed that our attraction to alcohol might be due to an evolutionary adaptation of our ancestors to recognize ethanol and associate it with ripe fruits (Dudley, 2014). When our hominid ancestors were able to metabolize ethanol, about 10 million years ago, through their digestive alcohol dehydrogenase (ADH4) enzymes, they were then able to exploit rotting and fermented fruits during their nomadic phase (Carrigan, Uryasev, Frye, Eckman, Myers, Hurley & Benner, 2015). In times of scarce calories in tropical forests localizing ripe fruits through volatilized alcohol may have been of substantial help to gather resources (Dudley, 2000).

Modern use of alcohol may be largely different from the way our primate ancestors consumed it. However, recent studies have shed light on possible genetic factors underlying binge drinking. Both the serotonin transporter (5-HTT) and the protein promoter (5-HTTPLR) responsible for the regulation of serotonergic function were associated with alcohol consumption in college students. The frequency of the short allele (S) in the 5-HTT gene was associated with higher ethanol tolerance in adults under 26 years old (the short allele conferring lower serotonergic activity compared to the long allele). In another college student study, Caucasian participants homozygous for the S allele of the 5-HTTPLR gene were found more likely to engage in binge drinking (higher frequency and quantity per event) and to admit drinking to get drunk more often (Herman, Philbeck Vasilopoulos & Depetrillo, 2003). However, a recent 10-year longitudinal study of a young Australian cohort revealed that participants carrying the short S-allele were less likely to engage in binge drinking activities (Olsson et al., 2005). Further studies need to be run to attest to the existing molecular genetic mechanism.

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Other cognitive genetics mechanisms seem at play in binge drinking, in particular among adolescents. Treutlein and colleagues (2006) investigated the role of the corticotropin releasing hormone receptor 1 (CRHR1) among adolescents in a longitudinal study. Taken together, their study showed that the CRHR1 genotype was related to the amount of drinking (binge drinking) but not to the frequency of drinking. Some prominent findings are related to the susceptibility to alcohol's effects (e.g. nausea) modulating by the presence of the ALDH2*2 allele among Chinese and Japanese individual which would explain the surprising low rates of drinkers in that population (20 and 40% occurrence respectively, see figure 3 for a summary, Higuchi et al., 2004; Plomin, Defries, Knopik & Neiderhiser, 2013).

Phenotype	Gene
Alcohol Dependence [ad]	ADH1B, ADH1C, SH3BP5, NXPH2, PKNOX2, SYT17, KIAA0040, ZNF124, PECR, PPP2R2B, ERAP1, ESR1
Alcohol Consumption [ac]	TF, HFE, SRPRB, PGM1, AUTS2, C12orf51, MYL2, CCDC63, OAS3,
Alcoholism [al]*	HIP1, MBNL2, DCC, C15orf32
Drinking Behavior [db]	ALDH2, CCDC63

Fig. 3. Candidate genes for the different types of alcohol patterns. Retrieved from Plomin, Defries, Knopik & Neiderhiser, 2013.

At the hormonal level, one might expect an association between binge drinking patterns and certain androgen hormones such as testosterone, since the corticotropin-releasing hormone is released from the hypothalamus upon exposure to certain environmental stressors and is linked to the ventral tegmental area, which is connected to reward processes (Treutlein et al., 2006). Surprisingly, an association between risky behavior (such as risky drinking) and hormones did not reveal testosterone as a key mediator. Across a white non-Hispanic sample of 68 males and 75 females all around age 22 in Florida, Rosenblitt and colleagues (2001) found instead that cortisol levels were negatively associated, only among males, with sensation-seeking. Their

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study did not reproduce a past finding showing a positive link between testosterone and sensation-seeking (Daitzman, Zuckerman, Sammelwitz & Ganjam, 1978).²

However, the main biological factor related to high testosterone, sensation-seeking, and amounts and episodes of binge-drinking is the sex of the individual. One of the most widely cited meta-analyses on gender differences in risk-taking comes from Byrnes and colleagues (1999) reporting a small effect in favor of men on drinking and drug use (making it difficult to assess gender differences specifically on binge drinking). In a Scottish study of gender differences in hazardous drinking at two points in time (1990 and 2000), men's level of alcohol consumption and binge drinking were systematically higher than women's and a higher proportion of men were classified as binge drinkers: 30.8% vs 11.3% in the youngest sample, 30.7% vs. 7.3% in the middle-age sample and 20.8% vs. 3.1% in the oldest sample (Emslie, Lewars, Batty & Hunt, 2009). To evaluate binge drinking patterns on an international level, Wilsnack and his colleagues (2009) evaluated men's and women's drinking behavior through large-scale surveys in over 35 countries between 1997 and 2007. As expected, men consistently reported drinking more frequently and in higher volumes than women, and lifetime abstinence from alcohol was always more prevalent among women (Wilsnack, Wilsnack, Kristjanson, Vogeltanz-Holm, & Gmel 2009).

Finally, developmental considerations also matter substantially in the understanding of the binge drinking phenomenon. For instance, Wilsnack and his colleagues (2009) also reported that heavy episodic drinking became less prevalent in older people; though the aging drop is much stronger among women (except for in India and Latin American countries). The frequency

² Many methodological flaws raises questions on past studies exploring this link, in particular important power differences (from 27 to 215 participants), large age ranges, specific samples (e.g. US army veterans) calling for a more narrow focus on a specific population, age and ecological system (young college males between 18 and 30 years old, see Rosenblitt, Soler, Johnson & Quadagno, 2001).

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of heavy episodic drinking among males, on the other hand, was primarily an Anglo-European phenomenon (Wilsnack, Wilsnack, Kristjanson, Vogeltanz-Holm, & Gmel 2009). In the US for instance, binge drinking is more common among 18-34 year-old adults though adults over 65 report binge drinking more often (CDC, 2010). In Europe, 24% of binge drinkers are between 20 and 24 years old and the frequency of risky drinking slows down progressively with age (OFDT, 2011). The type of alcohol consumed can be a good indicator of the reasons for drinking since wine consumption in Europe increases dramatically with age whereas young adults 18-34 years old preferred beers and hard liquor (INPES, 2005).

1.3. Binge Drinking Theories

Different theories in the past decades have shaped the various and different components mentioned above. For now, none of them offer a larger picture of the phenomenon but focus more on one level (e.g. social) or through one pathway (e.g. cortisol functions → emotional regulation → DRSE). Another methodology is to compare those who self-reported binge drinking with non-binge drinkers on different sociodemographic and lifestyle characteristics. This approach, however, is unsatisfying as it only stays at the descriptive level and makes it difficult to draw inferences and thus form a priori hypotheses. In research of binge drinking as well as in other subjects of potential investigation, the constitution of strong psychological science goes through a theory-driven cumulative research process with strong a priori odds and testable hypotheses (Ioannidis, 2005; Fielder, 2017). This section outlines the most prominent theories of binge drinking and states their limitations before presenting our own evolutionary framework.

1.3.1. A cognitive model of binge drinking.

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Oei and Morawska (2004) developed a framework based on alcohol expectancies and drinking-refusal self-efficacy. According to them, alcohol expectancies is a powerful candidate to fill the gap between the myriad of drinking variables and alcohol consumption itself. They view the predisposing factors as interacting with social influences and postulate that young binge drinkers are largely influenced by their beliefs about alcohol. One study for instance showed that adolescents display the same effects of “alcohol” when made to believe that they had drunk after actually being given a placebo (Marlatt & Rohensow, 1980), reinforcing the idea of the strength of expectations in the alcohol abuse use process. According to them, the decision to drink relies, in a particular context, on the capacity to refuse alcohol or not (i.e. exercising self-control) and outcome expectancies in that particular context.

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Authors (year)	Binge drinking definitions	Type of model	Main factors	Conclusion
Oei & Morawska (2004)	Men/Women: 6+/4+ definition: 2 week time-frame	Cognitive	Alcohol Expectancies (AEs) Drinking refusal self-efficacy (DRSE)	The 4 combinations of AEs/DRSE can explain 4 drinking styles (see fig. 2).
Norman, Armitage & Quigley (2007)	5+/3.5+ One-week follow-up	Attitudinal/Social	Ajzen's model (1985) + drinking past behavior as moderator.	TPB explained 58% of the variance in binge drinking intentions.
Johnston & White (2003)	5+ 2 weeks follow-up	Attitudinal/Social	Social Identity/Self-categorization/Inter-group	Classic TPB explains 69% of the variance in behavioral intentions. Groups norms included explained more variance ($\Delta R^2=.01$) as well as group identification ($\Delta R^2=.03$).
Durkin, Wolf & Clark (1999)	5+, cross-sectional	Social Bond theory (Exploratory)	Attachment to parents/Education/Religiosity/Studying/Belief in police-institution/Risky peers/Norm &	Explained almost 22% of the variance in binge drinking frequency.

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			values/Reward-Punishment	
Gibson, Shreck & Miller (2004)	5+, cross-sectional	Self-control theory	Self-control, shame proneness, embarrassment, moral behavior and peer delinquency.	Lower basal self-control engaged more in binge drinking.
Jessop & Wade (2008)	8+/6+ in a single day	Terror Management Theory	Fear, BD mortality salience	Increase binge drinking at 1-week follow-up
Diamond (1992)		Evolutionary	Honest signaling, tolerance to alcohol	Tolerance to alcohol increases reproductive success.
Hill & Chow (2002)	5+ drink/sitting	Evolutionary	Life-history theory	Higher frequency for men, young (18-29 y/o), single, childless, lower income.

Table 1. Summary of Binge Drinking theories.

Oei and Morawska's two-process theory postulates that in the first phase (acquisition) the drinking dynamic is dominated by control processes while in the second phase (maintenance) it is led by unconscious, conditioned processes. In their theory, AEs are important in determining if one should engage in drinking while DRSE act as a regulator for alcohol exposure once the drinking process is already engaged. Thus the relationship between AEs and DRSE would be the best combination to predict drinking types as shown in Fig. 4. For instance, binge drinkers have low AEs (considering that alcohol does not present particular advantages in sex, relaxation, coordination and so on) and high DRSE (they can easily refuse to drink alcohol if they're not willing to). On the other hand, however, social drinkers have both high AEs and DRSE and tend to consume alcohol at every social setting.

As a result, social and non-social binge drinkers present the same level of DRSE but differ importantly on AEs according to the cognitive theory of binge drinking. On the other hand, binge drinkers and alcoholics have the same AEs but alcoholics tend to have much lower DRSE making it difficult for them to resist drinking in different situations (alone, at home, parties, etc.). Oei and Morawska (2004) explained that cumulative research found that AEs (positive, physical, social pleasure and assertion) explained 10-19% of variance among adults and up to 45% in adolescents (25% in longitudinal studies, see Leigh, 1989). According to Oei and Morawska, expectancies are in general better predictors among adolescents because as one gets older, the tendency of drinking emerge. When adolescents become older, the quality of predictors such as AEs decreases as people tend to drink more out of habit (Leigh, 1989).

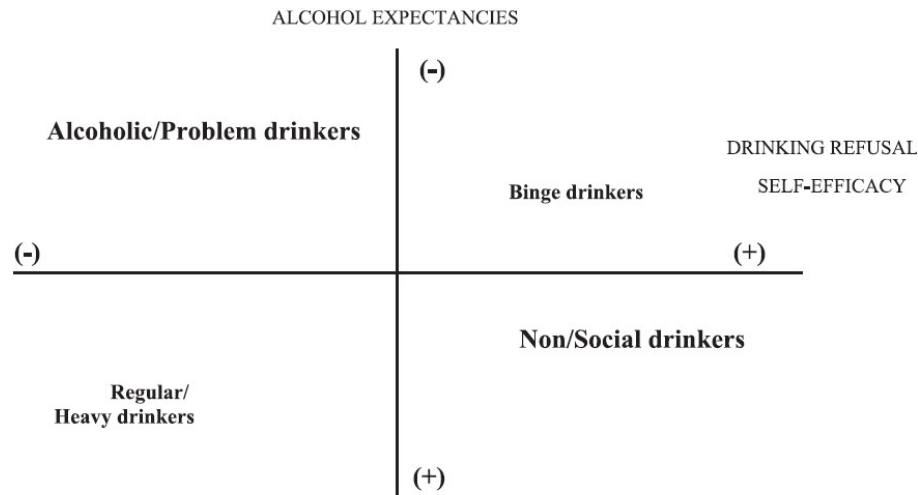


Figure 4. The cognitive model of binge drinking. Reprinted from Oei & Morawska (2004).

1.3.2. The theory of planned behavior

In 1985, Icek Ajzen from the University of Massachusetts, published an article titled “From intentions to actions: A theory of planned behavior” in which he developed an intention-based theory of action (Ajzen, 1985, 1991). According to him, intention to perform a specific behavior is its best predictor and three types of psychological constructs can have an impact on intentions: attitude toward this behavior (influenced by beliefs about it), subjective norms (modulated by normative beliefs) and perceived behavioral control (influenced by control beliefs, see Fig.3). This theory emerged in a context where, according to Ajzen, “general dispositions tend to be poor predictors of behavior in specific situations. General attitudes have been assessed with respect to organizations and institutions (the church, public housing, student government, one’s job or employer), minority groups (Blacks, Jews, Catholics), and particular individuals with whom a person might interact (a Black person, a fellow student). The failure of such general attitudes to predict specific behaviors directed at the target of the attitude has produced calls for abandoning the attitude concept (Ajzen, 1991, p.180).

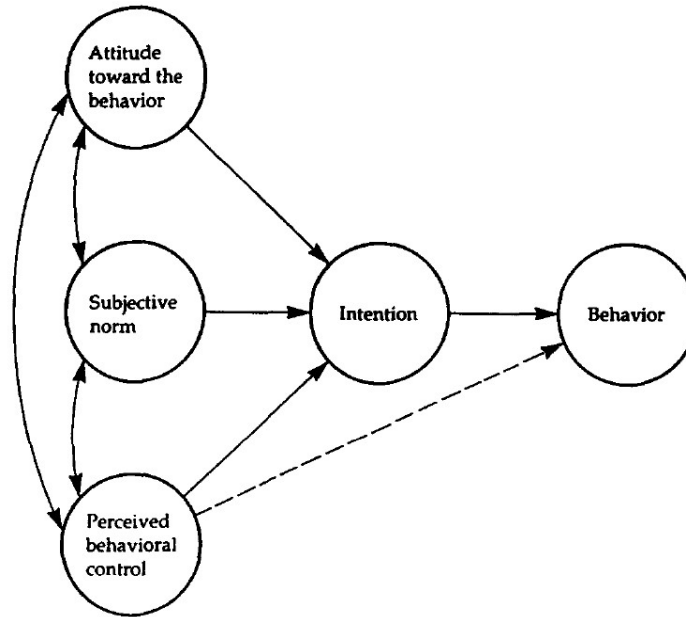


Figure 5. The theory of planned behavior. Reprinted from Ajzen (1991).

In this theory, intention is the central key to understand the acting out since it reflects the true motivation of a person and how hard this person is willing to invest time and energy (as well as sometimes health or others risks) into a specific action. Since it is almost impossible to exactly assert the actual behavioral control one has over a particular situation, Ajzen preferred to focus his theory on the perceived behavioral control, which is supposed to reflect the ease or difficulty for a person to achieve a particular task (this is the difference with Ajzen's previous theory of reasoned action, which did not include this variable; Ajzen & Fishbein, 1980). The second independent determinant of intention is the attitude toward this particular behavior that reflects the evaluation of a person regarding it while the final term is the subjective norm representing the perceived social pressure to or not to perform the particular action. The theory of planned behavior (TPB) has received considerable empirical support and interest and meta-analytical findings indicate that 39% of the variance in intention and 27% of the variance in behavior can be explained by the theory of planned behavior (Armitage & Conner, 2001). Recent meta-

analytical studies using both the TPB and the Theory of Reasoned Action (TRA) in other context (i.e. physical activity), found that both model fit current data very well, with better results for the TPB; self-efficacy and past behavior improving the model significantly (Hagger, Chatzisarantis & Biddle, 2002).

In the context of binge drinking, different studies have investigated how to implement the TPB to predict binge drinking among young students. For example, Norman and Conner (2006) had 273 undergraduate students complete TPB questionnaires related to binge drinking at two different points in time. TPB variables (attitude, subjective norm self-efficacy and perceived control) explained 66% of the total variance in binge drinking intentions and adding these variables in the model resulted in age and gender being fully mediated by TPB variables. They also found that past drinking behavior moderates the impact of TPB constructs on intentions by weakening the attitude-intention relationship as the frequency of past behavior increased. Using a hierarchical logistic regression model, the results showed that TPB variables fully explained the age effect and that intention, self-efficacy and past binge drinking were the only significant predictors in the final model.

Past drinking experiences are not the only variables that have been added recently to the TPB. Johnston and White (2003) proposed conceptualizing the subjective norm variable by taking a social identity/self-categorization theory perspective. One of the weaknesses of subjective norm in Ajzen's theory is that this construct lacks a theoretical background and is too general to apply to specific situations. Social identity theorists (Tajfel & Turner, 1979) proposed focusing on the way we categorize things (through stereotypes for instance) and self-enhancement processes to favor in-group versus out-group in specific relevant dimensions, meaning the perception of the group norm for people who strongly identify with the group

should be a far better predictor compared to the subjective norm of a particular individual. Johnston and White (2003) investigated the effect of such additional features in TPB in a longitudinal study of 289 undergraduate students in Australia. They asked them about their perception of reference group norms for binge drinking (e.g., “Think about your friends and peers at University. How much would they agree that drinking five or more standard alcoholic beverages in a single session in the next two weeks is a good thing to do?”) along with measures of in-group identification (“How much do you feel you identify with your friends and peers at University?” etc.). They found that participants who had more positive attitudes toward binge drinking perceived more pressure from others. Participants who strongly identified with the in-group also perceived that group norms or pressure are more important than those who identified weakly with their reference group.

Numerous TPB variants have been investigated in the last decades, sometimes by deeply modifying the theory, other times by adding specific mediators or moderators to evaluate historical or environmental cues that were missing in the original framework. Most, but not all of them, focus on the weakest part of theory: the perception of social norms, which with regards to meta-analysis (Armitage & Conner 2001) displayed the smallest norm-intention correlation. For instance, Norman, Armitage and Quigley (2007) proposed taking into account the binge drinker’s prototype: the image one has of the typical binge drinker (sociable, fun, aggressive, etc.). Past studies showed that health-risk behaviors among youth are in general displayed in front of others and that people of that age are particularly concerned about their social image (Simmons & Blyth, 1987). In their study, Norman and colleagues (2007) used a definition of a prototype invented by Gibbons, Gerrard and Boney-McCoy (1995, p.85):

“The following questions concern your images of people. What we are interested in here are your ideas about typical members of different groups. For example, we all have ideas about what typical movie stars are like or what the typical grandmother is like. When asked, we could describe one of these images — we might say that the typical movie star is pretty or rich, or that the typical grandmother is sweet and frail. We are not saying that all movie stars or all grandmothers are exactly alike, but rather that many of them share certain characteristics” (Gibbons, Gerrard, & McCoy, 1995 p. 85).

They were then asked to think about who they might consider the typical person to engage in binge drinking and to describe three characteristics that may apply to him or her. They were finally asked to rate their evaluation of this person and how similar they might feel to the characteristics of the typical binge drinker that they had just described. While the general TPB model explained an important part of the variance, the authors found that only the prototype similarity emerged as a significant predictor in predicting binge-drinking intentions; the same pattern to predict binge-drinking behavior emerged in a one-week follow-up.

Norman ran another TPB study that investigated the impact of habit strength on binge drinking (Norman, 2011). Using the self-reported habit index, participants needed to complete a statement starting with “Binge drinking is something...” followed by 12 items such as “I do frequently”, “I do automatically”, “I do without having to consciously remember”, “that makes me feel weird if I do not do it” and so on (Verplanken & Orbell, 2003, p. 1329). While TPB explained 75% of the variance in binge drinking intentions, adding habit strength produced a significant increase in the total variance explained ($\Delta R^2 = .03$). The same pattern emerged in the prediction of binge drinking behavior even though the intention-habit strength interaction failed to reach significance, making it difficult to assess the exact role of the latter in the global model assessed by TPB. They concluded by emphasizing the role of strong contextual cues (such as

student parties, happy hour, etc.) in the emergence and maintenance of habit strengths in binge drinking.

1.3.3. The social bond theory

Sociology has also investigated the binge-drinking phenomenon and social bond theory – among other perspectives derived from that field – offers a perspective on the relationship between the individual and the society. According to this theory, four elements are essential to a social bond: attachment, commitment, involvement, and belief. Durkin Wolfe and Clark (1999) ran an exploratory study of binge drinking among college students to empirically test the social bond theory. They predicted negative relationships between the different components of the social bond theory (attachment to parents, education, religious and general commitments, study involvement and belief in police and institutions) and the frequency of binge drinking. While all the measures correlated to a small to moderate degree with binge drinking frequency, the model as a whole explained only one-quarter of the variance in binge drinking frequency. Durkin, Wolf and Clark (2005) conducted another study this time evaluating the social learning theory (Akers, 1998). According to this sociological theory, any type of deviant behavior, such as risky drinking, is learned, primarily from the peer group. This process involves differential associations (to risky peers along with associated norms and values), differential reinforcement (anticipated rewards and punishments following the behavior consequences) and definitions (attitudes and meanings attached to the particular behavior). In a sample of 1,459 undergraduates from four different colleges and universities, Akers and his colleagues found that all the social learning variables correlated to binge drinking frequency from modest to strong effect ($r = 0.61$, for differential peer association) while the complete model accounted for 46% of the variance in binge drinking.

1.3.4. The self-control theory

One difficulty in evaluating binge drinking's correlates is understanding how the causal pathway is shaped. One could argue, for instance, that by impairing frontal functions, the primary factor affecting self-control would actually be binge drinking, eventually leading to a higher frequency of the latter in the future. Others would say that there are different basic levels of self-control among individuals leading them to start binge drinking for different situational reasons. Gottfredson and Hirschi (1990) stated that, while self-control develops differently in each individual's childhood due to inconsistent parenting styles (e.g. some parents' inability to recognize deviant behavior, or erratic reward/punishments patterns, etc.), "people who lack self-control will tend to be impulsive, insensitive, physical (as opposed to mental), risk-taking, short-sighted, and nonverbal" (1990, p. 90). As a result, they predicted that people lacking self-control will engage not only in criminal activities (which was the main target of their theory), but also in reckless behavior such as drinking, gambling, smoking or other risky behaviors that challenge one's capacity for self-restraint.

Gibson, Shreck and Miller (2004), proposed examining binge drinking among students through the lens of Gottfredson and Hirschi's theory. By improving on a past study that investigated a similar question (Piquero, Gibson & Tibbetts, 2002) they submitted questionnaires to 268 students of a university in the South of the U.S. Binge drinking was measured as a dichotomized variable depending on whether the student consumed five or more drinks per single sitting or not. Using twenty-four items with self-reported scales, they showed that people with low self-control were more likely to engage in binge drinking (although the strongest predictor in their study was the presence of delinquent peers, consistent with other criminological theories). Since the study did not control for past drinking behavior, it is difficult to assess how

much of their participants' history with risky drinking could explain the low self-control threshold. Moreover, distinguishing the effect of constructs such as self-control, impulsivity and sensation-seeking – not done in the present study is not an easy task considering the statistical and conceptual correlations between those concepts. A unified vision of these constructs will be very helpful in identifying the pathway, direction and influences among those psychosocial variables and the frequency of binge drinking among college students.

1.3.5. The terror management theory perspective

In an attempt to reduce behaviors detrimental to health, preventions programs or ads promoting health regularly disseminate fear-inducing messages. A recent meta-analysis revealed that fear does have a small to moderate positive effect on health behavior, being stronger when accompanied by statements about efficacy and high susceptibility and severity, in particular when repeated to a female audience (Tannenbaum et al., 2015). However, no research has previously tested the specific terror management theory on binge drinking behaviors. Jessop and Wade (2008) proposed, in two studies, first exploring if, in fact, exposure to TMT cues do increase mortality salience: in particular, if information related to mortality of binge drinking risks would induce such a mindset. Then in a second study they explored if exposure to this type of information modifies the intention to binge drink in a 1-week follow-up design.

In the first study, ninety-seven students completed a questionnaire with sections about mortality salience, (“please briefly describe the emotions that the thought of your own death arouses in you”, “jot down, as specifically as you can, what you think will happen to you physically as you die and once you are physically dead”), standard controls (e.g. a question about watching television), binge drinking mortality salience (e.g. “Binge drinking significantly increases your risk of getting liver, mouth and esophagus cancer, all of which can be fatal”) and

binge drinking control (e.g. “Binge drinking can make you look foolish in front of the people you care about”) and alcohol control condition (e.g. “Each molecule of alcohol is less than a billionth of a meter long”). This pre-test study confirmed that participants in the binge drinking mortality-aware treatment group showed higher death-thoughts accessibility when compared to the binge drinking control group that had not been asked to reflect on mortality.

In the second study, which undermined the effect of such binge drinking mortality salience exposure on binge drinking intentions, the researchers enrolled 224 UK residents in a two-stage study and exposed them to three of the aforementioned conditions: binge drinking mortality salience, binge drinking control, and alcohol control along with a binge-drinking self-esteem questionnaire. Among binge drinkers, exposure to information related to mortality of binge drinking tended to increase the frequency of suicidal thoughts when compared to binge drinkers in the alcohol control conditions. Self-esteem emerged as a good predictor of drinking intentions among binge drinkers as well as in non-binge drinkers. However, in the latter, there were no significant effects of the condition aside from an interaction with BDSE: in the mortality salience treatment group, higher BDSE predicted greater willingness to binge drink among non-binge drinkers. The second stage responders did not differ between the different conditions and thus the experiment design failed to predict binge drinking at a 1-week follow-up.

1.4. Is there a meaning to risky drinking?

The series of theories mentioned above investigate whether there is a meaning, conscious or unconscious, in adhering to binge drinking activities among young people. Beyond contextual factors such as peer influence or a party-centered life-style, are there also deeper causes explaining such conduct? In a final effort to make some sense of the phenomenon from a sociological point of view, Thomas Workman (2001) elaborated on the fact that college students

can relieve social pressures by the excessive use of alcohol, either through the peer contact it facilitates in drinking situations, or alcohol's physiological effects or value in celebration. It also appears that negative expectations for other low-risks alternatives to binge drinking make young people chose those activities less, despite their being safer (Turrisi, 1999).

Workman (2001) then asked what messages risky drinking do send between students and which ones reinforce binge drinking norms such that they are more efficient than the public health messages typically developed in prevention programs. Workman investigated those questions among 17 fraternities in the United States since fraternities are usually highly normative and coded; with binge drinking one of the multiple coded routines of the group. One of the 'functions' described by the fraternity students was that drunkenness proves one's ability to perform high-risk behavior, to pass a sort of test which gives the actor a sense of accomplishment. Resisting the effect of alcohol to induce unbalanced gestures, trembling, dizziness or vomiting signals to the group the strength of the person and his competitive aspects. Obviously, the audience not only influences a competitive aspect of risky drinking but also an entertaining one which pushes people into making things unpredictable and undertaking actions they would not otherwise. To reach that point, one needs to be drunk and in that sense, Workman questions the validity of the 5/4 criteria as usually implemented (NIAAA, 2004). Indeed, students reported in the study that their objective was only to get drunk, no matter the quantity necessary to arrive at state. In one sense, how much a student resists could be a better indicator of his binge drinking practices and values than his blood alcohol level per se.

Another 'function' of drunkenness emerging from the study was its role in encouraging physical exploration. By getting drunk, students discover their sexuality, physical limits, body functions, and physical evolution. In one sense, they test their capacity to see how much they can

be affected and if they can control the alcohol's effect or not. A typical experience reported was to run naked or, for men, to expose their genitals mainly in front of others as a way to show off and to display cues of masculinity. Of course drinking games can also have more serious consequences such as physical risks ending in multiple injuries. But the fraternity students described those risks as being a sort of game to test their capacity to function under an altered mindset. And the sexual risks inherent in such situations were described by the men in fraternities very differently than by women surveyed in other studies. Although sexual consequences are almost always seen as unpleasant (or worse, as sexual harassment or rape) by women, men tend to focus more on the bad sexual choices they might make when drunk and whether other males will find out (e.g., sleeping with a girl considered as the wrong girl or non-attractive).

In another qualitative study running multiple group interviews, Griffin, Bengry-Howell, Hackley, Mistral, and Szmigin (2009) investigated different classes of young British men. In the UK, there exists a long history of ritualized drinking to excess, in particular among upper-class young men. These drinking activities may serve to bind the group together, as seen in northeast England among white working-class youth (Nayak, 2006). Griffin and colleagues also studied the logic of being drunk and losing control and described students who wanted to get purposely 'wasted'. Among men aged 18 to 25, they observed that extreme practices of alcohol such as mixed drinks, round drinks marked then as more masculine (De Visser & Smith, 2007). In this new culture of intoxication, 'passing out stories' were described as unpleasant by their own members but also as sources of fun and entertainment. These extremes of drinking behavior are sometimes so ritualized (e.g. drinking games) that they become the group norm at the beginning of the gathering party.

1.4.1. The limits of social and cognitive theories

All of the studies and theories mentioned above present clear interests as they try to conceptualize binge drinking through attitudinal, motivational and situational characteristics. However, they do not analyze the different forms of binge drinking and, in particular, the way it is framed as a game among male college students. As mentioned before, solitary binge drinking and collegial binge drinking reflect two very distinct way of communicating. While the former is more relevant through the lens of alcoholism since its main purpose or result is to fulfill alcohol craving, the latter appears to also have an important social component, which may be to express competition, masculinity or entertainment. To understand the deeper meaning of risky drinking, one needs to investigate the underlying reasons for men's behavior and why they so often engage in games while binge drinking. Competition through drinking games might be seen as a way to reproduce social conflicts and power struggles in traditional, pre-modern societies.

In this way, drinking games do not generally involve aggressive behaviors (even though they can certainly end in physical fights later on, mostly due to alcohol's effect on cognition). However, it represents a field where competitors can judge each other's ability to resist alcohol, which may be a proxy for the abilities of the opponent in other disciplines (sports competitions, physical challenges, etc.). The costly signal perspective on binge drinking is a way to frame the binge-drinking problem as an intrasexual competition somehow related to reproductive success.

Situational, attitudinal or motivational factors are difficult to evaluate to a large extent and may be confounded by many others factors but ecology variables such as sex ratio, density, and socio-economic status (SES) vary widely among college campuses, cities or even states. Considering such variables, we can predict that a high male to female ratio, higher SES and higher proportion of students may correspond to risk drinking. Indeed, a higher proportion of

males implies a higher male intrasexual competition and may encourage more drinking games. To that extent, life-history theory proposes a general evolutionary framework and costly signal theory can target precise risky behaviors and how they could vary in specific experimental contexts.

1.5. The evolutionary roots of binge drinking

It may look difficult at first glance to make sense of all of those theoretical models and qualitative feedbacks on binge drinking. However, the evolutionary framework, offering not only distal explanation but also experimental hypothesis, can help to make sense of the different pathways mentioned above (figure 2). One particular theory, the costly signal theory (Diamond, 1992; Zahavi, 1975; Zahavi & Zahavi, 1999) can help reconcile those different perspectives. As a theory of signaling, Zahavi's theory essentially pertains to the cost of the signal being sent and how costly signals are necessarily honest (although honest signaling is not necessarily costly, particularly as genetic proximity increases; see McElreath & Boyd, 2007). This theory helps to explain something that troubled Darwin, who, while observing that certain males had sexually competitive advantages over other males, could not properly explain why females sometimes preferred other males (Darwin, 1874). Essentially, sexual selection can occur through two different channels: intersexual selection (how to select partners of the opposite gender, given a variety of candidates and potential criteria) and intrasexual competition (i.e. male-male competition to gain access to females).

Contrary to other risks where the cost can be difficult to evaluate at first glance (sexual risks, risky-driving, etc.), the alcohol cost, and in particular associated with binge drinking, is proximal as it can induce cognitive, erectile and cardiac dysfunctions in a relatively short-term window. Thus, attitudinal and motivational behaviors do not explain how health prevention

messages based on that data do not interfere and how specific situational factors can trigger and maintain risky drinking behaviors.

1.5.1. The honest signal theory

However, these patterns can make sense from the perspective of the honest signaling theory. From that point of view, most of the information surrounding us consists of signals produced either by human or non-human signalers and can be sent through many channels (calls, patterns, colors, etc.). Those signals are generally meaningful, otherwise the receiver would have evolved to ignore them (or, at least, to not be particularly attracted to them). It may be very useful in sexual selection for females to accurately recognize males of quality and for males to acquire more or better mates, assuming that the advertising allows both genders to achieve these objectives. Thus, the handicap imposed by such contests can serve as a proxy for the genetic quality of a male and the more challenging the contest, the more information the female receives about the genetic quality of the male. Of course, a male with the best genotype and without a handicap would be even fitter but he may not be able to advertise his quality and thus the contest may be the best way for females to naively verify the quality of the male. Such a test of genetic quality is also a way to exclude bluffers who might want to appear genetically fit but are actually underperforming (figure 5).

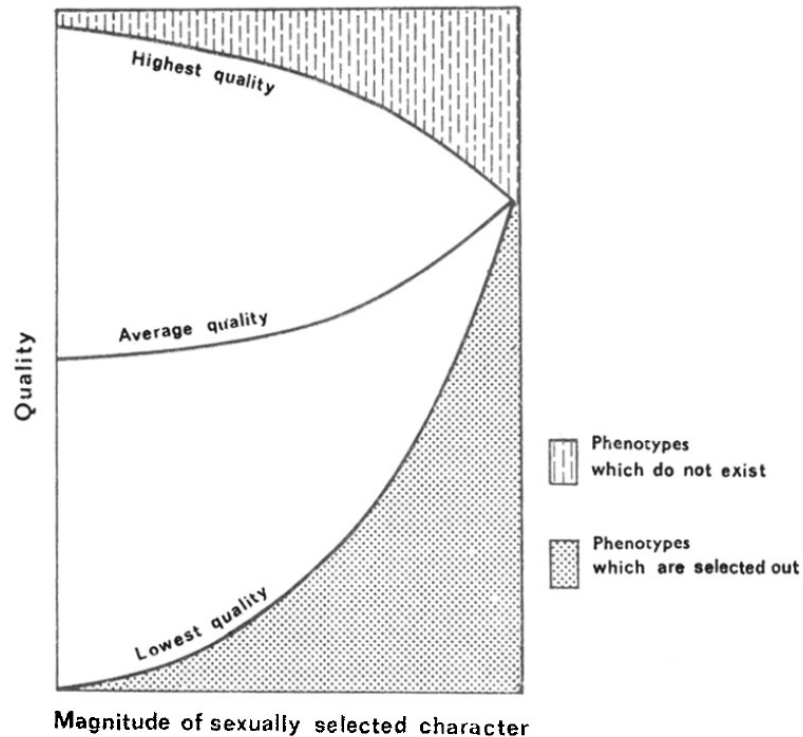


Figure 5. The effects of mate preference on the evolution of a sexually attractive character. Reprinted from Zahavi (1975).

However, one difficulty of this theory is in weighing the influence of intimidating and excluding potential rivals from the sexual competitions before they even begin. According to Zahavi (1975), the effect of mate preference is generally greater as a result of intrasexual conflicts. One possibility not considered in this line of argument, however, is that ornaments that would impress male could serve as a mediator for mate selection; in that sense, once the male has pushed away or fought off other male competitors (even though, as stated above, actual, intra-species physical aggression is rare in the animal world; most conflicts being resolved without direct violence), it remains true that more females are available to the male with the most visible characteristics.

Zahavi (1975) also brought up the apparent contradiction that in many species of birds, the female's appearance and behavior are more cryptic while the male is more colorful but that there are just as many species where both sexes are cryptic. The colorful male may be easier to distinguish for females and this explains why monomorphic species of experience a slower sexual bonding than dimorphic species (Lein, 1973). However, there might also be socioecological factors that explain those between-species differences. Dale and colleagues (2015) examined over 6,000 species of passerine birds to determine the different evolutionary forces at play in the different colorations between species and sexes: body size, tropical life history, sexual selection, cooperative breeding and migration were the main explicating variables. Birds are an interesting species to compare to humans because both species adhere to polygamous mating systems (or, at least in humans, that was the case during the Pleistocene when most of our current cognitive modules are thought to have been selected). And in both species, sexual selection is probably not the only force at play since male ornaments in birds are also used to compete for non-sexual resources (e.g., food territories). This leads to the concept of social selection (figure 6), which includes both sexual and non-sexual selections (Dale, Dey, Delhey, Kempenaers & Valcu, 2015; Lyon & Montgomerie, 2012; West-Eberhard, 1983).

1.5.2. Animal Literature

In Dale's study (2015), for instance, they found that variations in male and female coloration in birds are strongly correlated so that variation in one sex is conditioned by variations in the other sex. Larger species and tropical life history (birds breeding in the tropic and inhabiting areas with year-long environmental stability) were correlated with both sexes being more ornamented. In cooperative breeders, where female-female competition is higher (for

reproductive or non-reproductive resources), there is increased ornamentation in females (but not in males). Additionally, strong sexual selection on males produced an increase in male coloration

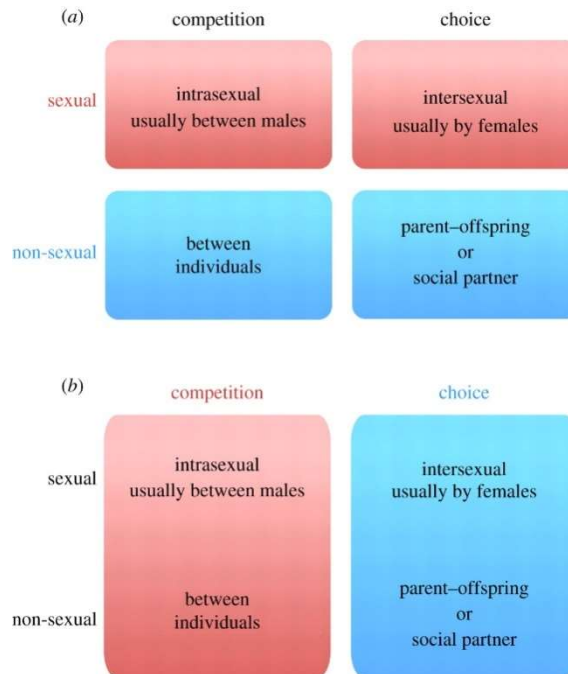


Figure 6. Social selection process. (a) As formulated by West-Eberhard [1–3], social selection influences the evolution of ornaments and weapons via choice and competition, respectively, in both sexual and non-sexual contexts. Sexual selection is considered by West-Eberhard to be the subset of social selection where fitness derives from mating and fertilization. (b) Recent empirical research has suggested that there is often no clear boundary between sexual and non-sexual components of social selection while, in contrast, the mechanisms underlying choice and competition may be fundamentally different. Reprinted from Lyon & Montgomerie (2012).

but a reduction in female coloration. Body size was also an important predictor since in larger species, both sexes were more colorful and less dichromatic which is logical given that a large body size decreases predation risk and weakens selection pressures to appear undetectable (“crypsis” in ecological term).

Other species display exaggerated characteristics that are detrimental to the carrier. The peacock, for instance, is famous for its long and colorful tail. Several studies have investigated

the link between the tail's size, the number and density of the ocelli and reproductive success. There is still debate as to whether the male peacock in its natural habitat effectively possesses an advantage by carrying denser ocelli (i.e. whether it attracts more females). It is thought that females selecting peacocks with larger ocelli choose males who can maintain and produce a high level of energy. Since only a true signaler could maintain this display, it is considered a marker of quality by the female. More recently, Loyau, Saint Jalme and Sorci (2005) investigated inter- and intrasexual selection for different traits in the peacock (*Pavo cristatus*). Indeed, we generally consider traits as influencing only a portion of sexual selection but if we distinguish those concepts theoretically, it is possible that different features send signals to different sexes (multiple signaling would be stable because of multiple receivers). The number of eyespots in the male peacock's tail, for instance, seems to be intended to meet the criteria of the female peacock while the tail's length may signal to other males.

Loyau and her colleagues identified three types of males in their experiment: those defending territories and mating with females on them, free ones without site attachment trying to mate on grounds of other males and finally those that never engaged in mating displays. They found that males defending their territories tended to possess longer tarsus as well as stronger and longer trains (controlling for ocelli did not vary effect). However, the only significant predictor of female visits regarding mating success was the number of ocelli such that the most ornamented male received the highest number of visits by females, regardless of how long or strong his train was. Males with shorter trains were actually more successful with females than those with long trains, since ocelli density and train length were inversely correlated. However defending a territory is one of the strongest determinants of mating success and also results in the accumulation of resources. Previous findings had already shown that peacocks with longer and

heavier trains were more likely to defend a territory and reproduce on it; territorial peacocks can use their trains to threaten floating peacocks without having to physically fight them (Møller & Petrie, 2002). Thus, despite the high cost of maintaining such features, peacocks able to afford to do so and send honest signals to their potential competitors in order to restrict access to their territory. In this study then, it seems that two forces of sexual selection, competition between males and female mating criteria, may explain different features in the male peacocks.

1.5.3. Honest Signaling as an Evolutionary Stable Strategy

Zahavi was not the first to state that signals are likely to be honest when they are costly to produce. Thorstein Veblen argued in the *Theory of the Leisure Class* (1899) that expensive items signal wealth precisely because one cannot fake them. Alan Grafen then published two major papers demonstrating that honest signals do exist and effectively depend on how costly they are to produce (Grafen, 1990a, 1990c). Grafen applied his model to mating choice sexual selection but also explained at the end that his formalism applied to other types of signaling as well, such as competition between males. Grafen distinguished three main factors contributing to costly signaling: the true quality q (the male cannot lie about his quality), his level of advertising a , and the perceived value p . In that sense, all males need to advertise more but only those with higher quality will be chosen by females who rely on the advertisement as a trustworthy information source about quality. The reduced fitness of the signaler is compensated for by how females interpret the signal.

While Zahavi's main focus was mate selection, Grafen proposed discussing how the evolutionary stable strategy (ESS) model could apply to intrasexual competition among males as well. Imagine that a male red deer dominates a harem of females and that other males, without harems, begin to challenge him for succession. By roaring, the harem master can try to indicate

it's stronger than the others and thus prevent a fight. In this case, q represent the master's ability to fight, a its roaring level and p the perception of the challenger's strength. Grafen explained that his model predicted a graded response of roaring with the most energetic challenger roaring at a higher level to indicate his strength to the haram master. Another famous example Grafen considered, which was also considered in Zahavi (1975), is the antelope herd fleeing a lion. Here, it is the height of the jump (a) that the antelope can produce which is an indicator of his true athletic capacity (q) and the lion is the one intended to correctly interpret those signals (p). The antelope must produce a jump that is impressive enough to convince the lion he will lose time by chasing her. By expending its energy and strength with the jump, the antelope may nevertheless save itself a long and exhausting race with the lion.

Similarly, the binge drinker finds himself in a situation like that faced by the red deer or the antelope herd. In a college party surrounded by potential mates, many different signals are being sent and there are not many opportunities to demonstrate genetic quality (except from physical appearance). Binge drinking can be a signal (a) that demonstrates true physical and genetic ability such as toxicity resistance (q) and potential mates and other competitors may interpret those signals as honest (p) since in drinking games, rules reduce cheating (although intoxication may interfere with the participant's capacity to correctly verify that rules are correctly applied, which may be compensated by intoxication also disturbing the cheater's potential strategy). However, in drinking games, it seems difficult for one to cheat or pretend he resists more than others since they are set up so that the competitors are each other's judges, ensuring that everyone is correctly drinking what they are supposed to do so (in general, drinking games are turn-based such that you cannot lose sight of who is supposed to drink what at moment t).

1.5.4. A Competitive Theory: the Life-History Theory

Zahavi's theory is not the only evolutionary framework that has been proposed to explain risky drinking. Hill and Chow (2002), for instance, asserted that risky drinking is related to life-history variations through gender, life-history stages (age, puberty, relationship status) and environmental variables (resources, mortality rates). The variability in male mating success is high with some men being highly successful (i.e. obtaining multiple partners) while others cannot mate at all. This high variability in outcomes leads men to engaged more in risky choices when there is strong competition for status and resources, given potentially higher pay-offs or greater losses. Men between the ages of 15 and 29 are known to be particularly at risk for fatal motorcycle accidents for instance (Hill & Chow, 2002) and this corresponds to a period where the young man leaves his parent's home, begins to study and work and needs to take risks to acquire resources eventually leading to mating success. Later, once the male has attained a successful mating status (such as mate retention and the assumption of parental duties), he should no longer feel compelled to engage in high risk situations.

Hill and Chow (2012) examined demographic variations to investigate if their predictions based on life-history strategies matched the reality of the drinking pattern. Consistent with their predictions, they found that men 18 to 29 years old were the most vulnerable group to risky drinking, and that being single and childless were two strong predictors of doing so. While they could not determine the role of education in risky drinking, they found that lower income ecology was more favorable to intoxication risks than a higher income family background, which new data tends to contradict as we saw earlier (Gallup, 2010). Life-history theory also assumed that risky drinking should not necessarily be viewed as deviant or pathological behavior if one considers that such behavior is consistent with expectations of optimality during human

evolutionary history. However, such life-history theory perspective does not inherently contradict a costly signal one at a more proximate level and, on the contrary, a Zahavian analysis can help to incorporate more precise experimental predictions whereas LHT might be a better model to fit drinking dynamic at the population level.

We can also investigate the history of alcohol use and excess use through the lens of paleogenetics which resurrects ancestral proteins to explore evolutionary history. Robert Dudley (2014) postulated in his book *The Drunken Monkey* that human ancestors gained evolutionary benefits by associating the taste and smell of ethanol with ripe fruits. Carrigan and colleagues (2015) tested that hypothesis by comparing modern and ancestral alcohol dehydrogenases ADH4 (the enzymes that break down ethanol and protect us against its adverse effects) across a wide range of primates. They found that the last common ancestor of humans and orangutans was able to metabolize dietary geraniol alcohol but not ethanol. Interestingly, the ethanol-active ADH4 emerged around the middle Miocene climatic transition (MMCT, ~16Ma) when massive extinctions along with more fragmented forests and grassland ecosystems promoted a more terrestrial diet (ripe fruits) and locomotion.

Dudley does not weigh in on whether chronic alcohol and binge drinking may have emerged at that moment, which would then constitute a single and unified behavior. He noticed though that binge drinking does not convey any health benefits as opposed to the small beneficial cardiovascular benefit associated with small quantities of daily alcohol consumption. He acknowledges that while binge eating might have been selectively advantageous in gaining more calories and accumulating resources over a period of time, animals rarely have the opportunity to practice binge drinking because of the low concentration of alcohol in gut-filling fruit pulp (which slows down alcohol exposure and digestion). However, the theory is not incompatible

with a later selective pressure to elicit specific binge-drinking patterns related to competition between males, which was geared towards reproductive success and resource accumulation, unlike chronic alcoholism which might have emerged from a mismatch due to our natural sensitivity to ethanol.

Borsari (2004) reviews the different types of drinking games and which skills they required: motor skills, verbal skills, gambling games (requiring probability calculation or courage in the face of randomness), media games (requiring recollection of facts), team-based games (requiring collaboration skills), and consumption games (requiring endurance to continue consuming). Even though they target different capacities, all of those games commonly test one's tolerance to the effects of alcohol. In the "Quarter game", for instance, players are asked to bounce a quarter into a shot glass and failure to do so obligates the participants to drink alcohol. Verbal games may require repeating increasingly complex phrases until one fails and has to drink alcohol. "Gambling games" randomly assigned the quantity of alcohol one must drink by dice. "Beer pong," which tests motor skills in a cooperative context, commonly represent team-based games. Numerous websites detail rules and provide the necessary equipment. Finally, consumption games such as the "100 Minute Club" require drinking until the body can no longer retain anymore alcohol (usually because a player begins vomiting or passes out). In that particular game, one is required to drink a shot of beer every minute for 100 minutes.

The reasons for playing games are various and Borsari (2004) tried to summarize the main ones. Interviewing students offers us qualitative insights into the motivations of youth to engage in such risky drinking. Self-intoxication is one of the main reasons that men engage in drinking games and it is a way for them to test their physical and physiological boundaries as they invoke masculine norms and the pride of being able to "hold their liquor" (Green & Grider,

1990). Second, as in the gambling game, players are allowed to assign drinks to test each other. Doing so allows the possibility of purposely intoxicating a competitor. Drinks can be assigned as punishment for not respecting a particular rule, because a player has a reputation of being resistant (and thus, needs to be tested), or when other players want to evaluate a newly-arrived player's tolerance to the effects of alcohol. The game sometimes involves dramatic outcomes where men force women to drink in order to try to intoxicate them and facilitate sexual activity, which is a common technique among rapists (Abbey 2002). Meeting new people is also a regularly reported reason for participating in drinking games. Men can bond as the game continues and the atmosphere relaxes and instills into them a sense of “teamwork” or “camaraderie” with the experience offering them stories to share outside of the party context. Finally, another important factor we have already mentioned is the sense of competition involving winners, losers and spectators. In fraternities, students reported that dominating other players in drinking games can be a way to impress women and display masculinity to the rest of the group (West, 2001).

As we can see, the socioecological context of the drinking games involves a set of controls that can eliminate cheating and make the signals reliable to receivers. Not only is one watched over by their peers to verify that they are truly drinking but some games have official rules and equipment that make it unlikely to gain access to extra material that would improve their results in the game. Though you can increase your tolerance to alcohol, studies have shown that we reach our threshold relatively quickly and, in that sense, one can hardly progress beyond their fundamental physiological capabilities. We are born with a certain number of enzymes to digest alcohol that varies quite little over the course of one's life, making it difficult to meaningfully train or increase tolerance. In that sense, resistance to alcohol can be seen as a

marker of true genetic quality with regards to the capacity to digest toxic products and to resist the painful effects of alcohol. The physiological effects of binge drinking are very different from that of slow consumption or even chronic drinking (figure 1). Indeed, acute alcohol consumption impairs prefrontal functioning such as that required in planning, attention, or set-shifting, in addition to releasing dopamine into the ventral striatum, which modulates reward expectations by overemphasizing immediate reward over delayed outcomes (Heinz et al., 2011). Impulsivity is also largely connected to that pathway and it is thus possible that regular binge drinking affects dopamine regulation in such a way that modifies impulsive behavior in the long-term.

1.6. Summary of predictions

The evolutionary framework can help elucidate the puzzling aspects of binge drinking. Despite a widespread knowledge of the dangers of alcohol, why do humans keep drinking and, in particular, why do young men abuse alcohol so regularly? Why are the gender differences so persistent across cultures and around the globe? Why are college campuses such critical places for the practice of binge drinking? Why does binge drinking always express itself through drinking games, gambling, motor skill tests, competition or simply extreme consumption? Are signals sent during these events to target women, other men, or both? Are they multiples signals or a unified one? These questions, as we have seen, can lead to interesting and relevant answers through the theory of costly signaling (Zahavi, 1975). Other theories capture only one level of explanation, be it social, socio-cognitive or perhaps genetic. The costly signal theory within a large life-history framework can explain several inter-level pathways and help generate testable, experimental hypotheses.

1.6.1. Alcohol tolerance as a cue to potential mates.

One way to indicate genetic quality is to carry features that are costly to produce and maintain. As such, tolerating the effects of alcohol would indicate both a high level of aldehyde dehydrogenase (ALDH), the enzyme that breaks down ethanol molecules, and/or a strong capacity to manage pain and cognitive disturbance, which would have been vital qualities in the ancestral environment when our primate ancestors looked for ripe and fermenting fruit (indicating a second quality of accumulating resources). Bigger individuals also have greater chances of digesting and resisting the effects of alcohol and larger stature was generally a crucial advantage over others males in the Pleistocene for progressing in the hierarchy and monopolizing the available mates.

As a result, resisting alcohol might be associated with greater reproductive success for the resistant man. For that to be true, the signal the resistant man sends to the potential female mate must be interpreted as indicative of the signaler's genetic quality. Alcoholism would not be seen as attractive to potential mates as it generally displays strong signs of dependence, social inadequacy, social isolation, and aggressiveness, among other symptoms. The 5/4 ratio may not be suited for experimental manipulation of perceptions. It would be better to work with a ratio of tolerance to alcohol's effects on a scale compared to the number of drinks consumed.

An ideal ecological framework would require observing highly alcohol-tolerant men to evaluate their reproductive success in a specific mating situation. However, such an evaluation would be almost impossible to ethically and accurately carry out. First, the field experiment may not generate any relevant data, as it is almost impossible to correctly control a person's actions under the influence of alcohol. Second, alcohol tolerance and its variability effects are so important that a cross-sectional study would make it difficult to evaluate the long-term reproductive influence of tolerance to alcohol's effects. Field studies on peacocks generally

follow the animal over the course of several months, making it possible to definitively conclude that being spotted influences reproductive outcome – no such long term conclusions could be reached from observing humans at a party, even though the events of the party are presumed to predict long-term outcomes. Finally, the cost/benefit ratio of an experiment of this type would be necessarily high while the “cause size” (Abelson, 1995) would be quite low, due to a noisy small effect size and important variations between the modalities.

With such experimental constraints, a better way of testing the reproductive success hypothesis would be to ask women to evaluate different profiles of alcohol-tolerant men and to see if their evaluations vary according to the resistance of the signalers. As we stated before, the resistance to the effects of alcohol would matter more than the number of drinks (although a minimum amount of alcohol consumed would be necessary to accurately send a signal on high tolerance to alcohol). The main symptoms of acute alcohol consumption are, from weakest to strongest: unbalanced posture, speech/articulation impairments, shaking, vomiting, fainting, and ethylic coma. A more general way of describing it can be “dizziness” or just general “feeling bad” if the effects are not tolerated.

On the other hand, the measure of attractiveness also could be evaluated through different pathways: self-reported, physiological or behavioral. Self-reported would be simply to ask women how attractive they rate the man’s profile on a 7-point Likert Scale or a same-sex mind reading in mating situation such as “How likely is it that John will have sex with Mary tonight?” with John being the alcohol-tolerant man, i.e. the signaler, and Mary the potential mate, the receiver. Additional measures of attractiveness can correlate with such measures. For instance, physiological components such as pupil dilation, heartbeat and sudation have all been associated with enhanced stimulation in mating or sexual situations. One may also consider attractiveness a

potential mediator to reproductive success. As a result, it might be interesting to measure both direct and indirect evaluations of an alcohol-tolerant target (a direct one of a target by female participants or a mating situation involving a man and woman) along with general and specific reproductive success perceptions.

A corollary to such predictions must be that the signaler (the tolerant man) is sensitive to the audience looking at him at the moment of the action. As such, we can predict that the presence of attractive women in drinking games or drinking events would increase the men's consumption in order to prove to potential mates their tolerance to the effects of alcohol and thus indirectly their genetic quality. In addition, it is plausible that the ratio of men to women would interact with the women's attractiveness to modulate men's alcohol consumption. A high ratio of men to women would indicate a strong competition between males and few potential mates available, increasing the strength of the signaling that men need to send to their opposite-sex counterparts.

Drinking alcohol could also indicate social status. In many instances, marketing uses the idea of tolerance to the effects of alcohol as a way to display resources (e.g. advertising often depicts wealthy men consuming large volumes of alcohol without appearing intoxicated). Indeed, the price of alcohol can vary dramatically and certain famous wines or whiskies can reach tens of thousands of dollars per bottle. Investing such an amount into a drink, an element that will be used in few minutes or hours, is a costly signal that only rich individuals can afford and, as a matter of fact, also a predominantly male tendency. As social status generally enhances reproductive success, one could also expect it to work that way among binge drinkers. In fact we predict that not only will displaying expensive products generally enhance attractiveness and perceptions of reproductive success, but that a relation between tolerance to the effects of alcohol

and social status might also emerge such that, among tolerant men, the one displaying resources will be seen as even more attractive and sexually successful than the equally tolerant man drinking alcohol of lesser value. In that sense, tolerance is a prerequisite to attractiveness and reproductive success so that men who cannot tolerate alcohol's effects will not see such an edge whether they display resources or not.

It goes without saying that the general framework implies a short-term mating context. Women's mating criteria in a short-term context have been shown to be very specific when compared to long-term ones: facial symmetry, masculinity, physical strength. While displaying resources can be a considerable advantage in long-term mating game, it is useful in the short-term only if the male also possesses the genetic quality required to enhance the woman's own fitness. Short-term context can take many different forms but bars and social parties (such as the ones we evaluated in a fraternity setting) are typically where men report observing the greatest numbers of potential short-term mates. We prefer to use the general ecology of the short-term context rather than trying to induce a long-term mating mindset since this priming has recently been the center of criticism and replication difficulties (Hu, 2014). So long as there is not a stable way to induce short-term mating mindset (if there is one), we would only use a general frame of mating presumed to reflect features that we would find in a short-term meeting (either one-to-one bar interaction, or multiple mates and male competitors in an open-space party).

1.6.2. Alcohol tolerance as a threat signal to same-sex rival

As discussed above, testing one's resistance to alcohol might not be a signal sent only to potential mates but also to same-sex rivals. We have described how the animal world is full of confrontational interactions that do not lead to actual fights: some threatening signals are sufficiently strong to prevent any form of direct fight or aggression. In fact in general such

harmless contact is the rule rather than the exception and drinking games can be seen as a way to reproduce physical tension in human interactions without any violent component. Hone and colleagues (2013) found, for instance, that low levels of sexual restriction and high levels of social competitiveness were positively correlated with the motivation to participate in drinking games. Drinking games can be seen as a venue for sexual competitions where males test each other's tolerance to alcohol's effects in order to evaluate their level of competitiveness and resistance. The low level of female participation in such games indicates, among other things, that the game itself is not a direct mating strategy but rather a way for men to eliminate potential competitors along the way.

We thus predict that men who are more tolerant to alcohol's effects would be seen as more sexually successful and competitive than men who cannot tolerate them. Again, evaluating the "tolerance" or "resistance" to the effect of alcohol could be described precisely (whether they displayed unbalanced motor movements or shaky hand gestures, vomited, etc.) or more generally (whether subjects reported feeling generally well or poorly). We predict that the best way to evaluate this would be in a drinking competition context where all the features of competitiveness can emerge. Intrasexual competitions can be tested through a number of proxies but we believe that one does not need to directly do so for outcomes of fighting but rather for competition between males in its common, modern-day manifestations, such as sports competitions, arm-wrestling or other contests frequently attempted during or after drinking games. Tolerant men would be seen as being more fit to be competitive in these other categories compared to non-tolerant ones. Another crucial point is to compare drinking alcohol in these situations to some other drinks that could serve as control group (since water is not a comparable item). We propose, for example, energy drinks (Red Bull, Monster, etc.) as good candidates

since males consume them more frequently and they produce dangerous effects if over-consumed (Azagba, Langille & Asbridge, 2014) and are also generally associated with sport-related identity, masculinity and risk-taking (Miller, 2008).

Several moderators could impact the relation between alcohol tolerance and the intensity of competition between males. Playing a drinking game with or without potential mates watching must be a strong enhancer of intrasexual competition among men (which may also depend on the girl's attractiveness levels too). Women's fertility might also interact with men's willingness to drink alcohol. A study by Tan and Goldman (2015) showed that men who smelled a t-shirt worn by a fertile woman consumed more alcohol than those who smelled one of a non-fertile woman. Attractiveness might not be the only feature influencing male competitiveness and having fertile women watching a drinking game should also increase male competition in a drinking game.

1.6.3. Agent-based modeling of binge drinking

The proposed framework, based on the application of Zahavian's principles to a human context, not only makes precise statements for local and experimental designs. In addition to these predictions, we can also forecast dynamics through agent-based modeling. To our knowledge, only one study involved the evaluation of the agent-based dynamic specifically including binge-drinking behaviors (Gorman, Mezic, Mezic & Gruenewald, 2006). In that model, agents interact based on simple behavioral rules dependent on their environment. This model allows variations that are impossible to reproduce through analytic or experimental methods. In keeping with the spirit of agent-based modeling, we believe binge drinking patterns emerged from local dynamic interactions that then depict macro-level social processes. For ethical and practical reasons, it is difficult or impossible to control and manipulate relevant

variables such as genetics, peer pressure, history of alcoholism, or to directly test the impact of binge drinking tolerance on reproductive success.

We speculate that it is possible to go beyond Gorman and colleagues' work (2006) by specifying the deep nature of the social influence of binge drinking. Based on the literature, we only propose 2 types of agents: nonbinge drinker ($<5/4$ drinks) and binge drinker ($\geq 5/4$ drinks, in the past 2 weeks, based on Courtney & Polich, 2009; LaBrie, Pedersen, & Tawalbeh, 2007). The main reason for doing so and excluding the classical recover agent (as seen in epidemiological model of alcoholism or diseases, Otto & Day, 2007) is we do not consider binge drinking a mental or mood disorder. Instead, because the majority of binge drinkers are not alcoholics (CDC, 2016), there is no such stage as "recovery" and until their mid- 30s, individuals can largely enter and leave binge drinking state. The erratic dynamic between those two stages must be distinguished from the specific binge drinking frequency and intensity. As noted above, the binge drinking rates and frequency are largely influenced by socio-situational factors (peer influence, family history) whereas drinking intensity may be more sensitive to dispositional factors (personality traits, ADHD2, sex).

Location can also be a strong determinant of binge drinking rates. It is well known that college campuses and particularly fraternity parties are, compared to off-campus bars, a strong geographical predictor of binge drinking, through drinking games in particular. Fraternity parties also nest other factors that are essential to a costly signal model such as the sex ratio, level of competition between males, and of course amount of alcohol available. In contrast to Gorman and colleagues' work (2006), we believe that young drinkers will anticipate the amount of alcohol necessary to fill their drinking purpose. And unlike drinkers moving around town in search of open bars or liquor stores, students hosting a party at their own house generally plan

their “pre-games” in advance by accounting for the number of people coming, tolerance of the different participants, timeline of the party, and number of drinking games to be played (besides whether they will go out afterwards to a nightclub or stay at the fraternity until the end of the evening. For reasons of simplicity, we will assume they stay in).

The level of competition could be computed according to the type and number of drinking games proposed to participants. As we have seen before, some drinking games involve more consumption than others (notably gambling and consumption games) and some parties encourage more frequent drinking games than others (certain fraternities are well known for public displays of drunkenness through a variety of risky games). The frequency and intensity of drinking games might interact with the audience present such that a high male-to-female ratio, indicating a large number of men when compared to women, will imply a stronger male intrasexual competition and thus a stronger propensity to binge drink.

Based on data already collected at a micro-level (online, laboratory and field experiments) along with population-based data (CDC, BRFSS), agent-based modeling would allow us to simulate dynamics that are ethically or simply experimentally impossible to reproduce. Such methods can help drastically improve the understanding of binge drinking dynamics in the context of college campuses along with the main predictors of excessive alcohol use. As in any model, the assumptions are purposely broad in order to provide a general picture of binge drinking patterns but can help to generate more precise, local and testable hypotheses that can lead to further research on the impact of prevention messages.

1.6.4. A costly signal perspective on prevention actions

A wide variety of prevention programs toward risky drinking have been put in place in North America and Western Europe, among other places. They offer different results and two

major issues remain. First, the programs generally lack theoretical coherence as they do not adhere to one single unifying theory or sometimes simply test pragmatic assumptions rather than a hypothesis-based theory. By doing so, they might miss important variables that can be determinant in the initiation and maintenance of binge drinking (as we went through in the different level factors, see, Figure 2). Biological components, such as gender, specific genetic factors modifying both serotonin and dopamine responses to alcohol, as well as tolerance to the effect of alcohol can all have a strong influence on binge drinking rates among young individuals. Some cognitive components linked to intrasexual competitiveness, impulsivity and risk-seeking sensation are important predictors of risky drinking too. From a social standpoint, peer pressure, family history of alcoholism and a party-centered life-style also need to be incorporated in order to identify the high-risk drinkers in the school class.

However the main issue with prevention programs is the consistent failure to measure their own effectiveness. In France, for instance, very few programs actually follow through with a long-term plan to evaluate if they have an effect and how strong and robust it is (Babor, 2010; WHO, 2006). Not only would such evaluation make it possible to calculate the cost-benefit ratio of investing in preventive education programs, it might also help to improve the theory and to implement hypothesis-testing and evidence-based prevention programs more automatically. By doing so, we can also increase transparency and generate open science around prevention programs so that other countries or health authorities could replicate their findings and eventually develop robust education tools.

With the costly signal theory, there is a different way of implementing the evolutionary framework to test the effect on consumption of or attitudes towards alcohol. First, if we localize the binge drinker in a broader life-history framework, the data available indicates that the onset

of binge drinking is around age 15 for at-risk drinkers and age 16 for regular drinkers (Courtney & Polich, 2009). This is a few years after the onset of puberty when sexual competition starts and primary sexual activities are observed. Costly signal theory would predict that men must be particularly sensitive to sexual signals at that time since reproductive success is a strong cue of high intrasexual competition. The question remains how such signals would be perceived in light of the risks that come with alcohol consumption.

In general, prevention programs (see INPES for instance) do not distinguish between the different types of signals they send, which include a large mix of long-term and short-term signaling invoking sexual risks, driving under the influence of alcohol, possible sexually coercive situations and so on. We propose that different risks send different signals in specific stages of one's life-history. In particular, at the early onset of sexual competition, we formulate the idea that negative sexual signals (such as how dysfunctional alcohol can render male reproductive functions) can impact male attitudes toward alcohol to a larger degree than general risk signaling (the danger of drunk driving), other proximal risks (cognitive impairments), or long-term medical conditions (aero-digestive cancers, cardiovascular complications). This hypothesis is also consistent with a behavioral economics perspective predicting that adolescents are attracted to ambiguous risks and that, compared to adults, young participants actually take smaller risks when their odds are clear (Tymula et al., 2012). Such an economic perspective offers insight into the way signals should be crafted and on what timeline they apply. Not only do we need to clearly state the type of signals sent through prevention messages (i.e. what risks), and to which group(s) (young/old, men/women, high vs. low SES) but also how certain the risks are for the target (with a closer temporal risk being viewed as more certain than a distal one).

Chapter 2: An Original Method for Testing the Function of Binge Drinking: Dating Website, Eye tracking and Hormonal Data.

While binge drinking had been widely investigated from both social (Durkin, Wolfe & Clark, 1999; Johnston & White, 2003) and cognitive psychological perspectives (Oei & Morawska, 2004; Morawska & Oei, 2005), few theoretical approaches actually explored its possible role in our evolutionary history (see, however, Hill & Chow [2002] for Life-History outlook and Dudley [2014] for a paleogenetic analysis). This is quite surprising as gender differences in risk-taking has robust findings (Byrnes, Miller & Schafer, 1999) and males are particularly engaged in drinking games (Hone, Carter, & McCullough, 2013; Marsh & Kibby, 1992) which might lead to sexual selection hypothesis. To understand this behavioral gap between males and females, the costly signal theory (Zahavi, 1975; Zahavi & Zahavi, 1999) informed us that high-quality males can send signals at a lower cost than low-quality males because the marginal cost is compensated by higher reproductive and competitive fitness among the formers (Getty, 2006; Grafen, 1990). Transposed into a human paradigm, experimental hypothesis can be inferred on the greater attractiveness, social dominance and competitiveness of men who tolerate alcohol against those with less tolerance.

Social cognitive theories (Ajzen, 1991) largely focused on the intentions and norms of the drinker and put both the attitudes and the norms as central to the appearance and maintenance of risky drinking (Johnston & White, 2003). While they have been successful at explaining the proximal effects that motivate drinkers, they do not explain why humans, and in particular youth males as compared to females, engage in binge drinking in the first place, knowing all the dramatic health and social consequences at play. Also, the focus on intentional factors somehow overshadows dispositional factors over situational ones (though later variants aimed at

integrating individual traits such as self-control, see Gibson, Shreck & Miller, 2004). One pro of evolutionary framework is that it can implement experiments to test which factors influence drinking amounts during occasions (such as peer influences, see Gardner & Steinberg, 2005) in a coherent theory that include predisposed variables. This is another important feature because implementing other moderators to the TPB theory, for instance, will not help us to understand either the deeper roots of binge drinking and why we should implement one variable over another.

Binge drinking had been ultimately the concern of several civil and health organizations since its practice is on the rise in western societies (CDC, 2016; OFDT, 2016; WHO, 2016). Contrary to chronic alcohol and tobacco consumption, binge drinking has seen its scale enlarged considerably in the last couple of decades in particular among 18-25 years old (OFDT, 2015). Among the myriad of particularity related to this phenomenon, the social aspects of binge drinking is particularly prominent in drinking games where rules organize the course of actions and can take the form of skills, chance or extreme consumption games (for the analysis and categorization of 100 types of drinking games, see LaBrie, Ehret & Hummer, 2013). However, the type of signals sent by such conducts is not a resolved issue, leaving it unclear if the primary target of binge drinking are other males (intrasexual competition) or potential mates (reproductive success).

The present study proposes to explore that lead through one laboratory and two online studies. The first study analyzed women's physiological and self-reported responses when facing masculine profiles differentially tolerant to alcohol's effects on a dating website created for the experiment. The second one used the same type of methodology to evaluate if there were differences when women rate men taking different type of risks (physical, economical or health

risks). The last study focused exclusively on male participants to investigate if specific tolerant-alcohol signals (compared to other type of risks) may not be directed primarily to other same-sex competitors through social dominance and competitiveness proxies.

2.1. Costly Signal

Zahavian's theory defends that the animal world is essentially a world of signaling (Zahavi, 1975; Zahavi & Zahavi, 1999). From deer putting their antlers in front of their rivals to intimidate them, to a babbler calling from further on eagles or peacock displaying its plumage before mating, numerous signals seem costly to maintain and dangerous for its owner (Maynard-Smith & Harper, 2004). The main question here is: to whom is the signal being sent? For instance, peacock tail's ocelli color and iridescence were positively correlated with copulation (Loyau et al., 2007) explaining half of the variation in reproductive success (Dakin & Montgomerie, 2013). Moreover, experimentally masking ocelli make copulation almost entirely declined (Dakin & Montgomerie, 2013). On the other hand, those features are also in play during intra-sexual competition such as rival's gaze patterns resemble patterns of mates's evaluation, in particular for upper eyespots (Yorzinski, Patricelli, Bykau & Platt, 2017). As a result, and according to Zahavi and then Grafen (Grafen, 1990; Zahavi, 1975), peacock's features could serve as dual function for intra- and intersexual selection.

Binge drinking is one of those risk-taking attributes that fit many Grafen-Zahavian expectations specifically because it displays the true genetic quality of its owner publicly (as one cannot fake tolerating alcohol) through mating or drinking games environments and is being received naively by signalers. First, historically beverages that had been consumed publically sometimes by lead clan chief (Diamond, 1992) indicated some sort of male-male competitive signals. Secondly, it fits the EES's criteria since it is largely a substance over which you cannot

cheat about your resistance and so whichever message sends is obviously taken naively. The other characteristics of binge drinking is that young people happen to practice it publicly, during social gathering and drinking games which may constitute the intrasexual competition proxy. Moreover, the majority of binge drinkers are not alcoholics (CDC, 2016) and thus this phenomenon should be distinguished from a classical analysis of addiction.

Various critics had emerged about the so-called “handicap principle” in particular about its specific relation with costly signaling (Higham, 2014). The central idea that Grafen added was that a signal would be honest only if it is marginally costlier for a low-quality signalers to give a high-quality signals when compared to high-quality signalers (Getty, 2006). The high-quality signalers should get net benefit from sending such signals to avoid the low-quality signalers from cheating. Számadó (2011) proposed different criteria that would make potential costs as honest signaling. Punishing cheaters is a cost imposed to an individual giving a fake signal and should be considered, according to some (Higham, 2014; Frazer, 2012; Maynard Smith and Harper 2003; Számadó, 2011) as part of the costly signaling. While in drinking games, some rules are actually imposed to cheaters (LaBrie, Ehret & Hummer, 2013), the same apply to dating situation when a man not being able to hold liquors or simply wine might be considered as socially marginal or physically unfit by the potential mate (Aronson et al., 2007).

Another proposition made by Higham (2014) is to consider potential costs as indices: signals that cannot be physically fake. Those “fixed signals” include features link to animal body (e.g., size) or external characteristics that cannot be modify. Among humans, the rate of alcohol dehydrogenases (ADH), the enzymes helping to chemically break down ethanol to make it less toxic, are largely genetically inherited and can be considered as fixed signals even though they

do not are visible and pass through proxies such as physiological reactions (vomiting, sweating, shaking, etc.).

However, one fundamental part of costly signaling is, as mentioned, the direct benefit of emitting such signals. Among humans, it can take the form of reproductive success advantages and/or male-male competition dominance giving access to larger resources or territories. Our first experiment proposes, through an online dating website created for the experiment, to answer this interrogation: how much alcohol tolerance can be a signal of high-genetic quality attracting potential mates? To our knowledge, no study had investigated how men tolerating the effect of alcohol would be evaluated by other women in term of attractiveness. We aimed at creating both an ecological context (through the original dating website) and non-invasive objective measures of the target's attractiveness (pupil dilation size). We also wanted to see if the preference for the alcohol tolerant man was being moderated by the fertility level of female participants (hormonal test, see "The ovulatory shift" section).

2.1.1. Pupil dilation as a cue to attractiveness

In the past decades, studies had shown that men and women differed on the type of sexual stimuli displayed. While men are particularly attracted by the erotic aspects of the stimulus, women are more sensitive by social and situational aspects (Rieger & Savin-Williams, 2012). Men may have evolved to be sensitive to cues that are constant across time points while women would have adapted to spot male's flexibility to environmental changes (Baumeister, 2000). Those gender differences make the use of eye tracking measures particularly relevant in our women study where the environmental cues (images and in-text) are determinant for the participant's response. Moreover, assessing sexual excitation through genital arousal have been debated since numerous participants reported being reluctant to such protocol (Chivers, Rieger,

Latty & Bailey, 2004) or report restraining/controlling their genital response during the experiment affecting the quality of the measure (Golde, Strassberg & Turner, 2000).

We proposed here to measure men's attractiveness by varying their level of alcohol tolerance, asking women how attractive they think the male is (through a "hot or not" type website) and also by measuring their visual attention and pupil dilation. Vincke and Vincke (2017), for instance, showed that both young men and women pay particular attention to alcohol stimuli. Not only did participants capture drinking signals sooner than other non-signaling functional behavior, but drinking behaviors were on average fixated more often and in a longer period of time than other stimuli. As Rieger and Savin-Williams (2012) showed within heterosexual females, pupils were less dilated when facing the more arousing sex (men) compared to neutral stimuli. Since this pattern has not yet been replicated, we propose here to analyze how self-report attractiveness evaluations were correlated with pupil dilation and fixation time among women and if tolerant men were evaluated more attractive through those measures when compared to moderate and low tolerant alcohol men.

2.1.2. The ovulatory shift

One recent evolutionary hypothesis that has been made regarding mating criteria is the existence of an ovulatory shift (Gildersleeve, Haselton & Fales, 2014; Thornhill & Gangestad, 2008). Women around ovulation – or, to a larger extent, in high fertility days – would be displaying different type of criteria for short-term mating than when they are in other phases of their cycle. For instance, Gildersleeve, Haselton and Fales (2014) show that for short-term mates, women were more willing to favor genetic quality at high-fertility days when compared to fertility days. The hormonal dramatic changes during the high-fertility period have been though by researchers, for decades, to have impact in both non-human and human animals (Pfaff &

Joels, 2016). Tolerating alcohol has been described by male participants as a way to show their masculinity and try to attract female attention (Marsh & Kibby, 1992).

Different way of measuring ovulation peak had been made through the past decades, either relying on counting methods (asking the last or next day of menstruation in addition to the length of the cycle) resulting to numerous imprecisions in estimating ovulation (Wilcox, Dunson & Baird, 2000). One objective physiological measures of the imminence of ovulation is the luteinizing hormone rise that starts to have a pulsatile dynamic 24-48 hours before ovulation and are accurate at 97% (Guermendi et al., 2001).

2.2. Current Study

To test this hypothesis, we build an original dating website aiming at displaying a high-quality ecological context to describe different men profiles tolerating more or less alcohol effects. Our objective in that first study was to show that female participants would evaluate the high tolerant man as more attractive than the moderate and low tolerant men (smaller pupil dilation and longer fixation time). In a laboratory experiment involving self-report measures (on the website), physiological data (pupil dilation, fixation time) and hormonal assessment (LH measurement to determine ovulation), we also predicted that women around ovulation would rate the tolerant man as more attractive compared to women in their low-fertility days.

2.2.1. Study 1

This first study aimed at testing how men's signals of alcohol tolerance would lead women to judge the more tolerant men as more attractive than low tolerant men. Being able to drink more than other men in a social context might indicate ancestral genetic quality that would give those men advantages in short-term mating (environment we intended to simulate with our dating website). We proposed that the high tolerant condition will be rated as more attractive

than the moderate and low tolerant conditions. Additionally, we also postulated that women around ovulation would judge alcohol tolerant men as particularly attractive when compared to women in low-fertility days.

2.2.1.1. Method.

2.2.1.2. Participants.

In total, 48 women from France were recruited through the University of Grenoble Alps (May 2014). After applying exclusion criteria (participants admitting using hormonal contraceptive at the time of the study, being pregnant, eye tracking measures errors, none-heterosexual participants), we ended up with 33 female participants. The mean age of the sample was 20.21 ($SD = 2.26$). Participants were more likely to be single ($n = 19$) than in relationship ($n = 14$). A demographic information that we did not expect (considering college campuses are generally known to be more liberal than the average population), was the frequency of believers in our sample with 66.67% admitting being either Christians or Muslims³.

2.2.1.3. Procedure.

Participants entered the social psychology laboratory at the University of Grenoble Alps and were introduced to the study by an experimenter. The experimenter explained to them (figure 1) that they were entering a marketing study testing a new dating website application and that several male students from the University accepted to be part of the experiment. They were explained that the application was sponsored by “Beer in Black. Online, Premium Beer” (logo at

³ This could interfere with our results since alcohol is explicitly prohibited in Islam (whether participants follow this rule or not, this may have impacted their normative expectations about people drinking alcohol). In general, religiosity negatively impact alcohol expectancies and motivation toward drinking considerably reducing alcohol consumption (Galen & Rogers, 2004). In a massive field study on 140 campuses, Wechsler, Dowdall, Davenport and Castillo (1995) also found that students describing religion as “not at all important” had a much higher likelihood of binge drinking than others ($OR = 3.57$). Though we did not measure directly religiosity in our sample, Christians usually report lower levels of drinking than non-religious individuals with Protestants having higher levels of perceived drinking controls than Catholics (Patock-Peckham, Hutchinson, Cheong & Nagoshi, 1998).

upper left corner on figure 7), company supposed to promote friendly drink. They were told that they would see 13 men's profiles and they will have to rate them as "hot" (6) or "not" (0, 0.1 metric scale) for a short-term relationship. We explained on the first page that participants would be able to chat with the ones they rated the highest.

In parallel and to enhance the quality of the application, we explained that we used an eye-tracker material to explore which part of the website catch the most participants' attention. Pupil's diameter inferior to .25mm and superior to .10mm were excluded from the analysis. Pupils located at less than 40cm and more than 100cm from the Tobii T60 were excluded from the analysis (Weigle et al., 2008). On average, pupil's distance from the eye tracker must be located within ~65cm and the gaze angle should not exceed ~42° (EyeLink Data Viewer User's Manual, 2008; data were analyzed through EyeLink Data Viewer). Pupil's size is measured by the number of pixels of the camera occulted by the pupil and may vary according to subject or camera's position. In order to propose a standardized measure of pupil dilation, we calculated a pupil dilation ratio: the maximum pupil size recorded during the last 17,500ms of the current stimulus (presenting during 20,000ms in total) divided by the maximal pupil size recorded during the 2,500ms of the next stimulus (Otero, 2011).

After a second page (all the other figures are reported in Appendix A) displaying few demographic questions (age, sex, country, relation status, sexual orientation, French-speaking level) women faced, in a within-subject-Latin-squared design, the 13 different profiles of students from the University of Grenoble Alps who accepted to participate in the study. Their profiles was presented in the three following conditions: highly tolerant ("During parties, I drink much more than my friends,"), moderately tolerant ("During parties, I drink as much as my friends,") or low tolerant to alcohol ("During parties, I drink much less than my friends,") and

rated them on a 7-points Likert scale. Several control pages were included to check that the participants memorize the information presented throughout the course of the entire session (“How much does the person in the profile you’ve just seen drink?”).

At the end of the study, participants faced another demographic questionnaire (that could have biased the results if they were presented before) including religiosity, annual salary, study goal, jobs, pregnancy and contraceptive questions. Finally, a short debrief page included the general goal of the study with menstruation questions was added (date of the last menstruation, cycle length). Participants were then given the Clearblue ovulation test and a pre-printed envelope they could use at home the same day and return the sample presently the next day or depositing through mail box.



Figure 7. The introductory webpage of Study 1.

2.2.1.4. Measures.

We used three main dependent variables in Study 1. First, the 7-points self-report Likert Scale where women had to describe how attractive they evaluated the target (from 0 = *Hot* to 6 = *Not*, on a “Hot or Not” scale). In parallel, we added eye tracking measures which consisted in two type of data: 1) fixation time: number of milliseconds when the participants was looking either at the beer or at the information about the tolerance to alcohol; 2) the pupil dilation ratio which was the maximal pupil size of the last 17,500ms of the target stimulus divided by the maximal pupil size recorded during the 2,500ms of the next stimulus.

While the self-report measure did not correlate neither with fixation ($r = -0.08, p = .64$) nor with dilatation measures ($r = 0.08, p = .64$), the fixation time and the dilation ratio correlated moderately but significantly ($r = -0.41, p = .02$), which make sense from a pure physiological standpoint (the longer people were facing one profile, the less their pupils were dilated, see figure 8 below⁴).

The 13 male profiles were taken at the Campus of the University of Grenoble Alps, with standardized background and procedure (4000x3000 pixels, same neutral face and position, luminosity was being checked afterwards). Thirty-two women students, between 18 and 35 years old who described themselves as heterosexual, pre-tested the material on 3 measures: attractiveness ($M = 4.21, SD = .41$), masculinity ($M = 4.42, SD = .29$, both measures on 7-points Likert scale from 1 = “*Not attractive at all*” to 7 = “*Very attractive*” and 1 = “*Not masculine at all*” to 7 = “*Very masculine*”, respectively) and apparent age of the target ($M = 28.68, SD = 2.34$). Those results indicated that our stimuli were being evaluated as relatively young and only slightly attractive.

⁴ The normal pupil size for adults in the dark (our laboratory condition) varies between 4 to 8 mm (Spector, 1990). As can be seen in figure 8, after only a second, the pupil dilation rapidly dropped to half its value. The only participant with extreme pupil dilation ratio (> 10 mm) is not technically an outlier according to our standards ($SDR = 3.89$, see footnote below).

2.2.1.5. Results.

2.2.1.6. Attractiveness.

When computed a score difference between the high, the moderate and the low tolerance profile, using a specific set of contrasts based on our hypothesis (2,-1,-1;1,0,-1) we did not find any significant difference. That is to say, the highly alcohol tolerance profile were not judged more attractive ($M = 3.71$, $SD = 0.89$), when compared to the low tolerant ones ($M = 3.50$, $SD = 1.18$), $t(32) = 0.89$, $g = 0.15$, $SE = .17$, $95\% CI [-0.18; .49]$, $p = .38$.⁵ Similarly, when comparing the high tolerant profile to the moderate alcohol tolerant profile ($M = 3.68$, $SD = .95$), we did not find significant difference, $t(32) = 0.21$, $g = 0.035$, $SE = .17$, $[-0.30; 0.37]$, $p = .84$.

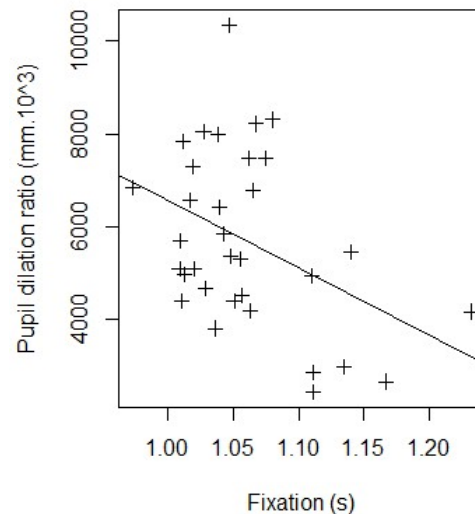


Figure 8. Graphic of the correlation between pupil dilation ratio (in millimeters) and fixation time (in seconds).

2.2.1.7. Fixation time.

⁵ We checked in every analysis for potential statistical outliers following the studentized deleted residual technics indicating that a level greater than 4 is consider as outliers (see McClelland, 2014). When no additional information were added, this meant the results remained the same with or without outliers.

While women effectively spend more time on the alcohol cues of the highly tolerant profiles than the low tolerant profiles, this difference was far from reaching significance, $t(32) = 1.09$, $g = 0.19$, $SE = .17$, $[-0.15; 0.52]$, $p = .28$. However, women did tend to spend more time on the alcohol cues when evaluating the high tolerant profiles compared to the moderate ones ($M = 5.52$, $SD = 1.99$) though this difference was only marginally significant, $t(32) = 1.84$, $g = 0.31$, $SE = 0.17$, $[-0.03; 0.65]$, $p = .07$.

2.2.1.8. Pupil dilation ratio.

The pupil dilation ratio showed that women's pupil diameter (in mm) was bigger when facing the low tolerant profiles ($M = 1.07$, $SD = 0.83$) when compared to the highly tolerant men ($M = 1.05$, $SD = 0.06$) which partially confirmed our hypothesis (but again this difference was only marginally significant, $t(32) = 1.83$, $g = 0.31$, $SE = 0.17$, $[-0.65; 0.03]$, $p = .08$). However, the pupil's diameter of women facing the high alcohol tolerant profiles were not significantly different than when they were exposed to the moderate ones ($M = 1.06$, $SD = 0.05$), $t(30) = 1.18$, $g = -0.21$, $SE = .18$, $[-0.55; 0.14]$, $p = .25$.

2.2.1.9. Ovulatory shift.

Contrary to our expectations, we did not find any interaction between the different types of profiles measures (self-reported attractiveness, fixation time and pupil dilation ratio) and the fertility status indicating by our hormonal data (LH urinary peak). Neither the within-subject comparisons between the high vs. low tolerant alcohol men nor the high vs. moderate profiles displayed significant findings (all p 's $> .1$). In our small sample, only 6 women came out positive on the Clearblue test, indicating ovulation, whereas the remaining 27 of them were not ovulating at the time of the study (81.82%). Such a costly mixed-subject design would require a much more balanced number of women in high- and low-fertility to produce any interpretable findings.

2.2.1.10. Discussion

We intended to create an original dating context to test our hypothesis about costly signaling of alcohol tolerance and reproductive success. Through an entire new dating website developed for the experiment, we exposed participants to 17 different men profiles describing different tolerance to alcohol (drinking much more, as much, or much less beer than their friends during parties). We measured the attractiveness of the target by asking women directly to self-report how “hot” they think the man was as well as following their fixation time and pupil dilation ratio through an Eye tracker Tobii-T60. From a pure methodological standpoint, the material in place (both the Eye tracker and the website) appeared to be functional because we could display a moderate correlation between fixation time and pupil dilation ratio. The longer participants faced the profile, the smaller their pupil’s diameters.

However, we were unable to find any strong evidence for our main hypothesis. The explicit self-report measure of attractiveness was far from being significant ($p > .1$) even though, descriptively, the results tend to go to the predicted direction. Regarding the physiological measures though, marginal effects emerged. Women tended to spend more time on the highly tolerant profiles compared to the moderately tolerant profiles but this difference was only marginally significant and the effect size was null to moderate. Quite surprisingly, there was no difference in the pupil dilation ratio for that comparisons despite the difference in fixation time. One possible explanation is that the difference was too small to make any physiological difference on the pupil’s dilation. The other marginal findings concerned this ratio where women’s pupil dilation ratio was smaller when watching a moderately tolerant men compared to the low tolerant men. Since we did not find differences in self-report evaluations, it is difficult to

interpret those findings. They can result either from false positive or from tensions between participant's norms about alcohol and their physiological reactions.

2.2.1.11. Limitations

Though original and innovative, our study presented several limitations. First, the final sample size was so small ($N = 33$) that even in a within-subject design, it is difficult to draw any strong statistical inference with such low power and small effect sizes. Additionally, our interaction with ovulation was unbalanced between participants and make the absence of evidence hardly a proof of anything. A sociodemographic aspect that we did not expect in a college campus (usually more liberal than the city itself), was the presence of a high percentage of Christian and Muslims women (more than two-third of the total sample). Knowing the aversion of religious prescriptions against alcohol consumption, this could be another explanation of the absence of effects (Galen & Rogers, 2004).

When we control for the luminance of the stimuli and the luminosity of the room, pupil dilation can respond to other factors such as cognitive load produce by all the information and the retrieve of memory ask during the control questions (Goldinger & Papesh, 2012). Creating specific zones of interests (beer picture and information about tolerance to alcohol) and applying a delay pupil dilation ratio permitted to avoid such technical difficulties but we cannot affirm that the cognitive load did not play any role in the emerging marginal effects on pupil dilation. In parallel, a longer fixation time, usually an indicator of more sexual interests (Rieger & Savin-Williams, 2012), might indicate completely different things depending on the context. Religious participants might actually be more choiced by men admitting drinking much more than their companions and this could provoke a longer time facing the webpage.

Moreover, our study suffered a major theoretical flaw. An alternative explanation of the absence of effects might come from the subtleties of the modalities that make hard for participants to discriminate. In particular, a social comparisons such as alcohol tolerance variability might make little sense for them if not compared to other broader type of risk-taking (especially if they are not binge drinker). To test if effectively alcohol tolerance is particularly salient for reproductive success among risk-takers, a substitute study should compare alcohol tolerance to other types of risk-taking (gambling, physical risk-taking) and evaluate if the risky drinker is effectively being rated as more attractive than the other types of risk-taking.

2.2.2. Study 2

This second study investigated how binge drinking would be evaluated when compared to other broad type of risk taking (gambling, physical risks). Being able to drink more than other men in a social context might indicate ancestral genetic quality that would have gave those men advantages in short-term mating context. We proposed that the risky drinking profiles would be evaluated by women as more attractive than the other risk profiles. Additionally, we also postulated that women around ovulation would judge the binge drinker as particularly attractive when compared to women in low-fertility days.

Human beings would socially compare alcohol-tolerant men, not only to their level of tolerance (which is subtle to evaluate) but also to other type of risk-taking. Recent studies suggested that ancestral risks (hunting, playing with fire) were judged both by men and women as more attractive than modern risks (e.g., gambling). While binge drinking as a social phenomenon is a recent activities, consuming and resisting alcohol had been documented since at least the Maya civilization by archeologists (Diamond, 1992).

We could then test if one type of risk-taking (i.e. binge drinking) is seen as more attractive than other type of risk-taking that are modern and does not necessary reflect the genetic quality of the target: for instance we can gamble for a short period of time without being necessary wealthy; you can partially hide your physiological reaction to a bungee jumping but you cannot control on the long-term the effect of acute alcohol consumption on your body). In the following studies, we tested through a male and female profiles, how those signals could affect attractiveness judgement (for a short-term relationship), social dominance as well as competitiveness. We predicted that the man tolerating alcohol will be evaluated as more attractive, more dominant and more competitive for a short-term relationship when compared to men engaging in other risky activities.

2.2.2.1. Method.

We used the same website that we coded for Study 1 but with only 2 profiles to evaluate: one man and one woman (see figure 9 below; pictures extracted from the Chicago Face Database and being controlled for many factors including age, attractiveness, age, and luminosity among others, Ma, Correll, & Wittenbrink, 2015). Participant had to randomly judge the two faces: while the male profile displayed one of the 3 risks (e.g. binge drinking), the female profiles thus showed one of the two remaining (e.g. bungee jumping or gambling) and vice-versa.

2.2.2.2. Participants

We recruited 197 female participants through the online Amazon Mechanical Turk website (May 2015). After applying criteria for inclusion (heterosexual, native-English speaker) and exclusion (study goals discovered, more than 2 errors in the 4 control question pages, being pregnant or using hormonal contraceptive), we ended up with 103 women ($M = 34.26$, $SD = 11.63$). Only 27.18% of our sample admitted being in an official relationship (much less than our

first study) and 18.45% of them admitted being atheist (against 53.40% admitted being Christians). In term of alcohol consumption, 51.46% declared drinking alcohol at least on a monthly basis (36.89% declared drinking daily or weekly).



Figure 9. Pictures used for Study 2 and 3. Retrieved from the Chicago Face Database.

Measures.

The main dependent variables in Study 2 were short-term attractiveness of the male profile (“How attractive do you think this man/woman is?” on a 1-7 Likert scale from 1 “*Not attractive at all*” to 7 “*Very attractive*”) as well as competitiveness (1 = “*Not competitive at all*” to 7 “*Very competitive*”) and social dominance (1 = “*Not dominant at all*” to 7 = “*Very dominant*”) for both female and male profiles.

2.2.2.3. Results.

Short and long-term attractiveness for the male profile.

We applied a specific set of contrasts to test our hypothesis comparing alcohol risks to the other risks and the control group on short-term attractiveness (3, -1, -1, -1; 1, -1, 0, 0; 1, 1, -1,

-1; see Brauer & McClelland, 2005; Judd, McClelland, & Ryan, 2008). When we compared the short-term attractiveness rating for the male profiles, we did not find any significant difference when the male profiles was compared on binge drinking tolerance ($M = 3.38, SD = 1.93, n = 22$) versus physical ($M = 3.78, SD = 1.38, n = 24$), economic risks ($M = 3.56, SD = 1.87, n = 33$) and the control group ($M = 4.04, SD = 1.04, n = 23$), $t(99) = 0.55, p = .59, R^2 = .01$. Likewise, the data did not revealed any significant difference when we compared the alcohol male profile male to the other risky behaviors profiles on the long-term attractiveness scale, $t(99) = 0.34, p = .74, R^2 = .04$.

Interaction Ovulation X Types of risks for the male profile.

When we ran an interaction to see if the fertility could interact positively with the binge drinking risk on the rating of the tolerant profile, we did not find that women in high-fertility evaluated the risky drinking profile as more attractive for a short-term relationship ($M = 3.48, SD = 1.99, n = 5$) when compared to participants in their low-fertility days ($M = 3.46, SD = 1.58, n = 11$) and to the other profiles, $t(77) = 0.85, p = .40, R^2 = .04$.

Dominance impression for the male profile.

Applying the same sets of contrasts, analyzing the dominance impression made by the male profile on our female participants did not reveal that the tolerant man was being evaluated as more dominant ($M = 3.57, SD = 1.29, n = 22$) when compared to the physical risky profile ($M = 3.77, SD = 1.17, n = 24$), the economic profile ($M = 3.22, SD = 1.28, n = 33$) or the control one ($M = 3.43, SD = 1.29, n = 23$), $t(98) = 1.43, p = .16, R^2 = .02$.

Dominance impression for the female profile.

When female participants evaluated the dominance appearance of the woman profile, they did not rate the alcohol-tolerant woman as more dominant ($M = 4.35$, $SD = 1.11$, $n = 15$) when compared to the physical ($M = 3.67$, $SD = 1.31$, $n = 38$), the economic ($M = 3.59$, $SD = 1.48$, $n = 22$) or the control ones ($M = 3.55$, $SD = 1.61$, $n = 27$), $t(98) = 1.26$, $p = .21$, $R^2 = .03$.

Competitiveness for the female profile.

Finally, no effect emerged when comparing the competitiveness of the different female profiles. Indeed, the binge drinker female was not rated as being more competitive ($M = 4.01$, $SD = 2.01$, $n = 15$) when compared to the physical ($M = 4.44$, $SD = 1.26$, $n = 38$), economic ($M = 4.45$, $SD = 1.16$, $n = 22$) or control ones ($M = 4.07$, $SD = 1.22$, $n = 27$), $t(98) = 0.48$, $p = .63$, $R^2 = .01$.

2.2.3. Discussion

This second study aimed at investigate if comparing binge drinking tolerance to other types of risk taking would lead women to judge the former as more attractive, competitive and dominant than the later. By presenting a pre-tested (Chicago Face Database) male and female faces (between-balanced) in our original dating website platform, we intended to distinguish effect that would specifically be attributed to evaluate a male profile (short vs. long-term attractiveness interacting with high vs. low fertility days of the participants, dominance) as well as same-sex judgement on a female profile (dominance and competitiveness).

All things considered, the results did not reveal the results we expected. Male profiles were not judged as more attractive when tolerating alcohol for short-term attractiveness neither they were rated as less appealing for a long-term engagement. The interaction with fertility did not emerge but with our very low statistical power in that particular analysis, it is difficult to

make any robust inference. Similarly, the female profile were not judged by women participants as any different on measures such as dominance and competitiveness.

This study suffers flaws on different levels. First, while displaying a much better power than the first study, the different profile and gender displayed make the repartition per group smaller than expected. More importantly, as Zahavi (1975) and Grafen (1990) mentioned before, the multiple signaling hypothesis is totally plausible and such binge drinking strength signals could be sent to other men to promote male-male competition. We decided to extend our website material to a male audience with a larger number of participants and with the goal of finding intra-sexual competition effects that would emerge to display genetic quality and impress other males (eventually leading to greater reproductive success with females).

2.2.4. Study 3

One question that interests biologists, economists and psychologists working on signaling theory is trying to capture not only where the signal comes from, but to whom is directed and what is the exact nature of the message being sent. Maynard Smith and Harper (2003) defined 'signal' as "any act or structure which alters the behavior of other organisms, which evolved because of that effect, and which is effective because the receiver's response has also evolved" (Maynard Smith & Harper, 2003, p. 3). The same authors distinguish cues that did not evolved *because* of its effect on the receiver. For instance, a spider vibrating a web during a fight against another spider gives information about its potential size and so is a signal while the size itself may not be a signal because a spider could win by attaching a weight to its back (following Maynard Smith and Harper's example, 2003).

Among human signaling, physical strength can be seen through different practices from kung-fu masters drinking raw petrol (Diamond, 1992) to Maya ritual enema with alcohol (Kerr, 1989). Differentiate signals that attracts mates to those that intimidate rivals is an ambitious task as those signals may regularly overlap across space and time (Fisher, 1930; Zahavi, 1975). Actually, many sexual signals put at risk their performers and weighting how the impact of the signal is split between sexual selection and male-male competition targets is difficult to demonstrate in the real world.

However, animal literature is filled with signaling that are address to competitors or potential predators. Aposematic signaling, for instance, that protects prey or defies rivals can be seen in a varieties of species including insects (e.g. bees), reptiles (e.g. coral snake) or even among frogs, fishes or mammals (e.g. skunks). Recent studies suggested that this signal could “quantitatively” indicate the level of toxicity the signaler is able to manage (Blount, Speed, Ruxton & Stephen, 2009). As Zahavi and Zahavi (1975) pointed out:

“Still another way to issue a threat is to show the degree of harm one is willing to suffer in order to win. When ants use formic acid and bees use chemicals in their fighting, they create an environment hostile to both signaler and rival. It makes sense that one able and willing to endure the noxious chemicals displays in a reliable way its ability and commitment to the fight.”

Zahavi & Zahavi, 1975, p. 22

When one is binge drinking, a variety of symptoms emerged progressively that indicated the level of dehydrogenize enzymes oxidizing ethanol to acetaldehyde among animals and humans causing headaches and vomiting, along with numerous cognitive short or mid-term impairments (aldehyde dehydrogenases, or ALDH, not only removes toxic from the body but also serve in cell differentiation, proliferation and oxidation, see van den Hoogen et al., 2010). In

consequence, ALDH's levels itself is not a signal but the process in which its effect are display or not is (drinking the same quantity but not being affected by the alcohol for instance).

The fact that binge drinking is most commonly emerging through drinking games (LaBrie, Ehret, & Hummer, 2013) prone for another type of signaling: indicating other males how genetically fit they are and how they could easily endure suffering (resulting from other activities such as physical confrontations for instance). Other types of signaling are being considered as honest signal such as economic resources displays (as it can be seen in finance) or physical risks (extreme sports) and are, in consequence, in theoretical competitions with our main hypothesis. Binge drinking, in that context, may indicate competitiveness (physical or others) as well as social dominance over other males (in particular in social gathering contexts). A more exploratory hypothesis is the effect of a woman displaying alcohol tolerance over male participants when compared to the other type of risks. Binge drinking consumption may indicate signal of needs from woman and indicate availability for short-term mating.

Using the same website and faces than in Study 2, we adapted this method by using it in a male sample. We predicted that male profile described as being more tolerant to alcohol than peers during parties would be rated as more competitive and social dominant that male profile displaying economic risks ("playing in the stock market") or physical involvements (extreme sports such as "bungee jumping and sky diving"). In parallel, we also predicted that the female profiles indicating tolerating alcohol would be seen as more attractive for a short-term relationship by our males sample when compared to the other type of risks. However, regarding long-term relationship rating, we forecasted that the alcohol female profile would be seen as less attractive than the other risky female profiles.

2.2.4.1. Method.

We used the same website and two images than for Study 2. Participant had to judge the two faces randomly displayed as either male (presenting one of the three risks) or female (presenting one of the two remaining risks or vice versa).

2.2.4.2. Participants.

We recruited 201 men from Amazon Mechanical Turk website for an online study (June 2015). After excluding men on the basis of some theoretical and practical concerns (heterosexual, native-English speaker) our final sample was constituted of 183 men ($M_{Age} = 31.15$, $SD_{Age} = 10.31$). One hundred twenty-eight participants declared being single at the time of the study (69.95%). Almost half of the sample (44.81%) admitted drinking at least one a week. More than a quarter of the men indicated being atheist (27.32%) and only 28 of them declared practicing extreme sport (15.30%) that might interfere with the physical-risk profile evaluation.

2.2.4.3. Measures.

The main dependent variables in Study 3 were short-term attractiveness (“How attractive do you think this woman is?” on a 1-7 Likert scale from 1 “*Not attractive at all*” to 7 “*Very attractive*”) and long-term attractiveness of the female profiles. Regarding the male profile, competitiveness (1 = “*Not competitive at all*” to 7 = “*Very competitive*”) and dominance (1 = “*Not dominant at all*” to 7 = “*Very dominant*”) were the two measures that guided our analysis.

2.2.5. Results.

Short and long-term attractiveness for the female profile.

We used the same set of contrasts than for Study 2 but, on the female profile, we tried to compare the binge drink profiles to the other ones on short and long-term attractiveness. When men evaluated the binge drinking female profile, they did not rate her as more attractive for

short-term relationship ($M = 4.37$, $SD = 1.15$, $n = 41$) when compared to the physical ($M = 4.01$, $SD = 1.51$, $n = 47$) or the economic risky profiles ($M = 4.29$, $SD = 1.48$, $n = 42$) or the control page risk-free ($M = 4.23$, $SD = 1.34$, $n = 48$), $t(173) = 0.41$, $p = .68$, $R^2 = .003$.

Similarly, men did not evaluate the female binge drinker as particularly less attractive for a long-term relationship ($M = 3.72$, $SD = 1.47$, $n = 41$) when compared to the physical ($M = 3.80$, $SD = 1.41$, $n = 47$), the economical ($M = 3.40$, $SD = 1.49$, $n = 42$) or the control profiles ($M = 3.59$, $SD = 1.66$, $n = 48$), $t(173) = 1.14$, $p = .26$, $R^2 = .02$.

Social Dominance and Competitiveness for the male profile.

When the male profile was analyzed, male participants evaluated the physical profiles as more socially dominant ($M = 3.71$, $SD = 1.11$, $n = 43$) than the binge drinker ($M = 3.57$, $SD = 1.41$, $n = 37$), even though this results was only marginally significant, $t(177) = 1.72$, $p = .088$, $R^2 = .02$. This results come from the analysis of the second contrast comparing directly the binge drinker to the physical profiles while controlling for the other ones. Indeed, while the first contrast (binge drinker vs. other profiles) was significant, most of the variance was explained by the second set of comparison.

Regarding competitiveness however, we did not see emerging any significant difference. The alcohol profile was not being rated as more competitive ($M = 3.96$, $SD = 1.56$, $n = 37$) when compared to the physical ($M = 3.96$, $SD = 1.24$, $n = 43$), economical ($M = 3.89$, $SD = 1.29$, $n = 52$) or control profiles ($M = 3.77$, $SD = 1.28$, $n = 48$), $t(177) = 0.62$, $p = .54$, $R^2 = .002$.

2.2.6. Discussion.

This third study aimed at focusing our analysis on male behavior. As we mentioned before, many studies in ecology but also some social psychological data tend to suggest that

signaling could cover a large extent of targets. In particular, females are not always the only target in costly signaling since those signals usually serve as multiple-purposes including reproductive success, intrasexual competition but also probably, to a larger extent, a mediation pathway leading to higher reproductive success for risky drinkers.

We used the same methodology as in Study 2 with the dating website and the pre-tested Chicago database faces to ensure both replicability and external consistency. With higher power ($N = 183$) and a methodology that show strong consistency (Study 1), we intended to show that a male sample would evaluate a risky drinker as more competitive and socially more dominant than male displaying other type of risky activities such as physical (through skydiving and bungee jumping) or economical conspicuous behavior (e.g., speculating on the stock market).

Altogether, the data did not reveal the pattern we were expecting and the binge drinker was not being evaluated as particularly more competitive than the other profiles. The only marginal significant results found concerned the competitiveness evaluation of the target but, while the binge drinker was being judged as more competitive than the other profiles, most of the variance was explained by the second contrast comparing the physical to the risky drinking profiles. It was actually the man taking physical risks through extreme sports who was rated as slightly more dominant than the binge drinker. This call for a methodological reexamination or theoretical approach considering physical risk signaling to a larger extent.

2.3. General Discussion

Research investigating the evolution of sexual signals had been increasingly embraced by both the biology (Beach, 1976; Maynard-Smith & Harper, 2003) and psychology communities over the past few decades (Buss, 1993; Thornhill & Gangestad, 2008). One of the main hypothesis that had emerged is that only individual with high genetic quality would be able to carry cost that

enhance reproductive success to a larger extent than low genetic quality mates (Getty, 2006; Zahavi, 1975; Zahavi, 1977). This does imply that costly signals are necessary honest but honest signals do not need to be costly (some cheap signals can be understood as honest in many situations, for example if both the signaler and receiver share genetic interest through parental affiliation, Maynard-Smith, 1991; McElreath & Boyd, 2007).

While Zahavi's general principle was first welcomed with skepticism in the biology community (Dawkins & Krebs, 1978), Grafen's brilliant and profound modeling helped to ensure that both males and females possess evolutionarily stable strategies in the Zahavian framework (Grafen, 1990a, 1990b). In particular, males should be advertising their true quality and being perceived as such by females and other males. Nevertheless, the empirical reality is complex and does not always permit to examine such outcomes. In the animal world for instance, while peacock's length and ocelli size and ornamentation are correlated with reproductive success (Dakin & Montgomerie, 2013; Loyau et al., 2007), the correlation between observable signal and the unobservable quality, by dismissing low-quality peacock cheaters and keeping the system stable, is a relation difficult to establish (Getty, 2006; Maynard Smith & Harper, 2003).

Among humans, while different risks are considered a handicap, we considered that tolerance to alcohol is the most theoretically-fitted one for several reasons. First, anthropological considerations make us think that those behaviors are both dated and targeting large social audiences (Diamond, 1992; Kerr, 1989). Secondly, among drinking games for instance, the rules can easily restrain participants from cheating (LaBrie, Ehret, & Hummer, 2013). Third, contrary to Veblen's economic analogy (Veblen, 1899), where rich people conspicuously consume wasting money on luxury goods (signal) to indicate great resources (unobservable quality), in the

binge drinker case, both the signal and quality are observable and can generate testable hypothesis either in laboratory or field conditions.

Here, we proposed to evaluate risky drinking signaling through three different studies involving physiological-lab conditions (Study 1) and online higher power studies (Study 2 and Study 3) using an original dating website created and coded specifically to test our hypothesis. All in all, we predicted that men binge drinkers will be evaluated as more attractive and more dominant for short-term relationships by women participants (Study 1 and 2) while men will rate their co-gender target as being more socially dominant and competitive when tolerating alcohol than while taking physical or economical risks. The idea here was to try to establish that risky drinking is more a specific sexual signals when compared to other types of human risky behaviors.

In Study 1, we used a laboratory setting to investigate if women facing alcohol tolerant profiles on a dating website would make them evaluate alcohol-tolerant men as more attractive than the none-tolerant ones. Along with eye-tracking measures (fixation time and pupil dilation), hormonal data were taken (LH urinary tests) to investigate if an interaction between fertility and mating criteria would emerge, making women in high-fertility days evaluating the alcohol-tolerant profiles as more attractive than women in their low-fertility days. While the eye-tracking methodology put into place appeared to work properly despite the low power (fixation time was negatively correlated with pupil dilation), we did not find any evidence of a particular attraction for the alcohol tolerant profiles. Women did spend more time, for instance, on the highly alcohol tolerant men when compared to the moderately tolerant profiles but this result was only marginally significant ($p = .07$). Moreover, the low statistical power along with the absence of difference on the attractiveness self-report scale make difficult to draw any robust inference.

Women might actually have spent more time on the alcohol tolerant men because they were more trouble by individual admitting beating his peers at drinking games. These results call for a larger study involving more women in a less invasive environment (online study) that would not trigger particular norms about alcohol consumption.

We thus conducted an online extension of that first study to compare risky drinking to other type of risks, namely physical risks (bungee jumping and skydiving) and economical conspicuous behavior (speculating on the stock market). Facing randomly a woman or a man, women had to judge the short- and long-term attractiveness of the male profile as well as the competitiveness and social dominance of the woman. Generally speaking, despite a higher statistical power, none of the expected hypothesis emerged and we concluded that it did not seem that women judge differently the risky behaviors at play in that particular dating context. An alternative explanation might be that such type of risky signaling are not necessary intended at targeting potential mates but competitors and thus would be directed to other men. By displaying such signals, high-quality men would indicate their genetic quality and physical strength to other males around. We thus needed to explore the impact of such signals specifically on males but using the same platform (online dating website) and designs (same faces and measures) to be able to compare Study 2 and Study 3.

In the third study, men faced the same female and male profiles than women in Study 2 but with questions split differently for theoretical reasons (short- and long-term attractiveness for the female profile and social dominance and competitiveness for the male profile). While our main hypothesis was not confirmed, the physical risky man was judged marginally more socially dominant than the binge drinker one ($p = .09$). Despite the higher power ($N = 183$) and the same type of methodology than in Study 2, we were not able to find any strong evidence supporting

our main claims. Either the differences between this different risks are too subtle or facing male profiles was too direct to make emerge any difference.

Limits

The three studies presented in this chapter had different methodological and theoretical flaws. In the first study, including only women, there were at least two major weaknesses that make the absence of evidence, if not uninterpretable, really difficult to discuss. First, the very few number of women that actually fit our inclusion/exclusion criteria drop to a level that make any basic statistical findings really complicated to analyze (either with significant or non-significant effects). Additionally, and more surprisingly, a vast majority of those participants reported being Christians or Muslims and that could have make them particularly reactant to alcohol consumption. However, the physiological data from our eye-tracking measures making sense, there is a possibility that our dating website protocol is still an interesting tool to investigate the main questions we aimed at addressing here. Not only, this setting might induce an implicit mating context (difficult to assess by other means, see Hu, 2014), but is also more ecologically relevant as those costly signals might be difficult to evaluate in a field experiment or in a neutral laboratory context.

The two studies that followed presented a more powerful setting, more basic design and more cross-wide risk comparisons. However, the lack of significant evidence might yield for a new paradigm or methodological conceptualization. First, it is likely to consider that, in the third study for instance, men being psychological challenged by the different risky male profiles, were not able to distinguish precisely if one appear as particularly more socially dominant or competitive. On the other hand, an online features like ours might reinforce participant's true self as facing anonymously such individual leading their impression being closer to how they would

behave in real life. Our second and third studies, taking place online through Amazon Mturk, did not provide any strong evidence for our claims. Despite involving bigger sample sizes and more simplified design, the few results that we had were really difficult to interpret.

Further researches

Direct conflicts involving physical violence are rare among humans and non-human mammals since the majority of them are almost entirely resolved without direct violence (McElreath & Boyd, 2008). Moreover, when a conflict emerges, they provide audience with information about the different competitors present. Consequently, being part of a group or audience being exposed to those regular mating or male-to-male competition may structure beliefs about both the signaler and the receiver. Around 20 years ago, Schaller and Conway (1999) proposed a meta-theoretical framework based on a social-evolutionary perspective in which beliefs emerged and are maintained based on processes that are analogue to those involved in evolutionary biology (Boyd & Richerson, 1985; Campbell, 1965; Cavalli-Sforza & Feldman, 1981; Hull, 1988; Plotkin, 1987; Rescher, 1977; Romanelli, 1991; Sperber, 1990). Shared beliefs would thus followed a similar pathways that did cognitive structures and some beliefs would be selected against others.

Many variables may impose constraints over such beliefs but a major set of conditions are based on communication vectors. The extent to which a belief is appropriately displays will favor its dissemination among individual in a specific population. As Schaller and Conway (1999) interestingly pointed out, the main question that follow is which factors influenced such a willing to display it publicly? The attainment of social goals is one of these factors at play when sharing beliefs and, according to the social-evolutionary perspective, any goal an individual forms may influence the shared beliefs of a particular group. While a classical theory suggest

that human beings motivation related primarily on acceptance by others (Baumeister & Leary, 1995), we proposed to extend this to evolutionary motivations such as mating and competing as we intended to show in the present chapter.

“Nonetheless, the social-evolutionary perspective suggests that impression-management goals may ultimately shape the contents of emerging stereotypes. If individuals strategically alter the contents of their communications in response to impression-management goals, and if the contents of their communications influence the emerging contents of group stereotypes, then impression-management motives may exert an unintended indirect influence on stereotype formation.” (Schaller & Conway, 1999, p.821).

If Schaller and Conway’s statement is true, the same should apply to how impression-management motive impact beliefs about intrasexual competition such as male displaying tolerance in dating or drinking competition contexts. We therefore proposed, in the next chapter, to investigate how impression-formation are made through a dating and drinking games environments. Male participants forming impressions over such situations should attribute higher reproductive success to men tolerating alcohol versus others. Similarly, a drinking competition context should trigger both mating reproductive success and competitive impressions as male holding liquor may indicate physical strength and high-genetic quality. To our knowledge, such protocol had not been tested yet and we propose to evaluate it online with a massive number of participants in order to ensure statistical power. Additionally, since another feature of reproductive and competition success is social status, we ran two other experiments to test a plausible interaction between tolerance to alcohol and social status displaying by the drink expenses.

Chapter 3: Alcohol Tolerance as a Costly Signal for Intrasexual Competition and Reproductive Success Moderated by Social Status: an Online Investigation of Impression Formation.

In a quite famous behavioral ecology study, FitzGibbon and Fanshawe (1988), collected data on hyenas hunting strategies. They followed hyenas that were running on and not applying discrete tactics to get their preys as it can be observed in other species (e.g., cheetahs, lions). While some of the gazelles ran away directly when hyenas were approaching, others jumped repeatedly. FitzGibbon and Fanshawe noticed that spotted hyenas only hunted the gazelles that did not jump (or just slightly) and avoided the those that displayed impressive stotting which confirmed that predators, in that particular case, at least observe the prey's ability to escape or not. Other studies collected evidence following the same pattern: for instance, Hasson and colleagues showed that when zebra-tailed lizard are seen by a predator near its hole, they move their tails from side to side in an extreme way, according to Hasson, to indicate its agility and capability to escape down the hole should the predator attack (Hasson, 1989; Hasson 1991). Similarly, threatening dogs usually stand in front of each other with stretched out bodies, posture usually explained by a willingness from the dogs to present themselves bigger than they really are (Ewer, 2013).

However, signals that communicate threats between rivals may paradoxically represent a substitute for aggression. Aggression leading to death is actually quite rare among the animal world as it is in human beings (Zahavi & Zahavi, 1999). On a personal level, some social behaviors have been described as potentially threatening or describing the opponent's force and skills such as toxic resistance among Maya or Kung-Fu Masters (Diamond, 2013). We proposed here that binge drinking is one of the best suited modern social behaviors that can help to test this

hypothesis in an experimental context. Tolerating a fort amount of alcohol in a short period of time might fit the functions outlined by evolutionary stable strategies (ESS, Maynard Smith, 1972), in particular the true quality of the messenger, the public advertisement as well as the naivety of the receiver (Grafen, 1990a; Grafen, 1990b; Johnstone & Grafen, 1992; Johnstone & Grafen, 1993; Zahavi, 1975; Zahavi, 1977). Empirically, demonstrating the degree of harm one is willing to suffer is one possible way to demonstrate his genetic quality (ants and bees both use harmful chemicals when fighting indicating their commitment to fight (Holman, 2012; Zahavi & Zahavi, 1999) but numerous other insect species, for instance, use pheromone signals to attract mates in *Drosophila* (Ferveur, 2005), to dominate other males among cockroach (Everaerts, Fenaux-Benderitter, Farine & Brossut, 1997) or more simply to recognize each other in mice (Hurst et al., 2001; see Ettore & Moore, 2008, for a more exhaustive review).

We defend that the selective advantage of tolerating the negative effects of alcohol appeared only recently in evolution (thousands years window) when alcoholic beverage started to be fermented in a systematic process such as in the Incas or Maya cultures for example (Bevington, 1995; Diamond, 2013). We do not defend here that alcohol recognition by the human biological system emerged at the same time and our hypothesis is thus totally compatible with others such as the “drunken monkey hypothesis” backed up by paleogenetics and arguing that the alcohol dehydrogenase class IV (ADH4) appeared when we started to look for fermented fruit on the solid ground around 10 million years ago (Carrigan et al., 2015; Dudley, 2000; Dudley, 2014).

In particular, the practice of enema in the Maya culture is the first and extreme anthropological proof of binge drinking we have so far (Diamond, 1992; Kerr, 1989). Not only did that practice restrain the brain from sending signals of nausea but an enema would require

other persons to assist and is thus, *per se*, a social signal distinguishable from solitary drinking would not confer the same evolutionary advantages. Binge drinking might be a modern updating of that type of behavior since it largely takes place during social events such as bar gatherings and college campuses (Courtney & Polich, 2009).

Here we proposed to conceptualize binge drinking in order to test it, in a series of 4 pre-registered experimental studies, social impressions formation over either a causal date environment in a bar or a binge drinking competition among men. We showed that male participants tend to rate the tolerant-alcohol man as being more sexually successful with the potential female mates described in the situation when compared to the lowalcohol tolerant men or to the red-bull tolerant men (control group). However, we were unable to prove our other hypothesis testing the impact of alcohol-tolerance on male intrasexual competition as well as it roles as a potential mediator of reproductive success. We thus argue for further research on the meaning of alcohol signaling resistance among male during drinking games to develop specific prevention messages addressing this major health issue.

3.1. Binge drinking data

Alcohol-related problems cause the world millions of deaths every year as well as billion of dollars of economic and health damage. Just in 2014, 3.3 million people died from misuse of alcohol and the toxic chemical is constantly related to a series of other dangerous behaviors (CDC, 2016; WHO, 2014). Over the past few decades, the particular phenomenon of binge drinking as drawn the attention of the health community since its practices had been peaking among youth, particularly in social contexts (e.g. social gathering, fraternities, see Courtney & Polich, 2009). While there is still a debate about the exact definition of binge drinking across time and countries, two main factors are determinants in its characterization: speed and amount

(Rolland et al., 2017). For instance, the National Institute for Alcoholism and Alcohol Abuse (2014) defined binge drinking as reaching a BAC of .08 gram in 2 hours or less (equivalent of 4/5 standards drinks or more for women and men respectively).

While usually regarded as a risk-taking, the ultimate component of binge drinking have never really been examined. Diverse theories aimed at encompassing the phenomenon but generally missed targeting its three-fold nature (biological, psychological, social). An evolutionary approach would permit, based on past studies, to make predictions regarding the experimental impact on risky drinking behaviors. Hill and Chow (2002), for instance, have used the life-history theory framework to make predictions at a global level finding that young single childless male from poorer economic background were more willing to engage in those activities. However, such framework make any experimental manipulations difficult and are better at evaluating the phenomenon in a larger population scale (as can be seen in population modeling, see Giabbanelli & Crutzen, 2013; Gorman et al., 2006; Ormerod & Wiltshire, 2009).

Moreover, conflicting results emerged about the role of the economic status of the drinker and if it is positively linked to risky drinking or not. We revisited those conflicts through the costly signal theory to predict that both tolerance to alcohol and high social status are cues that improve social selection (sexual and non-sexual). On the one hand, tolerance to the deterrent effects of binge drinking might send a signal to other men about the genetic quality of the signaler and thus his capacity for both reproductive success and intrasexual competition. The intrasexual competition, we predict, will mediate the relation between tolerance to alcohol and successful mating perceived by other men. On the other hand, drinking expensive alcohol is a sign of resources and must be considered as a cue indicating the social status of the signaler. We then present a series of four only pre-registered studies supporting our different claims and we

finally open the discussion about possible evolutionary psychology application to educational and prevention programs.

3.2. The Costly Signal Theory

One of the essential point of the handicap principle is that all honest signals are not necessary costly (depending on the nature of the peer relationship) but all costly signals are necessary honest (McElreath & Boyd, 2008; Zahavi, 1975). As well as with economic purchases, where it is difficult to maintain a highly false level of socioeconomic status through expensive cars or housing (Sundie et al., 2011), it is even more difficult to pretend holding liquor easily when confronted in a drinking game for example. Through the costly signal lens however, we could distinguish that the binge drinker who tolerate more the alcohol during a drinking game send signal of direct genetic quality while the man purchasing expensive items used his social status to indicate his potential as an eventual partner. Logically, holding expensive liquor should also lead to be evaluated by other men as competitive from both genetic and social status standpoints (performing under high intoxication is even magnified in movies such as the James Bond saga, see Johnson, Guha & Davies, 2013).

While originally an economic theory (Veblen, 1899), the costly signal perspective has gain his intellectual visibility through the work of Zahavi (1975) who applied the idea to the animal world and in particular to respond to one difficulty that Darwin had (explaining why female prefers certain males over others, Darwin, 1968/1859; Darwin, 1871). Zahavi observed that males with strong and expanded characters tend to attract more females than regular males and proposed that, while the cost of producing and maintaining such characters is physiologically and socially costly (because other rivals noticed them more or because the traits could affect their fight capacity), the benefits through reproductive success was so high that it compensated

these costs. According to this theory, peacock tails, for instance, may function as a costly signal and the one with the largest, symmetrical and colorful tails attracts more peahens (Møller & Petrie, 2002). There is still a debate in the literature to know which part exactly of the tail's is the most attractive – length, number and density of ocelli – but globally mating success is positively correlated with those traits in peacocks indicating that female might use multiple cues when engaging in mating selection (Loyau, Jalme & Sorci, 2005).

Though originally skeptical (Higham, 2004; review in Grose, 2011), the biologist community admitted this hypothesis as plausible when Alan Grafen found a pair of evolutionary stable strategy for both sexes (Grafen, 1990a, 1990b, see figure 10 below). The model revealed that while natural selection cannot modify the genetic quality of males, it can adapt the advertising level as a function of the true quality of male, assuming that female perceived naively the signal being sent. Finding such a pair of stable strategies indicates that other competitive strategies might not be able to modify the dynamic in place and always return to his prior equilibrium (McElreath & Boyd 2008). Having found that say nothing about its empirical validity, only that it is theoretically plausible, in the actual evolutionary framework, helping to draw precise testable hypothesis.

3.2.1. Biological signal in the animal world

Zahavi and Zahavi (1999) proposed an analysis to figure if animal signals are always reliable:

“We suggest a very simple principle: if a given signal requires the signaler to invest more in the signal than it would gain by conveying phony information, then faking is unprofitable and the signal is therefore credible. If a gazelle that is slow or weak sends the wolf a phony signal about its speed and strength by stotting, it wastes what little

strength it has on puny jumps that will only convince the wolf that it is easy prey. Such a gazelle would do better to flee for its life and hope for the best. To gauge the reliability of a signal, then, one has to consider the investment it entails. The cost—the handicap that the signaler takes on—guarantees that the signal is reliable.” (Zahavi & Zahavi, 1999, p. XV).

$$w[v(A^*(q), P^*(A^*(q))), q] \geq w[v(a, P^*(a)), q] \quad \text{for all } q, a$$

$$\int D[v(A^*(q), q), P^*(A^*(q))] dG(q)$$

$$\leq \int D[v(A^*(q), q), P(A^*(q))] dG(q) \quad \text{for all functions } P.$$

Figure 10. Conditions for A^* and P^* to be an ESS; with $A^*(q)$ the best level of advertising for a male of quality q and $P^*(a)$ the best perceived value of a male by female for each possible level of advertising. The net viability is defined as $v(a, q)$ depending on true quality and advertising. Male fitness is written $w(p, v)$ while female fitness (integrals) is aimed at minimizing the discrepancy between p and v , not between p and q . From Grafen (1990a).

For quite a long time, biologist assumed that when animal such as birds emitted loudly calls when a prey is approaching, the signal was intended to reach the rest of the group to alarm them of the eminent danger. But Zahavi noticed through numerous studies that, in babblers for instance, the “alarmer” climbs the top of the tree to bark and is being exposed while it could have been hidden through the bush giving the alarm signals more discreetly to his peers. By doing so, it displaced its location and the one of his peers. Once the raptors lands, the babblers mob it and keep barking at the predator every time it makes a moves. This species, along with many other ones, tend to show that the signal the barking babbler sent in the first place is actually directed to the predators and not the potential preys. Even though the raptors eventually caught some birds, their benefits must have outfit the risks of having some of the peers babblers captured.

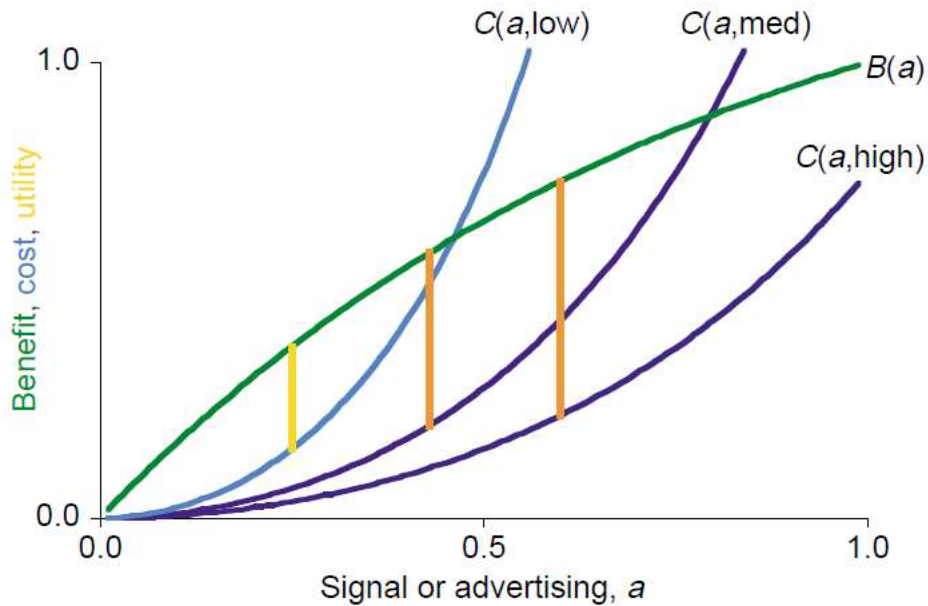


Figure 11. Function of Signaling. The green line $B(a)$ indicates the return benefits in function of a certain level of signaling. The light and dark blues lines symbolize the cost of the signal for high, medium and low-quality signalers.

The vertical yellow and orange lines are the utility cost (optimal signals is possible when the marginal cost – the slope of the cost line – equals the marginal benefit – the slope of the green line). From Getty (2006).

3.2.2. Binge drinking and costly signal theory.

While binge drinking as never been explored through the lens of the costly signal theory per se, other studies investigated if different types of risk-taking can be a signal said either to potential mate, or to competitors or even if the latter was a mediator of the former (Bird, Smith & Bird 2001; Wilke, Hutchinson, Todd & Kruger, 2006). Additionally, certain studies also showed that the signals was triggered by the presence of attractive potential mates leading males to take more risks at sports (as this is the case in gambling, skate-boarding or even virtual environments, see Baker & Maner, 2008 and Ronay & Von Hippel, 2010; Frankenhuis, Dotsch, Karremans & Wigboldus, 2010). From a general standpoint, we must note that it is tremendously difficult to evaluate the cost/benefit ratio of risk-taking in general if we do not take into account the fitness advantages of some of this behaviors.

Meta-analysis and modeling have shown that men as well as males among mammals, tend to engage in risk-taking activities in a larger extent than women and females respectively, through those differences varies among the type of risky activities (Byrnes, Miller & Schafer, 1999). Various studies had shown that risk-taking propensity can be evaluated as attractive by potential short-term feminine mates and certain studies even differentiate between modern risks (e.g., driving without seat belts) as being evaluated by both sexes as less attractive than hunter-gatherer types risks (e.g., handling fire, wild animals, etc., see Petraitis, Lampman, Boeckmann & Falconer, 2014). Here we defend two key points: first, we assumed that there is not a strict distinctions between ancients and modern risks in the sense that the former had been updated in a modern context and that mismatch represent, in the case of alcohol, chronic alcoholism and not binge drinking. Although all of those studies had focused exclusively on reproductive success through the lens of attractiveness, we defend here that intra-sexual competition among males might be the key to unfold many of the apparent contradictions such as the fact that binge drinking tolerance per se does not seem to be more attractive to women (Boudesseul et al, 2018).

As noted earlier, binge drinking represents a good candidate as it matches most of the factors elaborated in Grafen's ESS model such as true genetic quality of the drinker, true display of this quality and naive perception by the target of that signal. Secondly, binge drinking also takes form in competitive contexts through many type of drinking games that are particularly popular among competitive individuals (e.g., athletics in US colleges and universities). As consequences, it is possible that binge drinking might have been selected in a social selection context (sexual and non-sexual) as it may have encompassed direct sexual benefits (through reproductive success) as well as non-sexual advantages (access to resources during or after the game, for instance). One strong possibility during the drinking games dynamic that we tried to

analyze earlier (chapter 1) is that by tolerating alcohol better than others, the winner of those social drinking games pushes away eventual competitors both physically and geographically and can then have access more directly to potential mates.

We thus predict that, in both mating and competitive contexts, participants will evaluate a tolerant-man as being more competitive and that its opponents will be less willing to engage in other type of physical competitions with him. Second, we predict that there will be an interaction with the social status such as tolerating expensive alcohol is both a social status signal as well as an indicator of high genetic quality. All of the experimental studies presented here had been pre-registered on AsPredicted.org.

3.3. Current Research

In two online experimental studies, we investigated the effect of alcohol-tolerance signals on the evaluation of the reproductive success and competitiveness of a male target in both mating and competitive contexts. Secondly, in two other experimental designs, we added the social status through the alcohol expenses to test an interaction between tolerance to alcohol (which indicate genetic quality) and resources displays (which indicate socioeconomic status). We predicted that high tolerant men will be evaluated as more sexually successful and more competitive when compared to a low alcohol-tolerant man as well as compared to a control group (red-bull tolerant target). On the other hand, we also expect that tolerant men with high status will be seen as more sexually successful and more physically competitive than tolerant man with low apparent status (i.e., drinking “cheap” whisky).

3.3.1. Study 1

We first tested how signals of tolerance to alcohol in a mating context (a man drinking with a woman in his side) can lead participants to evaluate the target as more sexually successful

and competitive. Alcohol tolerance might be ancestrally perceived as a signal of genetic quality toward potential mates and as a threat indicator to other men in case of intra-group competitions. Men described as more tolerant to alcohol might be perceived by men participants as more competitive and as sexually more successful than none-tolerant men. An alternative hypothesis is that signal of threat may actually be a mediator toward reproductive success by frightening others males and having potential mates available. The study was preregistered on AsPredicted.org to increase transparency, reproducibility, and reduce publication bias (van't Veer & Giner-Sorolla, 2016).

3.3.1.1. Method.

3.3.1.2. Participants.

In total, 596 participants from the United States were recruited through the Amazon Mechanical Turk website (between November and December 2016). We analyzed only men behavior in the next studies because they are much more likely to participate in binge drinking than are women. Since we could not properly pre-filtered only male participants initially, we processed it afterwards. The mean age of the sample was 37.26 ($SD = 12.74$). As preregistered, we ended up with 183 male participants after all exclusions criteria were applied (participants who found out the main goal of the study; those who did not remember correctly what was the man drinking on the picture; participants who failed the seriousness check, Aust, Diedenhofen, Ullrich, & Musch, 2013; those who failed the attentional check, answering something other than “5” to the open question “two plus three equals”; who self-described themselves as woman, homosexual, bisexual or other, none-fluent or none-native English speaker along with people who never drank, as well as outliers displaying studentized deleted residual strictly greater than

4, see McClelland, 2014). Male participants were more likely to be in relationship ($n = 112$) than single ($n = 71$) and all of them had already consumed alcohol.

3.3.1.3. Procedure.

The participants entered a Google form through Amazon Mechanical Turk and were paid \$0.25 for a 5 to 10 minutes assignment task (7 minutes on average). After being presented a brief procedure instructions, participants faced an image of a man at a bar holding a yellow drink (modified on Photoshop to look both like potential energy drink as Red Bull or whisky on the rock) and a young woman right behind him grabbing his shoulders as in a casual date (see Figure 12 below; pre-tested online on 7-points Likert scales by 53 men who described themselves as heterosexual and native English speakers: $M_{\text{attractiveness}} = 4.38$, $SD_{\text{attractiveness}} = 1.11$, $M_{\text{masculinity}} = 4.11$, $SD_{\text{masculinity}} = 1.33$, $M_{\text{age}} = 29.87$, $SD_{\text{age}} = 3.67$). At the end, participants self-reported socio-demographic information about age, marital relationship status as well as three additional questionnaires: the intrasexual competitiveness scale (Buunk & Fisher, 2009), the Brief Sensation Seeking Scale (Hoyle et al., 2002) and the Alcohol Use Disorders Identification Test Consumption (Bradley et al., 2007). Those controls are essential because they had been regularly related to risky drinking behaviors among males and reflect both cognitive dispositions (Andrew & Cronin, 1997; Hone, Carter & McCullough, 2013) as well as substance use disorders (Bush et al., 1998).



Figure 12. The picture presented during study 1.

A small description of the scene accompanied the picture where we could introduce more subtly the different conditions (in “[]” inside the text) in a 2x2 between-design subjects: alcohol-tolerant man, none-alcohol tolerant man, Red Bull tolerant man and none Red Bull tolerant man.

« James and Mary have been out on a few dates but have not had sex yet. James drank three glasses of whisky [Red Bull] in front of Mary and does [not] feel really well. Rate the different statements below from “strongly disagree” (1) to “strongly agree” (7). »

3.3.1.4. Preliminary results.

AUDIT-C (*Alcohol Use Disorders*). To assess participants’ hazardous drinking for both chronic and binge drinking on a short-version of the original scale, there were 3 items: “How often do you have a drink containing alcohol?”, “How many units of alcohol do you drink on a typical day when you are drinking?”, “How often have you had 6 or more units if female, or 8 or more if male, on a single occasion in the last year?” Items were rated from 0 to 4 ($\alpha = .71$).

BSSS-8 (*sensation seeking*). To determine participants’ level of sensation seeking, we used the brief sensation seeking scale containing 8 items ranging from 1 = *Strongly disagree* to 5

= *Strongly agree* ($\alpha = .75$, see Hoyle et al., 2002 or Stephenson et al., 2007 different validations of that scale).

Individual differences (*intrasexual competition scale*). Male were asked, on 12-items scale, how much statements assessing intrasexual competition applied to them ranging from 1 = *Not at all applicable* to 7 = *Completely applicable* ($\alpha = .87$, Buunk & Fisher, 2009).

Measures.

The key DVs were explicit judgments of the man's reproductive success ("James is going to have sex with Mary tonight") along with intrasexual competition questions (one trait: "James could be one of your teammate player" and one counter-trait: "If necessary, you could physically fight James"). The intrasexual competition DV did not include the two mentioned items because their alpha was really low ($\alpha = -0.17^6$) and the two measures were then analyzed separately in all of the following analysis as preregistered before the study was run.

3.3.1.5. Results.

Reproductive success impressions.

When specific contrasts were applied (to test alcohol-tolerance against no-tolerant and against Red Bull tolerant: 2, -1, -1; 0, 1, -1). and the data logged (initially highly right-skewed), our specific contrasts (c1) revealed that participants evaluated the alcohol-tolerant man ($M = 3.85$, $SD = 1.56$, $n = 53$) has being more willing to have sex with Mary when compared to the none alcohol-tolerant man ($M = 3.10$, $SD = 1.60$, $n = 52$) and to the Red Bull-tolerant man ($M =$

⁶ Contrary to popular beliefs, Cronbach's coefficient can display any values from infinite negative to +1. Two anomalies, artificially high alphas and negatives, can however emerged when there is very bad internal consistency (Knapp, 1991). Cronbach's alpha is $k/(k-1)[1 - \sum s_i^2/s^2]$, with k the number of scores (the scale), s_i^2 is the variance of item i and s^2 is the variance of total-test scores. Whenever the bracket expression is negative, a negative alpha will emerge. That indicates a greater within-subject than between-subject variability, reflecting a very bad measure.

3.67, $SD = 1.67$, $n = 36$), $t(180) = 1.99$, $p = .049$, $\eta^2 = .03^7$. When controlling for AUDIT-C, sensation-seeking and intrasexual competition levels, the main effect hold, $F(5, 177) = 1.72$, $p = .049$, $\eta^2 = .02^8$.

Intrasexual competition impressions.

Cooperation DV

When we applied the same contrasts to test directly the tolerance to alcohol to the 2 other factors of interests, the analysis revealed that participants evaluated the alcohol-tolerant man ($M = 4.41$, $SD = 1.64$, $n = 53$) has being more willing to be a teammate when compared to the none alcohol-tolerant man ($M = 3.67$, $SD = 1.73$, $n = 52$) and to the Red Bull-tolerant man ($M = 3.86$, $SD = 1.51$, $n = 36$), $t(180) = 2.31$, $p = .02$, $\eta^2 = .03$. When controlling for the moderators mentioned above, the main effect hold and tolerant-alcohol man were still being more willing to be accepted as a teammate compared to the men in other conditions, $F(5, 177) = 2.66$, $p = .04$, $\eta^2 = .02$.

Interpersonal violence DV

On the other hand, the willingness to fight did not revealed any significant difference when participants judged the alcohol-tolerant man ($M = 3.08$, $SD = 1.65$, $n = 53$), compared to the none-tolerant alcohol man ($M = 2.92$, $SD = 1.64$, $n = 52$) and the Red Bull-tolerant man ($M = 3.56$, $SD = 1.96$, $n = 36$), $t(180) = -0.50$, $p = .62$, $\eta^2 = .01$.

⁷ We checked in every analysis for potential statistical outliers following the studentized deleted residual technics indicating that a level greater than 4 is consider as outliers (see McClelland, 2014). When no additional information were added, this meant the results remained the same with or without outliers.

⁸ While the omnibus was not significant ($p = .067$), our contrast c1 that tested our specific hypothesis was. According to Brauer & McClelland (2005), the omnibus test is statistically less powerful and theoretically less pertinent that a pre-planned specific contrast. We proposed here to focus on the specific contrast that we pre-registered for our different studies.

Mediations analysis

We tested a second prediction aiming at determined if the intrasexual competition (inserted as two different outcomes in the model because of the very low Cronbach's alpha, $\alpha = .17$) could play a role in shaping the relation between the evaluation of a tolerant-alcohol man and his perceived reproductive success. We ran a multiple mediation model following Preacher and Hayes's guidance (2008) using their SPSS macro (percentile bootstrap procedure with 5,000 bootstrap samples, IV coded in 1/-1).

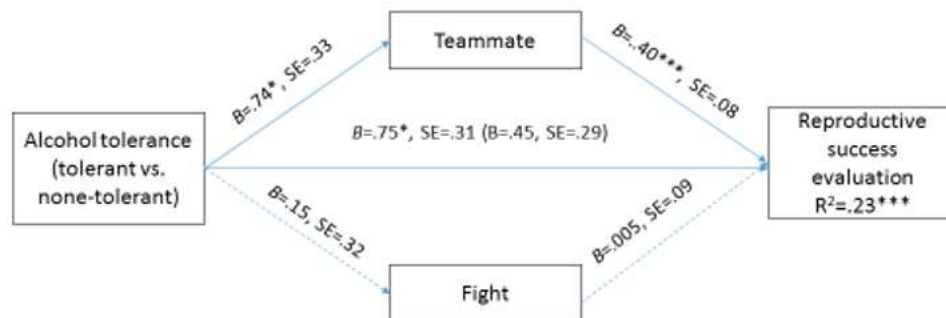


Figure 13. Mediation of the relationship between the different conditions of interests (alcohol-tolerant vs. non-tolerant) and the perceived reproductive success by intrasexual competition (sportive inclusion or interpersonal violence engagement). Values designate non-standardized regression coefficients (B). * $p < .05$, *** $p < .001$.

The results indicated that the evaluation of the target as a potential teammate mediated the relation between the perceived alcohol-tolerance and reproductive success (the more the man was tolerant to alcohol, the more he was willing to be a teammate, the higher his reproductive success (respectively $p < .05$ and $p < .001$) while the intrapersonal violence outcome did not significantly mediate this relation (figure 13 and table 2). Additionally, the direct effect of the alcohol-tolerance on the evaluation of the target's reproductive success it not significant ($p = .12$)

and the effects emerged only when taking into account the two mediators ($p = .02$) which could indicate that a large part of the effect is explained by the cooperation mediator.

Bootstrap Results for Mediation Effects			
	Mediation Effect (<i>SE</i>)	95% Confidence Interval (CI)	
		Lower	Upper
Mediators			
Total mediated effect	.30 (.17)	.01	.65
Interpersonal violence	.01 (.04)	-.08	.10
Cooperation	.30 (.16)	.03	.64

Note. Boldface numbers indicate significant effect under 95% CI (SE) through 5,000 bootstrap samples (bootstrap percentile).

Table 2.

Study 1: Mediation and confidence intervals of the multiple mediation effects of tolerance to alcohol over the two mediators (interpersonal violence and cooperation).

3.3.1.6. Discussion.

Study 1 compared the influence of alcohol-tolerance over the perceived reproductive success of a man and his intrasexual competitiveness through an online formation impression task. The analysis revealed that the target describing a more alcohol-tolerant man was attributed higher reproductive success and higher rate of cooperation (teammate) by participants when compared to a man not tolerating alcohol (comparison group) or to a Red Bull tolerant target (control group). However, the second intrasexual competition measure involving interpersonal violence did not revealed any effect. Additionally, a multiple mediation analysis shown that the

cooperation measure might be the pathway explaining the main effect of alcohol tolerance on the perception of reproductive success of the target.

This first study took place in a mating context while a man was meeting a woman at a bar for a casual date. One plausible explanation for the failure of the interpersonal violence outcome may be whether the context implies competition or not. We thus conducted a similar study with the same design but in a male competitive context where two men were playing a drinking game in front of other women (“whisky pong”, an updated version of the classical “beer pong” really popular among college students and athletics). A more competitive context might trigger a stronger impression of an alcohol tolerant man has being more willing to engage into a fight and/or had having genetic quality which make him more resistant to pain or eventual injuries in a real physical fight.

3.3.2. Study 2

In the second study we tested the same hypothesis but in a different context: does a drinking game, an assumed competitive context, triggers an impression of high competitiveness when the target is tolerant to alcohol? Does this context increase the perceived reproductive success for this same man? Does those combined measures mediate the pathway between the alcohol tolerance and the perception of reproduction success? Similarly to the first study, this second project was equally preregistered on AsPredicted.org.

3.3.2.1. Method.

3.3.2.2. Participants.

Originally, 602 Mturkers from the United States participated in our study on the Amazon Mechanical Turk website. We again took into account only men data in the following study. After filtered only men, we ended up with 166 male participants after all exclusions criteria were

applied (we used exactly the same exclusion criteria as explicated up above in the first study). The mean age of the finale sample was 38.05 ($SD = 12.86$). Male participants were more likely to be in relationship ($n = 101$) than single ($n = 65$) and all of them had already consumed alcohol.

3.3.2.3. Procedure.

The participants entered the same Google form through Amazon Mechanical Turk and were paid \$0.25 for a 5 minutes task. Following the same instructions that displayed in Study 1, participants faced an image of a man playing a game close to beer pong against another man surrounding by two women cheering them (see figure 14 below; pretested on 67 heterosexual men who described themselves as native English speakers: $M_{\text{attractiveness}} = 3.66$, $SD_{\text{attractiveness}} = 1.50$, $M_{\text{masculinity}} = 3.78$, $SD_{\text{masculinity}} = 1.56$, $M_{\text{age}} = 25.37$, $SD_{\text{age}} = 3.33$). At the end, participants self-reported the same socio-demographic information that in our precedent investigation.



Figure 14. The picture presented during study 2.

A small description of the scene preceded the picture where we manipulated the different conditions (in “[]” inside the text) in a between-design subjects with 3 conditions: alcohol tolerant man, none alcohol tolerant man and red bull tolerant man.

« Robert, on the left, and James, on the right, are playing a drinking game against one another. Claire and Mary are observing them. After having already had a few glasses of whisky [Red Bull], James, on the right is still [not] able to accurately shoot the ball into the cups and is losing the game. Rate the different statements below from “strongly disagree” (1) to “strongly agree” (7). »

3.3.2.4. Preliminary results.

AUDIT-C (*Alcohol Use Disorders*). To determine participants' level of regular and binge drinking used, we used the short-version of the original AUDIT scale. The same items that displayed in Study 1 were used in the present study. Items were rated from 0 to 4 ($\alpha = .76$).

BSSS-8 (*sensation seeking*). To determine participants' level of sensation seeking, we used the brief sensation seeking scale containing 8 items ranging from 1 = *Strongly disagree* to 5 = *Strongly agree* ($\alpha = .81$, see Stephenson et al., 2007 for a validation of that scale).

Individual differences (*intrasexual competition*). Male were asked, on 12-items scale, how much statements assessing intrasexual competition applied to them ranging from 1 = *Not at all applicable* to 7 = *Completely applicable* ($\alpha = .88$, Buunk & Fisher, 2009).

Measures.

The key DVs were explicit judgments of the man's reproductive success (“James is going to have sex with Mary or Claire tonight”) along with intrasexual competition questions (one trait: “James could be one of your teammate player” and one counter-trait: “If necessary, you could physically fight James”). This intrasexual competition DV did not include the two mentioned items because their alpha was negative ($\alpha = -0.33$) and the two measures were then analyzed separately in each following analysis.

3.3.2.5. Results.

Reproductive success impressions.

When the same set of contrasts than in Study 1 were applied, an independent t test revealed that participants evaluated the alcohol tolerant man ($M = 4.64$, $SD = 1.51$, $n = 42$) has having more chances to have sex with Mary or Claire when compared to the none alcohol-tolerant man ($M = 3.91$, $SD = 1.91$, $n = 44$) and to the Red Bull tolerant man ($M = 3.97$, $SD = 1.07$, $n = 33$), $t(163) = 2.25$, $p = .026$, $\eta^2 = .03$. When controlling for AUDIT-C, sensation-seeking and intrasexual competition levels, the main effect still hold, $F(5, 160) = 2.90$, $p = .02$, $\eta^2 = .02$.

*Intrasexual competition impressions.**Cooperation DV*

When we compared the same sample of man over cooperation specifically (“James could be one of your teammate”), the analysis revealed that participants evaluated the alcohol tolerant man ($M = 4.45$, $SD = 1.91$, $n = 42$) were not more willing to be a teammate when compared to the none alcohol-tolerant man ($M = 3.91$, $SD = 1.60$, $n = 44$) and to the Red Bull tolerant man ($M = 4.39$, $SD = 1.60$, $n = 33$), $t(163) = 0.92$, $p = .36$, $\eta^2 = .01$.

Interpersonal violence DV

The second intrasexual competition measure, the willingness to fight, did not revealed any significant difference when participants evaluated the alcohol tolerant man ($M = 3.45$, $SD = 2.00$, $n = 42$), the none tolerant alcohol man ($M = 3.68$, $SD = 2.05$, $n = 44$) and the Red Bull tolerant man ($M = 3.81$, $SD = 2.04$, $n = 33$), even though the results were only descriptively in the predicted direction, $t(163) = -0.78$, $p = .44$, $\eta^2 = .004$.

Mediations analysis

We tested a second prediction trying to determine if the intrasexual competition (inserted as two different outcomes in the model because of the very low Cronbach's alpha, $\alpha = -0.33$) could play a role in shaping the relation between the evaluation of a tolerant alcohol man and his perceive reproductive success. We ran a multiple mediation model by following Preacher and Hayes's guidance (2008) on SPSS (percentile bootstrap procedure with 5,000 bootstrap samples).

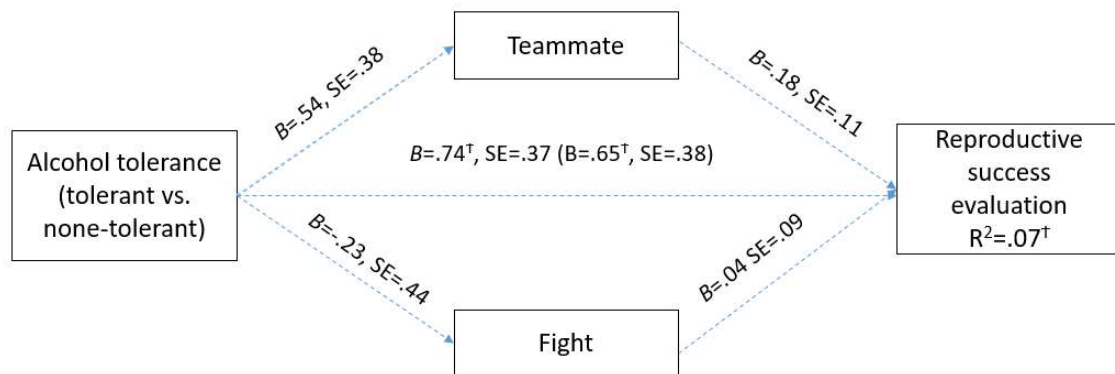


Figure 15. Mediation of the relationship between the different conditions of interests (alcohol tolerant vs. non tolerant) and the perceived reproductive success by intrasexual competition (sportive inclusion or interpersonal violence engagement). Values designate non-standardized regression coefficients (B). † $p < .01$.

The results indicated that the evaluation of the target as a potential teammate or willingness to fight him did not mediated the relation between the perceived alcohol-tolerance and reproductive success (figure 15 and table 3). Additionally, the indirect effect of the alcohol tolerance on the evaluation of the target's reproductive success still stand after adding the two mediators which indicate that our two variables did not explain this link (even though the indirect effect was only trendly significant).

Bootstrap Results for Mediation Effects			
	Mediation Effect (SE)	95% Confidence Interval (CI)	
		Lower	Upper
Mediators			
Total mediated effect	.09 (.12)	-.07	.39
Interpersonal violence	-.01 (.05)	-.21	.05
Cooperation	.10 (.11)	-.02	.44

Note. Boldface numbers indicate significant effect under 95% CI (SE) through 5,000 bootstrap samples (bootstrap percentile).

Table 3: Mediation and confidence intervals of the multiple mediation effects of tolerance to alcohol over the two mediators (interpersonal violence and cooperation).

3.3.2.6. Discussion.

Study 1 and 2 investigated the potential role of alcohol tolerance in the perception of reproductive success in a mating context (Study 1) as well as in a competitive environment (Study 2). The first online study indeed revealed an effect of alcohol tolerance with the alcohol tolerant man as being viewed as having higher chance of reproductive success when compared to the none alcohol tolerant man (target) and the Red Bull tolerant man (control group). This may indicate that, in a dating context, being able to resist the cognitive and physical effects of alcohol may reveal genetic quality particular to this type of drink (since the model worked against a man drinking a considerable amount of Red Bull too) or, at least, that other potential rivals (men) believe so and may be tempted to hold back for any further competition in order to avoid direct interpersonal violence. Coherently, the tolerant-alcohol man was also viewed as being a better potential teammate (sportive context) when compared to the other profiles even though the direct fight measure failed to reach significance. A mediation pathway had been found through the

cooperation outcome (teammate) since it explained most of the relation between the tolerant alcohol men and the reproductive success evaluation.

As for Study 2, we intended to replicate the results found in the first study but in a competitive context (drinking games) by pre-registering all the design all over again. While our analysis revealed that the reproductive success impression still hold, leading participants to evaluate the alcohol tolerant man as more susceptible to have sex with the available partner than the none tolerant alcohol man or the Red Bull tolerant man (control), the two intrasexual competition measures failed to reach significance though going descriptively in the predicted direction. As a consequence, the multiple mediation model did not reveal any significant pathway through those two dependent variables and the main effect of alcohol tolerance on the reproductive success impression still hold after adding the two intrasexual competitive mediators into the full model.

Several reasons could explain this partial success at replicating Study 1. First, it is possible that a specific dating context implies a mating mindset that makes male participants more sensitive to cooperation when compared to a competitive environment. Also, since direct violence is pretty rare in the animal and human worlds in general (most of conflict being resolved without direct aggression, Zahavi & Zahavi, 1999), it is possible that our measure of potential fight did not fit a modern intrasexual competitive context. On top of that, despite trying to extend our sample, we failed to reach a high statistical power making it difficult to completely eliminate the risk of false-negative (type-II error).

Finally, one possible confounding that we did not take into account in the first two studies was the perceived social status of the different men presented. In the two contexts, it is possible that participants formed a specific social status of the male making it more valuable in

the dating scene when compared to the drinking game scene. We thus decided 1) first to modify the dependent variable in consequence by keeping the reproductive success questions (which replicated in both studies) along with the teammate (to test for false-negative in the second study) but to update the interpersonal violence measure and presenting two proxies that did not involve direct aggression (arm-wrestle competition and binge drinking contest); 2) we then added another independent variable describing the social status of the target through the market value of the alcohol he was drinking (cheap, \$20 the bottle vs. really expensive \$2000 whisky) to test for possible interaction between genetic quality (alcohol tolerance to physiological effects) and social status (higher social competitive rank) and evaluate the possible social selection (sexual and non-sexual) process at play while evaluating a binge drinker in both dating and drinking games contexts.

3.3.3. Study 3

Next we tried to replicate the effects of the first two studies, knowing the direct effect of alcohol tolerance upon the perception of reproductive success, but also the impact of a cooperative variable acting as a mediator between tolerance to alcohol and reproductive success. Based on the literature about intrasexual competition among men as well as reproductive success criteria, one possible confounding might be the social status that our original images implicitly displayed to participants (see Hopcroft, 2006 for a review and a scrupulous analysis of data in the US from 1989-2000 General Social Survey). In the first study, the young men with a drink and nice shirt may look as a businessman or someone willing to invest substantively to show off about his socioeconomic status in order to attract potential mates (even though, this mating criteria seem to be more critical for long-term relationship, it is important to mention that

numerous of studies had also found similar effect for short-term mating, though physical attractiveness and genetic quality impact mating criteria to a larger extent in that context).

Given that our second intrasexual competition dependent variable did not seem to work at all, we updated it to a more indirect physical fight (“If necessary, you could engage in a arm-wrestle with James”). Similarly, we added a third variable to our intrasexual competition subset, to test a competition involving binge drinking directly (“You could play a drinking games against James”). Many studies in sociology and psychology described binge drinking as being a form of competition and it thus highly possible that it is considered as being a proxy to competition among young males. The global design of the study remained the same for the rest of the model. We also increased substantially the statistical power of the next two studies in order to fit our preregistered criteria to meet a 95% power (Cohen, 1977).

3.3.3.1. Method.

3.3.3.2. Participants.

In total, 1348 participants from the United States were recruited through the Amazon Mechanical Turk website (from June 2017 to July 2017). We processed similarly that in the first two studies by excluding women post-hoc (since it is not possible to pre-filter participants by gender on Mechanical Turk) and ended up with 523 males. After applying the same exclusion criteria than the first two studies (being a heterosexual, native English speaker male from the US and having passed the control and seriousness checks) our final sample was composed of 350 men. The mean age of the sample was 36.09 ($SD = 12.58$). Male participants in a romantic relationship at the time of the study ($n = 225$) outnumbered the one who self-described as “single” ($n = 125$). All of our final male participants had already consumed alcohol in the past.

3.3.3.3. Procedure.

The participants entered the same Google form through Amazon Mechanical Turk as used in the first two studies and were paid the same rate (\$0.25 for a 5 to 10 minutes assignment task). There is a large debate in a psychology community to determine the fair wage participants should receive when participating to non-profit experiments/tasks in the Turk and this debate is far from being closed. However, some arguments were made in the defense of low rate when study were not intend at making profit and when University with limited resources were engaged as in our case.

After the pre-instructions, the participants faced the exact same image that in Study 1 but we modified the description to incorporate our second independent variable “social status” (cheap versus really expensive alcohol). A small description of the scene complemented the picture where we could introduce more subtly the different conditions (in “[]” inside the text) in a 2x2 between-design subjects: alcohol tolerant man with high status, alcohol tolerant man with low status, none alcohol tolerant man with high status, none alcohol tolerant man with low status (as well as red bull tolerant condition for control but included only in the analysis of the main effect).

« James and Mary have been out on a few dates but have not had sex yet. James drank three glasses of a very cheap [expensive] whisky (\$20 [\$2,000] a bottle), in front of Mary and does [not] feel really well. Rate the different statements below from “strongly disagree” (1) to “strongly agree” (7). »

3.3.3.4. Preliminary results.

AUDIT-C (*Alcohol Use Disorders*). To assess participants' hazardous drinking for both chronic and binge drinking on a short-version of the original scale. There were 3 items: “How often do you have a drink containing alcohol?”, “How many units of alcohol do you drink on a

typical day when you are drinking?”, “How often have you had 6 or more units if female, or 8 or more if male, on a single occasion in the last year?” Items were rated from 0 to 4 ($\alpha = .68$).

BSSS-8 (*sensation seeking*). To determine participants' level of sensation seeking, we used the brief sensation seeking scale containing 8 items ranging from 1 = *Strongly disagree* to 5 = *Strongly agree* ($\alpha = .78$, see Stephenson et al., 2007 for a validation of that scale).

Individual differences (*intrasexual competition*). Male were asked, on 12-items scale, how much statements assessing intrasexual competition applied to them ranging from 1 = *Not at all applicable* to 7 = *Completely applicable* ($\alpha = .88$, Buunk & Fisher, 2009).

Measures.

The key DVs were explicit judgments of the man's reproductive success (“James is going to have sex with Mary tonight”) along with intrasexual competition questions (one trait: “James could be one of your teammate player” and two counter-traits: “If necessary, you could engage in a arm-wrestle with James” and “You could play a drinking games against James”). This intrasexual competition DV did not include the three mentioned items because their alpha was negative ($\alpha = -0.27$) and all the measures were being analyzed separately to meet internal consistencies requirements for that type of analysis.

Results.

Reproductive success impressions.

When specific contrasts were applied⁹, an independent t test revealed that participants evaluated the alcohol tolerant man ($M = 3.66$, $SD = 1.62$, $n = 166$) has being more willing to

⁹ $c1 < -3 * (DF\$Condition=="alcohol_statut-tolerant+") + 3 * (DF\$Condition=="alcohol_statut+tolerant+") - 2 * (DF\$Condition=="alcohol_statut-tolerant-") - 2 * (DF\$Condition=="alcohol_statut+tolerant-") - 2 * (DF\$Condition=="redbull_tolerant+")$

have sex with Mary when compared to the none alcohol tolerant man ($M = 2.89$, $SD = 1.60$, $n = 132$) and to the Red Bull tolerant man ($M = 3.33$, $SD = 1.54$, $n = 52$), $t(347) = 3.64$, $p < .001$, $\eta^2 = .05$. When controlling for the age of the participants, AUDIT-C, sensation-seeking and intrasexual competition levels, the main effect still hold, $F(6, 343) = 10.3$, $p < .001$, $\eta^2 = .04$ but the second contrast also became significant ($p = .035$) as well as the intrasexual competitiveness factor ($p < .001$).

Intrasexual competition impressions.

Cooperation DV

When we applied the same specific contrasts to test directly the tolerance to alcohol to the 2 other factors of interests, the analysis revealed that participants evaluated the alcohol tolerant man ($M = 3.75$, $SD = 1.69$, $n = 166$) has not being more willing to be a teammate when compared to the none alcohol tolerant man ($M = 3.50$, $SD = 1.84$, $n = 132$) and to the Red Bull tolerant man ($M = 3.50$, $SD = 1.57$, $n = 52$), $t(347) = 1.33$, $p = .18$, $\eta^2 = .005$.

Interpersonal violence DV

On the other hand, the willingness to engage in arm-wrestle did not revealed any significant difference when participants evaluated the alcohol tolerant man ($M = 4.43$, $SD = 2.01$, $n = 166$), the none tolerant alcohol man ($M = 4.67$, $SD = 1.91$, $n = 132$) and the Red Bull tolerant man ($M = 4.17$, $SD = 1.93$, $n = 52$), $t(347) = 0.38$, $p = .71$, $\eta^2 = .01$.

Binge drinking competition

c2 <- 0* (DF\$Condition=="alcohol_statut-tolerant+") + 0*(DF\$Condition=="alcohol_statut+tolerant+") +1* (DF\$Condition=="alcohol_statut-tolerant-") +1* (DF\$Condition=="alcohol_statut+tolerant-") -2* (DF\$Condition=="redbull_tolerant+")

Finally, the third intrasexual competition that we added in the experiment concerned the willingness to engage to a binge drinking competition with the target. However, participants did not judge the tolerant alcohol man ($M = 4.25$, $SD = 2.21$, $n = 166$) as being more threatening in a binge drinking competition than the none tolerant alcohol man ($M = 4.14$, $SD = 2.09$, $n = 132$) or that the Red Bull tolerant man ($M = 4.17$, $SD = 2.02$, $n = 52$), $t(347) = -0.43$, $p = .67$, $\eta^2 = .0005$.

Interaction between Alcohol tolerance and Social Status

We also tested our predicted interaction between the tolerance to alcohol and the social status of the target to determine if the picture describing a tolerance and high-status male will be perceived as having a higher reproductive success as well as being seen as more competitive compared to the none alcohol tolerant target and to the low tolerant males.

After applying our specific set of contrast¹⁰, the reproductive success perception of the tolerant man with high status was not being judged as statistically more successful ($M = 3.70$, $SD = 1.67$, $n = 88$) when compared to the tolerant man with low status ($M = 3.62$, $SD = 1.56$, $n = 78$). Even though the low tolerant man with high status ($M = 2.81$, $SD = 1.40$, $n = 64$) or with low status ($M = 1.77$, $SD = 1.77$, $n = 68$) displayed descriptively lower rating, the separate 2x2 ANOVAs on each variable in a 2 (tolerant vs. none-tolerant) x 2 (high vs. low status) did not yield any significant effect, $F(3, 346) = 5.79$, $p = .13$, $\eta^2 = 0.04$ (see fig. 3).

When we analyzed the intrasexual competition measures, we found that for the cooperation dependent variable (teammate), participants evaluated the high status tolerant men

¹⁰ c3 <- 1* (DF\$Condition=="alcohol_statut+tolerant+") - 1*(DF\$Condition=="alcohol_statut-tolerant+") +0* (DF\$Condition=="alcohol_statut-tolerant-") +0* (DF\$Condition=="alcohol_statut+tolerant-")
c4 <- 3* (DF\$Condition=="alcohol_statut+tolerant+") - 1*(DF\$Condition=="alcohol_statut-tolerant+") -1* (DF\$Condition=="alcohol_statut-tolerant-") -1* (DF\$Condition=="alcohol_statut+tolerant-")
c5 <- 2* (DF\$Condition=="alcohol_statut+tolerant+") + 1*(DF\$Condition=="alcohol_statut-tolerant+") - 2* (DF\$Condition=="alcohol_statut-tolerant-") -1* (DF\$Condition=="alcohol_statut+tolerant-")

($M = 3.57, SD = 1.67, n = 88$) as being seen as a worse potential teammate than the low status tolerant men ($M = 3.96, SD = 1.69, n = 78$), or when compared to the high status low tolerant target ($M = 3.22, SD = 1.81, n = 64$) or the low status low tolerant man ($M = 3.76, SD = 1.84, n = 68$), $F(3, 346) = 2.40, p = .02, \eta^2 = .01$ (the effect came significant, but the second contrast comparing the high status/tolerant target to the rest also yielded a significant interaction, $p = .04$, see figure 16).

Then, when we compared the participants perception on the physical measures (arm-wrestle), they did not judge the high status tolerant target ($M = 3.55, SD = 2.09, n = 88$) as being more competitive on arm-wrestle than the low status tolerant man ($M = 3.60, SD = 1.93, n = 78$) neither to the high status low tolerant man ($M = 3.53, SD = 2.06, n = 64$) or the low status low tolerant individual ($M = 3.13, SD = 1.75, n = 68$), $F(3, 346) = 0.82, p = .41, \eta^2 = -0.001$ (see figure 17).

Finally, as expected, we conducted the same 2x2 between-subject ANOVA on the third intrasexual competition DV testing the willingness to engage in a binge drinking competition with the target. Nevertheless, and contrary to our preplanned hypothesis, the high status tolerant man ($M = 3.83, SD = 2.23, n = 88$) was not viewed as more competitive in binge drinking game when compared to the low status tolerant target ($M = 3.65, SD = 2.20, n = 78$) nor to the high status low tolerant man ($M = 4.06, SD = 2.10, n = 64$) or to the low status low tolerant man ($M = 3.66, SD = 2.08, n = 68$), $F(3, 346) = 0.54, p = .22, \eta^2 = -0.004$.

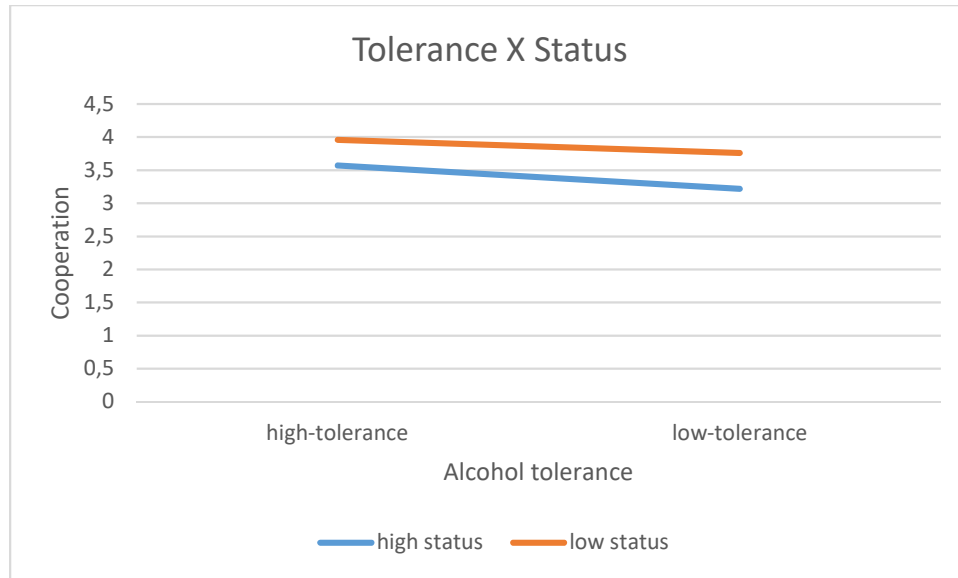


Figure 16. Interaction effect between alcohol tolerance and social status upon the willingness to cooperate.

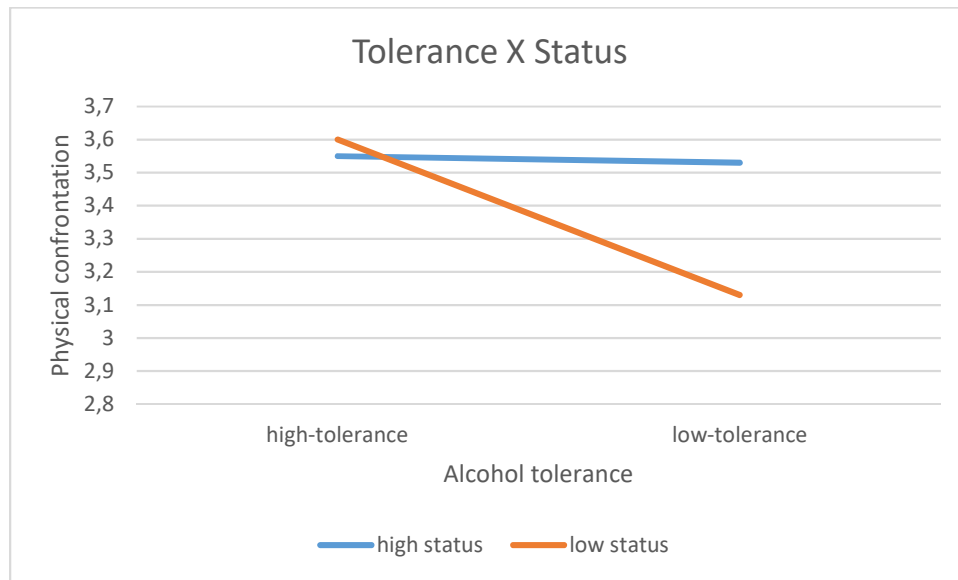


Figure 17. Interaction between the alcohol tolerance level and the social status on the willingness to confront physically the target.

Mediations analysis

We tested a second prediction trying to determine if the intrasexual competition (inserted as three different outcomes in the model because of the negative Cronbach’s alpha) moderated

by the social status could play a role in shaping the relation between the evaluation of the tolerant alcohol man and his perceive reproductive success. We ran a multiple moderated mediations model by following Preacher and Hayes's guidance (2008) using their PROCESS macro on SPSS (percentile bootstrap procedure with 5,000 bootstrap samples).

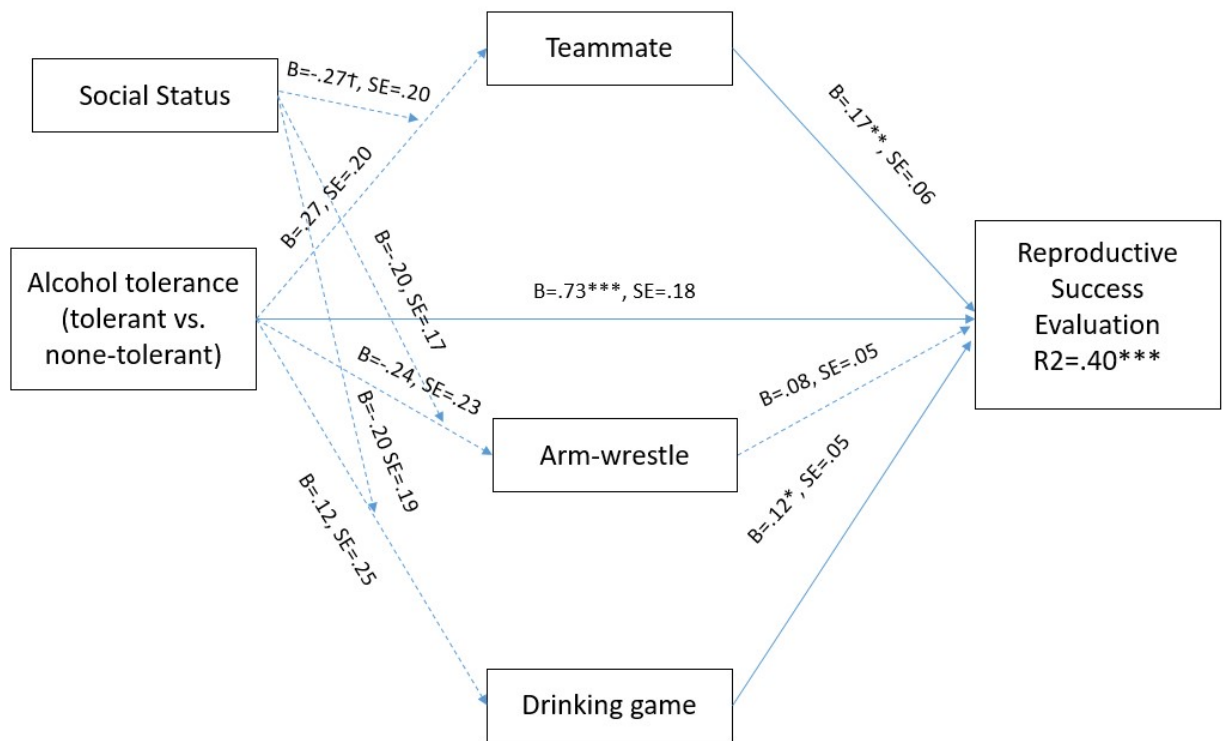


Figure 18. Multiple Moderated Mediations of the relationship between the different conditions of interests (alcohol-tolerant vs. non-tolerant) and the perceived reproductive success by intrasexual competition (sportive inclusion or binge drinking engagement) moderated by social status. Values designate non-standardized regression coefficients

(B). † $p < .1$, * $p < .05$, *** $p < .001$.

The results indicated that the evaluation of the target as a potential teammate did not mediate the relation between the perceived alcohol-tolerance and reproductive success because only the *b1* path was significant meaning that the more willing you were judged as being a potential teammate, the higher the reproductive success attributed ($p = .003$). However, the *a1*

path between alcohol tolerance and teammate was not significant, this was not a mediation *per se*. The analysis displayed the same pattern with the “drinking game” competition measure while the physical mediator did not revealed any effect (see figure 18). Additionally, the direct effect of the alcohol-tolerance on the evaluation of the target’s reproductive success being highly significant, that would mean that most of the effect is present in that particular relation (a small trend emerge with the alcohol tolerant man with low statut being more willing to be a teammate and so more willing to be evaluated as sexually successful, $p = .07$ and $.003$ respectively). The Bootstrap procedure (Table 4) confirmed that when running 5,000 multiple random samples from our initial data, none of the mediator came out significant, all of them with mediation effect close to zero.

Bootstrap Results for Mediation Effects			
		95% Confidence Interval (CI)	
	Mediation Effect (SE)	Lower	Upper
Mediators			
Arm-wrestle	.04 (.05)	-.02	.20
Cooperation	.02 (.07)	-.12	.19
Binge drinking	.03 (.06)	-.08	.19

Note. Boldface numbers indicate significant effect under 95% CI (SE) through 5,000 bootstrap samples (bootstrap percentile). The total mediated effect was not included in Study 3 and 4 because the PROCESS macro in SPSS did not display it in multiple moderated mediations, mostly because it is not very interpretable in that particular type of model (Hayes, 2013).

Table 4: Mediation and confidence intervals of the multiple mediation effects of tolerance to alcohol over the three mediators (arm, wrestle, cooperation and binge drinking competition).

3.3.3.5. Discussion.

The third study tried to improve Study 1's protocol by adding a social status variable proxy (cheap vs. expensive whisky) giving signals about the socioeconomic level of the men drinking. On the other hand, we updated the physical confrontation variable by changing a direct fight variable to indirect proxy of physical confrontation (arm-wrestle) and a direct drinking competition proposal. All in all, we tried to see if we replicate the main effect of alcohol tolerance on reproductive success as well as the cooperative mediation pathway observed in Study 1. Secondly, we predicted a 2x2 tolerance by status interaction with the high status/alcohol tolerant man being evaluated by participants as more sexually successful and more competitive than the low status/alcohol tolerant man.

The results revealed that the tolerance to alcohol (high + low status) had a positive effect on the evaluation by other male participants of the reproductive success of the target and that this effect was resistant to adding moderators that might have influenced this relation (intrasexual competitiveness, alcohol use disorder and sensation-seeking level). However, the different intrasexual competition measures did not reach significance making it impossible to conclude if alcohol tolerance do play a role in male-male competition. Knowing that our preplanned power analysis predicted a really high value (.95 expected with 300 participants and we ended up with 350 men at the end), it is highly unlikely that a lack of power explained the impossibility to reject the null, calling to a set of measure aiming at testing male-male competition in a systematic way.

Surprisingly, not only did the tolerance-status interaction did not go the way we expected, it revealed that the low-status-high tolerant target was judged by participants as a better potential teammate than the high-status-low tolerant man. One possible explanation might be that

drinking cheap alcohol is viewed as being more resistant than drinking expensive one and that there is an unexpected effect of tolerating such type of liquor (thus, we would drink expensive alcohol for culinary reasons and cheap one to get drunk). The mediation analysis did not reveal anything specific at the exception of a possible unexpected pathway: the tolerance was negatively moderated by the social status which led to a more positive evaluation of the target as teammate ($p = .07$, not significant but trend) and being more willing to be a teammate led to higher evaluation of the reproductive success of the target ($p = .003$). However, the moderation by the social status being only trend, we have to be extremely careful of such interpretation (Wood, Freemantle, King & Nazareth, 2014). Generally, misinterpretations of near significant p values come from the fact that giving low power, adding more data could lead to a less significant p value. Giving our really higher power in that case ($> .95$), this is quite unlikely but, in any case, a p value in the .05 region denote a quite weak degree of evidence making it difficult to reach a conclusion on any side.

3.3.4. Study 4

Study 3 outlined a direct relation between alcohol tolerance and the perception of reproductive success despite the social status of the target. All the dependent variables testing the intrasexual competition (cooperative teammate, arm-wrestle or binge drinking competition) did not display neither any significant nor strong effects. We thus decided to reproduce the Study 2 but with a competitive context adding the social status that we described in Study 3. One possibility is that the interaction emerged only when men are currently involved in a competition surrounding by women and not during an isolated scene focusing on a dating success that might look already acquired.

3.3.4.1. Method.

3.3.4.2. Participants.

In total, 1301 participants from the United States were recruited through the Amazon Mechanical Turk website (from June 2017 to July 2017). We processed similarly that in the first two studies by excluding women post-hoc (since it is not possible to pre-filter by gender on Mechanical Turk) and ended up with 520 males. After applying the same exclusion criteria than the first two studies (being a heterosexual, native English speaker male from the US and having passed the control and seriousness checks, our final sample was composed of 303 men. The mean age of the sample was 36.41 ($SD = 12.72$). Male participants in a romantic relationship at the time of the study ($n = 187$) outstripped the one who self-described themselves as “single” ($n = 116$). All of our final male participants had already consumed alcohol in the past.

3.3.4.3. Procedure.

The participants entered the same Google form through Amazon Mechanical Turk as used in the first two studies and were paid the same rate (\$0.25 for a 5 to 10 minutes assignment task). After the pre-instructions, the participants faced the exact same image that in Study 2 but we modified the description to incorporate our second independent variable “social status” (cheap versus really expensive alcohol).

A small description of the scene accompanied the picture where we could introduce more subtly the different conditions (in “[]” inside the text) in a 2x2 between-design subjects: alcohol tolerant man with high status, alcohol tolerant man with low status, none alcohol tolerant man with high status, none alcohol tolerant man with low status (as well as Red Bull tolerant condition for control but included only in the analysis of the main effect).

« Robert, on the left, and James, on the right, are playing a drinking game against one another. Claire and Mary are observing them. Despite having already had a few glasses of a very cheap [expensive] whisky

(\$20 a bottle [2,000\$ a bottle]), James, on the right is still [not] able to accurately shoot the ball into the cups and is winning [losing] the game. Rate the different statements below from “strongly disagree” (1) to “strongly agree” (7).»

Reproductive success impressions.

AUDIT-C (*Alcohol Use Disorders*). To assess participants' hazardous drinking for both chronic and binge drinking on a short-version of the original scale. There were 3 items: “How often do you have a drink containing alcohol?”, “How many units of alcohol do you drink on a typical day when you are drinking?”, “How often have you had 6 or more units if female, or 8 or more if male, on a single occasion in the last year?” Items were rated from 0 to 4 ($\alpha = .71$).

BSSS-8 (*sensation seeking*). To determine participants' level of sensation seeking, we used the brief sensation seeking scale containing 8 items ranging from 1 = *Strongly disagree* to 5 = *Strongly agree* ($\alpha = .78$, see Stephenson et al., 2007 for a validation of that scale).

Individual differences (*intrasexual competition*). Male were asked, on 12-items scale, how much statements assessing intrasexual competition applied to them ranging from 1 = *Not at all applicable* to 7 = *Completely applicable* ($\alpha = .87$, Buunk & Fisher, 2009).

Measures.

The key DVs were explicit judgments of the man's reproductive success (“James is going to have sex with Mary or Claire tonight”) along with intrasexual competition questions (one trait: “James could be one of your teammate player” and two counter-traits: “If necessary, you could engage in a arm-wrestle with James” and “You could play a drinking games against James”). This intrasexual competition DV did not include the three mentioned items because their alpha

was negative ($\alpha = -.0.83$) and all the measures were being analyzed separately to meet internal consistencies requirements for that type of analysis.

3.3.4.4. Results.

Reproductive success impressions.

When we applied the same contrasts that in Study 3, a one way-ANOVA revealed that participants did not evaluate the alcohol tolerant man ($M = 4.09$, $SD = 1.72$, $n = 131$) as being more willing to have sex with Mary or Claire the same night when compared to the none alcohol tolerant man ($M = 3.85$, $SD = 1.69$, $n = 121$) nor to the Red Bull tolerant man ($M = 3.67$, $SD = 1.52$, $n = 52$), $t(300) = 1.61$, $p = .11$, $\eta^2 = .01$. 2

Intrasexual competition impressions.

Cooperation DV.

When we applied specific contrasts to test directly the tolerance to alcohol to the two other factors of interests, the analysis revealed that participants did not evaluate the alcohol tolerant man ($M = 4.43$, $SD = 1.81$, $n = 131$) as being more willing to be a teammate when compared to the none alcohol tolerant man ($M = 4.01$, $SD = 1.74$, $n = 121$) nor to the Red Bull tolerant man ($M = 4.76$, $SD = 1.48$, $n = 52$), $t(300) = 0.80$, $p = .42$, $\eta^2 = .02$.

Interpersonal violence DV.

On the other hand, the willingness to engage in arm-wrestle did not revealed any significant difference when participants evaluated the alcohol tolerant man ($M = 4.56$, $SD = 1.97$, $n = 131$) compared to the none tolerant alcohol man ($M = 4.66$, $SD = 1.95$, $n = 121$) and the Red Bull tolerant man ($M = 4.71$, $SD = 1.76$, $n = 52$), $t(300) = 0.61$, $p = .55$, $\eta^2 = 0.001$.

Binge drinking competition.

Finally, the third intrasexual competition that we added in the experiment concerned the willingness to engage to a binge drinking competition with the target. However, participants did not judge the tolerant alcohol man ($M = 4.67$, $SD = 2.03$, $n = 131$) as being more threatening in a binge drinking competition than the none tolerant alcohol man ($M = 4.75$, $SD = 2.07$, $n = 121$) or when compared to the Red Bull tolerant man ($M = 4.92$, $SD = 1.91$, $n = 52$), $t(300) = -0.65$, $p = .52$, $\eta^2 = 0.002$.

Interaction between Alcohol tolerance and Social Status.

We also tested our predicted interaction between the tolerance to alcohol and the social status of the target to determine if the picture describing a tolerance and high-status male in a binge drinking contest will be perceived as having a higher reproductive success as well as being evaluated as more competitive compared to the low status tolerant alcohol tolerant target and to the none-tolerant males.

As for the reproductive success perception, the tolerant man with high status were not judged as statistically more successful ($M = 4.17$, $SD = 1.62$, $n = 64$) when compared to the tolerant man with low status ($M = 4.01$, $SD = 1.81$, $n = 67$). Even though the low tolerant man with high status ($M = 3.89$, $SD = 1.76$, $n = 57$) or with low status ($M = 3.78$, $SD = 1.65$, $n = 64$) displayed descriptively lower rating, the separate 2x2 ANOVAs on each variable in a 2 (tolerant vs. none-tolerant) x 2 (high vs. low status) did not yield any significant effect, $F(3, 299) = 0.64$, $p = .92$, $\eta^2 = -0.004$.

When we analyzed the intrasexual competition measures, we found that the cooperation measure (teammate) did not display any interaction, $F(3, 299) = .01$, $p = .80$, $\eta^2 = .003$, nor did

the physical confrontation ($F(3, 299) = 0.11, p = .76, \eta^2 = -0.009$) or the binge drinking competition, $F(3, 299) = 0.15, p = .55, \eta^2 = -0.009$.

Mediations analysis

We tested a second prediction trying to determine if the intrasexual competition (inserted as three different outcomes in the model because of the negative Cronbach's alpha, $\alpha = -.083$) could play a role in shaping the relation between the evaluation of a tolerant alcohol man and his perceive reproductive success when social status moderated the tolerance-male-male competition relation. We ran a multiple mediation model by following Preacher and Hayes's guidance (2008) using their macro on SPSS (percentile bootstrap procedure with 5,000 bootstrap samples).

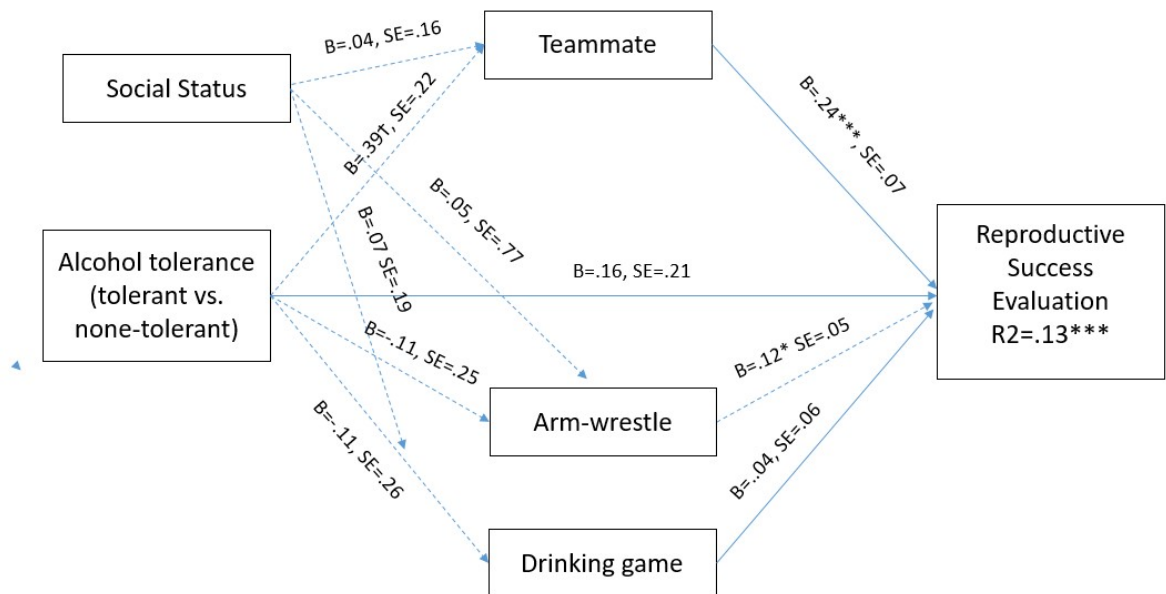


Figure 19. Mediation of the relationship between the different conditions of interests (alcohol-tolerant vs. non-tolerant) and the perceived reproductive success by intrasexual competition (sportive inclusion or interpersonal violence engagement). Values designate non-standardized regression coefficients (B). † $p < .1$, * $p < .05$, *** $p < .001$.

.001.

The results indicated that the evaluation of the target as a potential teammate may mediate the relation between the perceived alcohol tolerance and reproductive success (the more the man was tolerant to alcohol, the more the participants was willing to be his teammate, the higher his reproductive success). However, only the *b* path was significant ($p < .001$) while the *a* path revealed only a marginally significant effect ($p = .08$). The intrapersonal violence outcome, on the other hand, did not significantly mediate this relation (figure 19 and table 5). Additionally, the direct effect of the alcohol tolerance on the evaluation of the target's reproductive success was not significant ($p = .12$) and the effect emerged only when taking into account the two mediators ($p = .02$) which could indicate that the major party of the effect is explained by the cooperation mediators.

Bootstrap Results for Mediation Effects			
	Mediation Effect (SE)	95% Confidence Interval (CI)	
		Lower	Upper
Mediators			
Arm-wrestle	-.02 (.06)	-.17	.10
Cooperation	-.06 (.11)	-.33	.14
Binge drinking	-.00 (.04)	-.10	.06

Note. Boldface numbers indicate significant effect under 95% CI (SE) through 5,000 bootstrap samples (bootstrap percentile).

Table 5: Mediation and confidence intervals of the multiple mediation effects of tolerance to alcohol over the three mediators (interpersonal arm-wrestle, cooperation and binge drinking competition).

3.3.4.5. Discussion.

Study 4 tested the same set of hypothesis than Study 1 to 3 but in a drinking competitive context. We were unable to reject the null hypothesis in this last study and the analysis always failed to reach significance. Despite being descriptively in the good direction, the alcohol tolerant man was not evaluated by the participating as being significantly more willing to have a sexual relationship with any of the girls described in the picture. More counter-intuitive, the descriptive statistics indicate that in the cooperation measures, the Red Bull tolerant man may be the one most of participants may be more willing to pair with. Even though, this did not reach significance either, one possible explanation is that Red Bull may be associated implicitly by male participants with sportive drink since it sponsored extreme sport events among other things. Finally, the physical and binge drinking confrontation did not yield any probing results, nor did the interactions.

The multiple moderated mediations did revealed a weak pathway with high tolerant men being judged as more willing to be a teammate (only trend significance, $p = .08$) while the men willing to be a teammate was evaluated by the participant as having more chance to have sex with the female target ($p < .001$). Again, this mediation is weak and difficult to interpret since the a pathway was only a trend but with our high power, this is possible that adding more data would led to lower the p value.

3.4. General Discussion

Why do so much men engage in binge drinking in comparisons to women? Why, in particular, do young men are overwhelmingly participating in binge drinking games that not only decrease their erectile function or sexual desire but also affect their cognitive skills in such a way that it may be difficult either to defend themselves in case of physical conflicts with another man or to be able to seduce potential mates? We argued that they might be an evolutionary

explanation to this phenomenon and that being able to resist the effect of alcohol (shaking, vomiting, trouble speaking, etc.) may demonstrate high genetic quality.

The main problem is: to whom is the message sent? To a potential mate, to another man or to both? We defended, based on the costly signal theory (Diamond, 1992; Zahavi, 1975; Zahavi & Zahavi, 1999) that they could be multiple targets to those signals and than men could be the main one. However, we also thought the context was crucial to determine the type of message being sent. In a dating context, if no potential competitors are present (which can happen in a causal one-to-one date), tolerating the effect of alcohol are obviously sent to the women and might be considered an evolutionary stable strategie (Grafen, 1990a, 1990b) to demonstrate the true genetic quality of the individual (the man) perceived naively by the receiver (the woman) and publicly advertised. Nevertheless, even in a dating context, we postulated that alcohol tolerance could pinpoint multiple targets and that other men might actually be the main receivers of the signal by indicating both the reproductive potential of the signaler as well as his competitiveness.

In Study 1 to 3, the perception of reproductive success was effectively higher for the men tolerating alcohol than for the men describing as having alcohol-related symptoms (experimental group) or compared to men tolerating the effects of Red Bull (control group). Despite our expectations, even in the second Study 2, where the context was a drinking competition between two men surrounded by two women, the reproductive success variable still reach significance demonstrating that there might be a robust effect on that signal independently of the context (only Study 4 failed to reach significance on that measure, despite going descriptively in the same direction). All our study were pre-registered to avoid publication bias, reinforce reproducibility and transparency as well as display high statistical power ($> .95$, Cohen, 1977).

Interestingly, Zahavi and Diamond's original points seem to be at play when men perceived other alcohol tolerant man (which may be in itself a sign of competitiveness and could possibly restrain other men for trying to interfere in the mating process). Additionally, it is important to precise that our measures were specifically focusing on short-term mating since we were asking the participants about the likelihood of having a sexual relation in the following hours (in the succeeding night). Indeed, many studies tend to show that mating criteria displaying genetic quality are particularly salient for short-term mating (Gildersleeve et al., 2014; Kenrick, 2013; Li & Kenrick, 2006; Thornill & Gangestad, 2002) but that those same criteria decrease dramatically when women are being asked about long-term relationship (Buss, 1998; Stewart, Stinnett & Rosenfeld, 2000). The Study 4, while being descriptively in the good direction, failed to reach significance. This is hardly due to statistical power as we mentioned before since our preregistered large sample experiments tend to avoid such statistical difficulties. One of the reason might be that adding the two type of status in the tolerant man in a binge drinking contest might have confused participants because playing games with such expensive alcohol might be seen as highly artificial.

We had a competitive none-mutually exclusive hypothesis to Zahavi's framework. We intended to develop a model incorporating the intrasexual competition between men as another important feature to the signaling of alcohol tolerance. We predicted, not only that alcohol tolerance will be perceived as a stronger competitive feature by other men, but that intrasexual competition between men would mediate the relation between tolerance to alcohol and reproductive success. Globally, the results were largely contradictory to our second hypothesis as the cooperation DV effectively came out significant only in the first and fourth study (and mediated the relationship with reproductive success) but failed to be reproduced in the two

following studies. More surprisingly, the tolerance to Red Bull, though never reaching significance, seem to strengthen the perception of competitiveness of the target (which can be due, as we mentioned before, to the link between the Red Bull brand and extreme and risky sports advertising).

Finally, in Study 3 and 4, we added a social status variable to test a possible interaction predicting that among tolerant men, the highest status man will be perceived as more sexually successful and competitive compared to the lowest status man. However, even though the results were quite mixed for the reproductive success measures (significant and moderately strong in Study 3 and none-significant in Study 4), the intrasexual competition measures did not revealed the interaction we were looking for in those online studies, leading to further discussion about the role of social status in the consumption of alcoholic beverage.

A number of limitations weakened our studies. Primarily, it is interesting and quite surprising to notice that the different indexes of men intrasexual competition (cooperation, physical confrontation and even binge drinking further competition in the last two studies), did not correlate with each other, revealing either an average very low alpha or even a negative one. While the cooperation measures worked partially in our project, the two other measures did not revealed any particular directions leading us to interrogate the quality of intrasexual competition measures in general and their generalization outside of a specific context. One reason might be that any particular environment brings its proper intrasexual competition measures making it difficult to generalize in the a case of dating or drinking competition.

Secondly, the fact that the willingness to be a teammate worked in Study 1 and 4 but that the other measures never did made us consider intrasexual competition as indirect violence through proxy like sports or other type of none-physical competition. After all, among human

and non-human animals, most of conflicts are being resolved without violence and external features indicate, per se, the strength of the prey for the predator or the other rival when there is fight for resources, territories or potential mates.

Moreover, contrary to our pre-registered hypothesis, none of the intrasexual competition measured mediated the relation between alcohol tolerance and reproductive success except in Study 1 (and possibly in Study 4) where the cooperation measure explained part of the main effect. It is also possible that the original Zahavi-Grafen framework would work in such a way that men perceiving men resisting negative effects of alcohol as being more sexually successful and naturally withdraw from any further competition (since the reproductive success measure was always the first presented, there might have been an order effect influencing the subsequent responses and the following competition dependent variables). In that particular case, animal literature may exemplify this idea when you have just a confrontation without fight and animals or insects give up on their mate even before any type of physical confrontation. The reproducibility of the direct effect of alcohol tolerance on reproductive success may also lead to the claim of the costly signal theory as multiple-target signals. Tolerating alcohol may be a message to both females (genetic quality) and males (competitiveness) but the tolerance itself would be a cue of competitiveness in general with men naturally withdrawing from having to battle for mating competition.

On the other hand, two other demographics we did not expect could have influenced the results. First, the age of sample (> 30 years old) may have played a role since binge drinking in college is highest at 18-25 years old and our sample might have already been too old to display a particular type of intrasexual competition over such drinking context. Also, consider that we recruited only online participants from the United States, that might have interfered with our

predictions. The American culture, wherein binge drinking is largely extended, is also much more exposed to prevention messages or educational programs that may interact with the norm about engaging such conducts. Countries where binge drinking is on the rise and where preventions is not developed enough might be a better sample target to replicate those findings.

Other studies had explored specifically drinking games as a venue for sexual competition. While male students are, for instance, well-aware of the risk of binge drinking, this biological enigma appears less puzzling when we look at both student's motivations and drinking games rules (Hone, Carter & McCullough, 2013). As we developed before (Chapter 1), drinking games have explicit rules that permit to punish cheaters, test physiological and cognitive abilities (e.g., beer-pong), and give explicit reasons such as wanted to win and take risks to justify their participation (Johnson & Sheets, 2004). Participants also give mating reasons to play drinking games and mention sexual possibility as a reason to stop the game (Borsari, 2004; Johnson, 1999; Johnson, 2002). In a more systematic study, Hone, Carter and McCullough showed that sex differences in binge drinking frequency and intensity were partially mediated by mating effort and social competitiveness. However, their study was purely correlational and it is thus impossible to trace the dynamic at play. To our knowledge, our studies were the first to try to manipulate experimentally drinking tolerance and mating motivation in an impression-formation tasks involving a large sample of men.

To summarize, while the alcohol tolerance appeared to play a role on the perception of reproductive success by other males, the intrasexual competition did not mediate this relation leading us to think that binge drinking might be a message addressing directly to other males indicating them the genetic quality of the target and his chance of potential mating (in that case, no need to even demonstrate physical or whatever type of other physical resistance). Further

studies should try to reproduce this findings in a field experiment (bars or fraternities) to evaluate what might be the evolutionary reasons of such risky conducts or consider developing countries sample as a more adapted population. Digging such experimental issues can help to build prevention programs that would craft specific messages directing at men. While they perceived tolerant alcohol men as being more sexually successful, the reality is all different and the medical and physiological data we have tell, on the contrary, that binge drinking impact negatively sexual functions (Derby et al., 2000).

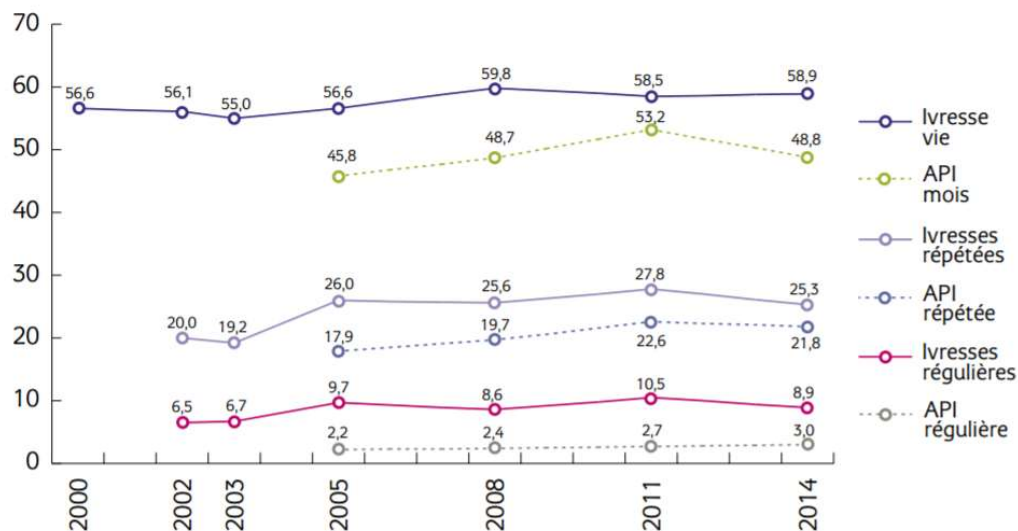
Chapter 4: Risks Signaling as a Prevention Tool Against Binge Drinking: a Field Experiment in a French High School and an Online Replication.

Alcohol consumption is the second largest cause of death in France with about 50,000 victims a year as well as numerous cancers, cardiovascular, digestives and mental diseases directly imputable to the toxic product (Castelnuovo et al., 2006; CDC, 2016; Corrao, Bagnardi, Zambon & La Vecchia 2004; OFDT, 2016). On the other hand, the social cost of alcohol in France is estimated to exceed billions of euros per year, those include massive health costs (despite a high-maintenance health) in addition to economic (lack of productivity) and social expenses (violence, drunk driving, sexual risks, etc., see OFDT, 2016). Understanding risky drinking through the lens of an evolutionary framework can help draw precise experimental hypothesis. In particular, binge drinking tolerance can be analyzed as multiple signals toward female mates and male competitors. Acting against those signals by updating people's explicit beliefs about both sexual and cognitive impairments caused by binge drinking may act as a shield against this ancestral practice. More specifically, associated binge drinking with sexual dysfunctions may be particularly effective among adolescents and young adults entering sexual competition (Hill & Chow, 2002; Kaplan & Gangestad, 2004).

Among the myriad of alcohol practices, one that is of great of concern for European and US authorities is what is named "binge drinking". It is generally defined as drinking more than 4/5 (women/men) standard drinks (10 grams of alcohol) in less than 2 hours (EMCDDA, 2016; NIAAA, 2004). In France, this massive alcohol consumption tendency has dramatically increased in the past couple decades whereas chronic alcohol and tobacco consumption seem to be falling tremendously since the 60s (OFDT, 2014). Not only this practice presents health risks in itself (ethylic coma, consciousness lost, vomiting-related deaths) but is also generally

connected to a number of harmful behaviors such as inter- and intra-personal violences (aggressions and suicides respectively, see CDC, 2009; McMurrin, 1999), drunk driving (Keall, Frith & Patterson 2005), HIV infections (Robertson & Plant, 1988) and general high-risk conducts that can damage both the drinker and the surrounding individuals.

The ESCAPAD survey (OFDT, 2014), realized every 3 years during the Defense and Citizenship Day (Journée Défense et Citoyenneté), following 17 years old French youth, revealed that alcohol was the most diffused toxic substance with about 9 out of 10 adolescents admitted having already drunk (89.3%) far ahead from tobacco (68.4%) and cannabis (47.8%). Since 2002, the regular use of alcohol (at least 10 standards drinks in the last 30 days) is on the



Source : Enquêtes ESCAPAD - OFDT

Figure 20. ESCAPAD Survey, 2014 © OFDT. “Ivresse vie” = Percentage of lifetime intoxication. “API mois” = binge drinking episodes per month. “Ivresse répétées” = At least 3 intoxications a year. “API répétée” = At least 3 binge drinking episodes a year. “Ivresses régulières” = At least 10 intoxications a year”. “API régulières” = At least 10 binge drinking episodes a year.

rise. People of this range of age consume more regularly (12.3%) in 2017 when compared to 2011 (10.5%). Young males are particularly adept of regular drinking (17.5%) in comparisons to young women (6.8%). Binge drinking practices during the past month represented, in this survey, almost half of the French teenagers (48.8% in 2014, in green on figure 20) and the vast majority of those alcohol intoxication occurs during social events in one's friend's party (89.4%) which emphasize the social characteristics of such practice in opposition to alcoholism (Weitzman, Nelson & Wechsler, 2003).

Various attempts to reduce this trends have been made both in North America (Wechsler et al., 2002) and Western Europe (WHO, 2012) trying to prevent such risky conducts from emerging in teenagers. Those tools generally target the risks at play while drinking massively in a short period of time but, so far, no theoretical background had helped to build specific hypothesis-generating prevention programs to control and test the strength, robustness and replicability of those effects. While making prevention spots may be a really good way to target adolescents, not controlling for the different type of signals displayed inside the video may, in best cases, have low impact and, in worse cases, have a counter-effect, increasing positive attitude or consumption toward alcohol (as for some types of fear signals, see Witte & Allen, 2000 for a meta-analysis). For instance, the French Institute for Health Prevention and Education (INPES) have made over the past years dozen of professional clips directing at adolescents, adults, educational and health professionals. However, the different type of risks associated with binge drinking are usually mixed up together (violence, sexual abuse, ethylic coma and accidents, etc.).

In this article, we used the same professionalism by hiring a video-making companies (BP Production) but instead of mixing the different risks at play, we made several videos in the

exact same conditions but with different outcomes: sexual impotence OR cognitive impairing OR long-term effects (cancers, cardiovascular diseases). We proposed that the sexual dysfunction clip will be the most impactful on alcohol attitude and expectancies, following by the cognitive one and by the long-term video. Moreover, we also think that the two short-term risks videos (sexual and cognitive) will be more impactful than the long-term clip (Tymula et al., 2012). Distinguishing risks at play in binge drinking while targeting specific populations might be the key aspect to affect such conducts or at least to send relevant signals aiming at reducing positive attitudes and expectancies toward binge drinking.

4.1. Costly Signal Theory

We proposed here to use an evolutionary framework attempting at differentiate the risks at play in prevention videos according to the lifetime of the participants in an ecological environment (French high school). The costly signal theory (Zahavi, 1975; Zahavi & Zahavi, 1975) proposes that specific messages are sent through the lifetime of an animal or individual and that context-specific responses may trigger special types of behavioral responses. For instance, among non-human mammals, the peacock is one of the most famous examples of a costly signal. The peacock's tail length and number of ocelli are positively correlated with reproductive success and territory display (Loyau, Jalme & Sorci, 2005). According to Zahavi's theory, such features indicate the genetic quality of the owner. If a male can afford to maintain such a costly character and still be able to survive and fight, that would indicate to other potential mates high genetic quality material transferable to offspring. On the other hand, it shows strength to potential competitors. Indeed, the cost of such signal is not only internal but external in the sense that other males can spot the feature from far away which makes the signalers really

exposed to possible attacks and weaken it (difficulties to fight or to escape; head ornaments among ring-necked pheasant males for instance, Mateos & Carranza, 1997).

Similarly, humans seem to display behavior that carry extra costs, unnecessary at first glance, but that might had evolutionary interests such as attracting other women or impressing other male competitors (Sundie, Kenrick, Griskevicius, Tybur, Vohs & Beal, 2011). Alan Grafen (1990a, 1990b) modeled this theory finding two stables evolutionary strategies: one for female and one for male. Basically, males display their true genetic quality publically (they cannot cheat or lie on their tolerance to alcohol in our particular case) and female believe that the message sent is true. Our main objective in this chapter was to counter this signal by sending to men and women the true effects of binge drinking: sexual impotence (throughout erectile dysfunction, lower sexual desire, etc.), cognitive deficits (diminished short-term memory and concentration, etc.) and long-term risks (cardiovascular diseases, cancers, etc.). However, contrary to current prevention programs in France and the US, our idea was to produce professional videos with high school students that differentiate those risks and evaluate to what extent such new messages could interfere with the evolutionary signals that men may sent to other peers.

The timeline of the risks displayed in our videos made our theory in competition with a more proximal behavioral economical one. Adolescents had been shown to be more willing to gamble and take risks when exposed to ambiguous economics risks while actually taking fewer risks than adults when the odds at play were clearly exposed (Tymula et al., 2012). As a consequence, there is a parallel hypothesis postulating that the sexual and cognitive deficits spots will be more impactful globally than the long-term video. This could be due to time-perception of adolescents about future risks and we defend that our distal evolutionary postulate is not mutually exclusive with a proximate analysis. In that sense, both predictions could work at the

same time and sexual spots will still be the most impactful for teenagers when compared to the other ones. However, we also postulate that the cognitive and sexual spots together will have a stronger effect than the long-term video.

We ran two studies to test our predictions. First, we implemented our material during different classes in a French High School (in Grenoble) to evaluate the effect of our spot in a specific early- or not drinking population entering sexual competition. Then, we tried to replicate those findings in an online sample of more advanced students that are older and more in a regular contacts with alcohol. Taking together, this findings should be used as a first step toward more targeted health prevention programs.

4.2. Study 1: Field Study in a French High School

The following study aimed at evaluating the effect of different signals associated to alcohol risks upon young men and women in an ecological environment (high school course). While the past prevention spots used to mixed the different risk associated with binge drinking, our videos attempted at implement one risk per video (sexual, cognitive, long-term risks) while keeping the rest of the video exactly equal to be able to compare the results on various measures.

After the spot, and following various questionnaires, female participants evaluated a man (Nicolas) drinking whisky with a women's friend (Manon) during a causal date. We wanted to evaluate if the different spot diffused (in between-design) influenced the way they judged Nicolas's situation, Manon's intentions as well as Nicolas's attractiveness level. We predicted than when facing the sexual clip, women would tend to judge Nicolas's situation and attractiveness more negatively and Manon's intention to date Nicolas as lower when compared to the cognitive and long-term risks spots. Additionally, we also thought that the short-term spot

combined (sexual and cognitive) would present the same pattern of results when compared to the long-term risks video.

In parallel, men were exposed to a situation where a man has participated in a binge drinking game and ended up in a state of advanced intoxication. This aspect of massive drinking reflects the competition that can be established between men during competitions in liquor games. Similarly to the women study, we evaluated how men judged Nicolas's situation but added willingness to cooperate with him (teammate) and to play against Nicolas in a sportive competition. Again, we predict that the sexual spot will be the most impactful when compared to the other spots and that men would be less willing to be a teammate when viewed the sexual clip and more tempted to play against him in a sportive competition when compared to the other clip (and, similarly for the short- vs. long-term comparisons).

4.2.1. Method.

4.2.2. Participants.

In the present study, 269 participants from a French high school (Lycée Emmanuel Mounier in Grenoble) were recruited in April 2017 during class sessions (62,8% of women) with a mean age of 15.94 ($SD = 0.93$). While playing randomly in 13 different classes (8 classes 10th grade and 5 classes of 11th grade), the different spot were pretty well balanced in the different groups (sexual spot = 60 participants, cognitive = 72 participants, long-term diseases = 68 participants and 69 students in the control group where they did not view any of those spots).

4.2.3. Procedure.

We hired a professional film company (BP Production) and worked with the Mounier High school in order to provide both a professional outcome and updated one with scenes and languages that could match student's current way of behaving and speaking (this work took

about 6 months). Few students of the high school actively participated in the conception, realization as well as scripting of the different clips (the movies are all available here with English subtitles:

https://www.dropbox.com/sh/udnfso6bc31w4u8/AAB_7scvj_SAKvltWaYnwcMQa?dl=0).

During a class sessions, the participants were explained that the University of Grenoble Alpes was running a series of prevention actions in the region aiming at preventing alcohol abuse among youths. Before running the clip, we presented the students with several questionnaires (sensation-seeking, impulsivity, alcohol consumption and frequency). Once the clips was run, women students were asked to react to a scene with a man drinking whisky right next to a friend during a casual date (the same one used in chapter 3, see a reproduction of figure 12 below) whereas male students were asked about a male playing a drinking game and ending up massively intoxicated (see figure 23 below; pretested on 67 heterosexual men who described themselves as native English speakers: $M_{\text{attractiveness}} = 2.51$, $SD_{\text{attractiveness}} = 1.26$, $M_{\text{masculinity}} = 3.46$, $SD_{\text{masculinity}} = 1.42$, $M_{\text{age}} = 24.21$, $SD_{\text{age}} = 3.79$).



Figure 12. Picture displayed after the clip for women participants.



Figure 22. Picture displayed after the clip for men participants.

4.2.4. Descriptive results.

We briefly presented below, in the different tables, the descriptive states of our sample. Quite surprisingly, the total number of alcohol drinks in their lifetime (or during the last 30 days, see Appendices) did not displayed major differences between men and women. In their total lifetime, men only had a little more of drinking days (30 days or more) when compared to women (12.12% against 11.76%). Regarding chronic alcohol, among men there is a cider and beer consumption superior to 10% and, surprisingly, 15% of the male student reported drinking champagne every day (it might have been during a festive week at that time). On the other hand, women did not consume any alcohol beverages every day and only cider seemed to be a regular trend among them monthly (more than 20% of them reported drinking cider on a monthly basis).

Binge drinking, the major concern of this article, clearly depicted a pattern of men drinking more than 4 or 5 drinks or more in an occasion when compared to women (8% of men reported drinking, on average, more than 4 or 5 drinks on average while women were only

around 3%). Similarly, regarding alcohol intoxication, while the vast majority of the high school students reported never having been drunk, the few that reported being drunk more than 4-10 times or more were only men.

Measures.

BSSS-8 (*sensation seeking*). To determine participants' level of sensation seeking, we used the brief sensation seeking scale containing 8 items ranging from 1 = *Strongly disagree* to 5 = *Strongly agree* ($\alpha = .62$, see Stephenson et al., 2007 for a validation of that scale).

BIS11 (*impulsivity*). All participants were asked, on 20-items scale (The Barratt Impulsiveness Scale, Patton et al., 1995), how much statements assessing impulsive behaviors applied to them ranging from 1 = *Completely disagree* to 4 = *Completely agree* ($\alpha = .73$, see Billieux et al., 2012 for a recent use).

Spot understanding.

Participants were asked if they understood correctly the different spots at play on scale from 1 to 7. On average, participants understood very well the different spots at play ($M = 6.26$, $SD = 1.33$) but few participants actually answered that specific check question with only 140 answers over 269 participants in total (ending reporting understand only on the sexual and the long-term diseases spots due to lack of responses). An omnibus ANOVA did not reveal any difference between the different spot, $F(2, 137) = .73$, $p = .49$, $\eta^2 = .01$.

Dependent variables.

The key DVs were quite different for men and women. After having watched one of the three clips (sexual, cognitive, long-term diseases), a picture was presented to women (a man

drinking with a girls on his side, Manon) and to men (a highly intoxicated man following a drinking game). Both female and male participants had to react to all the sentences on a 1 to 7 Likert scale ranging from “*Completely disagree*” to “*Completely agree*”.

The first one was shared by both genders: “You would not like being in the same situation that Nicolas”. Then, female confronted two others affirmations “Manon seemed to finally have a crush for Nicolas” and “Nicolas is pretty attractive”. The two last reproductive success measures displayed a very weak internal consistency and were thus treated independently ($\alpha = .29$).

Men faced two different sentences: “You could participate in a sporting event in Nicolas’s team” and “If necessary, you could play against Nicolas in a sporting event”. The two last intrasexual competition measures displayed a weak internal consistency and were thus treated independently ($\alpha = .51$).

4.2.5. Results.

Situation embodiments (women only).

When we applied contrasts to test the sexual spots against all the other spots, against the cognitive spot, and against the control spots respectively (3, -1, -1, -1; 1, -1, 0, 0; 1, 0, 0, -1; Brauer & McClelland, 2005), a one way-ANOVA revealed that our contrast of interest was only marginally significant. Women were not less willing to encounter themselves in the same situation than Nicolas after viewing the sexual prevention spots ($M = 4.78$, $SD = 2.28$, $n = 46$) than after viewing the cognitive spot ($M = 5.54$, $SD = 1.92$, $n = 41$), the long-term ($M = 4.50$, SD

= 2.51, $n = 42$) or the control video ($M = 5.59$, $SD = 1.91$, $n = 41$), $t(166) = 1.82$, $p = .07$, $\eta^2 = .04$ ¹¹.

Reproductive success (women only).

When the same set of contrasts was applied to test the effect of the prevention spots on the reproductive success of the target, the analysis revealed no difference after being exposed to the sexual spot ($M = 3.78$, $SD = 1.79$, $n = 46$) when compared to the cognitive ($M = 4.17$, $SD = 1.74$, $n = 41$), long-term ($M = 4.00$, $SD = 1.93$, $n = 42$) or control videos ($M = 4.33$, $SD = 2.07$, $n = 41$), $t(166) = 0.28$, $\eta^2 = .01$.

Attractiveness (women only).

Finally, when this set of contrasts was applied upon the attractiveness of Nicolas, female participants did evaluate the latter as being less attractive after viewing the sexual spot ($M = 1.67$, $SD = 1.14$, $n = 46$) than women having being exposed to the other spots, $t(166) = 2.43$, $p = .02$, $\eta^2 = .04$ (with one outlier displaying a $SDR > 4$).

However, when the sexual spots was compared to the cognitive spot ($M = 1.51$, $SD = .98$, $n = 41$), as this was the case in the second set of contrasts, Nicolas was being judged as even less attractive after viewing this spots when compared to the sexual one, $t(166) = 2.39$, $p = .02$, $\eta^2 = .04$. Even after controlling for the impulsivity and sensation-seeking levels, this set of contrasts remain significant ($p = .04$).

Additional analysis

¹¹ We checked in every analysis for potential statistical outliers following the studentized deleted residual technics indicating that a level greater than 4 is consider as outliers (see McClelland, 2014). When no additional information were added, this meant the results remained the same with or without outliers.

We also compared the short-term clear risks videos (sexual and cognitive spots) to the long-term ambiguous ones with contrasts (+1,+1,-2,0;+1,+1,-1,-1;+1,-1,0,0). In that case, women were less willing to be in Nicolas's situation after visioning the clear risks spots ($M = 5.14$, $SD = 2.14$, $n = 87$) than after the long-term ambiguous videos ($M = 4.60$, $SD = 2.52$, $n = 42$), $t(166) = 2.07$, $p = .04$, $\eta^2 = .04$.

However, neither the reproductive success measures nor the attractiveness ones were significant for that hypothesis (respectively $p = .43$ and $p = .09$).

Situation embodiments (men only).

Regarding the male sample, participants were not less willing to accept themselves in Nicolas's situation after viewing the sexual clip ($M = 5.93$, $SD = 2.13$, $n = 14$) than after having watched the cognitive ($M = 5.00$, $SD = 2.51$, $n = 31$), long-term diseases ($M = 5.19$, $SD = 2.55$, $n = 26$) or the control spot ($M = 5.82$, $SD = 2.25$, $n = 28$), $t(93) = 0.70$, $p = .49$, $\eta^2 = .03$.

Teammate (men only).

On the other hand, when asked if they would take Nicolas as a teammate participants, male participants did not rate differently Nicolas after viewing the sexual clip ($M = 2.71$, $SD = 2.02$, $n = 14$) than after viewing the cognitive ($M = 2.76$, $SD = 2.08$, $n = 31$), the long-term diseases ($M = 2.27$, $SD = 2.05$, $n = 26$) or the control spots ($M = 2.67$, $SD = 2.30$, $n = 28$), $t(92) = 0.89$, $p = .37$, $\eta^2 = .01$.

Sport competition (men only).

Finally, the willingness to engage in a sportive competition against Nicolas did revealed a significant difference when participants evaluated Nicolas after viewing the sexual spot ($M =$

4.64, $SD = 2.30$, $n = 14$) versus viewing the cognitive ($M = 5.17$, $SD = 2.51$, $n = 31$), long-term diseases ($M = 3.38$, $SD = 2.61$, $n = 26$) or the control group ($M = 4.71$, $SD = 2.60$, $n = 28$), $t(93) = 2.47$, $p = .02$, $\eta^2 = .07$. However, our second contrasts also came out significant meaning that they would rather confront Nicolas in competition after viewing the cognitive videos than the sexual one, $t(93) = -2.61$, $p = .01$, $\eta^2 = .07$.

Additional analysis

We also compared the short-term clear risks videos (sexual and cognitive spots) to the long-term ambiguous ones with contrasts (+1,+1,-2,0;+1,+1,-1,-1;+1,-1,0,0) like we did in the women sample. However, our first contrasts of interest never came out significant for the embodiment or the cooperation measures ($p > .1$). The competitive measure, play against Nicolas in a sportive competition, was only marginally significant, with participants being more willing to fight Nicolas after viewing the sexual and cognitive spots ($M = 5.00$, $SD = 2.43$, $n = 45$) when compared to the long-term videos ($M = 3.38$, $SD = 2.61$, $n = 26$) or the control group ($M = 4.71$, $SD = 2.60$, $n = 28$), $t(93) = 1.92$, $p = .058$, $\eta^2 = .07$.

4.2.6. Discussion.

Our analysis revealed that while the spots were, on average, very well understood by all the participants, men did not display any differences about their willingness to be in the target's situation. Whereas, on the other hand, women were less likely to accept being in the same situation than Nicolas after visualizing the sexual spot when compared to the control spot. However, the cognitive video also appeared to send a strong signal and that interfered with our purely reproductive success hypothesis.

Although the reproductive success and teammate measures did not display any differences on the impression tasks after viewing the different spots, female participants evaluated Nicolas as being less attractive after watching the sexual impotent message compared to the other conditions. However, a second contrast, recurrent in our study, also explained a significant part of the variance in that measure with Nicolas being rated even less attractive after the cognitive impairment spot than after the sexual impotent one ($p = .02$). This attracted our attention since those videos were displayed in a scholar context, during a class of 11th grades, few weeks before a French exam (the first part of the Baccalauréat, the equivalent of the American SAT).

Finally, the same pattern emerged for men when asked whether they would be willing to participate in a sportive competition against Nicolas. The influence of the cognitive impairment spot was stronger than the sexual impotent video meaning that male students would be rather more willing to fight against Nicolas after viewing his cognitive difficulties. Again, the scholar context may partially explained this differences as well as the really young age ($M = 15.94$, $SD = 0.93$) of the participants who probably modulated the impact of the sexual message.

4.3. Study 2: Online Replication

4.3.1.1. Methodology

4.3.1.2. Participants

4.3.1.3. Procedure

From September to December 2017, we recruited through social network sites (Facebook, Twitter) or Forums 85 male participants and 165 female participants from France. After excluding people who declared never had consumed alcohol, failed to described the video or answered the seriousness check, we ended up with 77 men ($M = 23.88$, $SD = 4.76$) and 100

women ($M = 23.01$, $SD = 5.01$). Participants entered an online Google form where they had to fill up the BSSS8 and the BIS11. Contrary to the first study however, after viewing one of the three preventions spots (sexual, cognitive, long-term disease) or the control page (no video), they had to answer about a situation of a men tolerating alcohol in a dating context (for women, see figure 12) or in a drinking competition (for men, see figure 14).

Contrary to the field study, men and women in our online sample presented major gender differences on several aspects. First, in both their total lifetime and in the last 30 days, men constantly reported having drinking more (respectively 84.70% and 4.71%) than women (69.81% and 1.89%). Similarly, women are more than twice likely to not have drink at all in the past 30 days (18.24%) when compared to male participants (9.41%). Regarding binge drinking again, the differences was stronger than in the high school sample with men being, in general, much more likely to binge drink (21.18%) compared to women (9.44%)

Measures.

BSSS-8 (*sensation seeking*). To evaluate participants' level of sensation seeking, we used as in Study 1 the brief sensation seeking scale containing 8 items ranging from 1 = *Strongly disagree* to 5 = *Strongly agree* and found acceptable internal consistency ($\alpha = 0.72$, see Stephenson et al., 2007).

BIS11 (*impulsivity*). All participants were asked, on 20-items scale, how much statements assessing impulsive behaviors applied to them ranging from 1 = *Completely disagree* to 4 = *Completely agree* (see Billieux et al., 2012, $\alpha = 0.67$).

Dependent variables.

After the video clip (or no clip for the control group), men and female faced the similar measures than in the precedent study but the individual on the picture was described that time as being tolerant to alcohol. Men and women answered the measures on a 1 to 7 Likert scale ranging from “*Completely disagree*” to “*Completely agree*”. Bother gender had to describe how much they “would not like being in the same situation that Nicolas”. The intra-sexual competition measures for men revealed a pretty strong internal consistency and will then be used as one DV ($\alpha = 0.80$).

However, the reproductive success measures did show really poor internal consistency for the women sample and thus the two measures were treated separately (“Manon finally fall for Nicolas” and “Nicolas is pretty attractive, $\alpha = 0.48$).

Situation embodiments (men only).

When we applied the same set of contrasts than in Study 1, a one way-ANOVA revealed that our main contrast of interest was far from reaching significance ($p = .79$). Male participants were not as willing to be in Nicolas’s situation after viewing sexual spots as for any other spots or the control condition.

Intrasexual competition (men only).

Similarly, the intrasexual competition measurement (combining the will to be in Nicolas’s team as well as how much participants would be to play him in a sportive competition) did not reveal any difference between the type of videos visualized by male participants ($p = .91$).

Additional analysis

When we evaluated the short-term risk videos (sexual and cognitive) against the other types (long-term disease and control), our first contrast of interest did not reveal any significant difference ($p = .76$). On the other hand, while the main contrast comparing short-term videos against the long-term spot did not reach significance ($p = .28$), the second contrast comparing the former to the long-term and the control conditions came out significance ($p = .04$). However, this result is quite hard to interpret since it is merely making sense that the first contrast did not reach the significance threshold.

4.3.1.4. Results.

Situation embodiments (women only).

As for men, there were no difference among female participants upon their willingness to be into the character's situation when comparing the different spot. More specifically, women were not less willing to be in Nicolas's state after the sexual videos when compared to the other videos ($p = 0.89$).

Reproductive success and attractiveness (women only).

Women did not consider than the female painted in the situation was less willing to fell for Nicolas after viewing the sexual spots compared to participants who visualized the other preventions videos ($p = .24$). However, there were a marginal effect for the attractiveness of the target. Indeed, women tend to find Nicolas less attractive after viewing the sexual spot ($M = 2.32$, $SD = 1.49$) when compared to participants exposed to the cognitive ($M = 3.21$, $SD = 2.08$), long-term ($M = 3.29$, $SD = 1.35$) or control conditions ($M = 2.30$, $SD = 1.35$), $t(96) = 1.79$, $p = .08$, $R^2 = .09$ (interestingly, only the third contrast comparing the sexual and the control conditions came out significant, $p = .02$).

Additional analysis

When we used the set of contrasts to compare the short-term to the long-term preventions videos effects, the analysis revealed that both embodiment and reproductive success measures failed to reach significance ($p = .89$ and $p = .11$ respectively). However, women tend to find Nicolas particularly less attractive after viewing the short-term clips (sexual and cognitive, $M = 2.67$, $SD = 1.77$) when compared to the long-term disease video ($M = 3.29$, $SD = 1.35$), $t(96) = 2.46$, $p = .02$, $R^2 = .09$. Though the second contrast was also significant meaning that when aggregated together, the long-term and the control conditions were viewed as particularly less attractive (because of the very low rating in the control condition, $M = 2.30$, $SD = 1.35$, $p = .04$).

4.3.1.5. Discussion.

The second study aimed at reproducing the major findings of Study 1 through an online protocol using Social Network sites. After entering a Google form, male and female participants were both exposed to the different preventions videos. Then, while women faced a dating situation, men were asked to evaluate a drinking competition between two males surrounded by two women.

However, the results were quite unclear compared to the high school experiment. For the men sample, the analysis did not reveal any significant difference on the embodiment or the intrasexual measures. The only arguable result was about the second contrast comparing intrasexual competitiveness between short-term risk videos and the other two conditions (long-term and control) but since the first contrast of interest was not significant, it meant that the specific short vs. long-term risks comparison did not reveal any meaningful difference.

On the other hand, as in the high school study, the results were somehow more interesting among women. For instance, while the reproductive success did not differ after viewing the difference videos, a marginal effect emerged upon Nicolas's attractiveness. Women tend to find him less attractive after viewing the sexual videos compare to the other (even though they found him significantly less attractive in the control conditions). Similarly, women tend to find less attractive the individual in the dating situation after viewing the short-term risks videos (sexual and cognitive) compared to the long-term risk ones. A higher statistical power per group may explained why the second hypothesis came out significant while the first set emerged only marginally significant.

4.3.2. General Discussion

Why do youth engage much more in binge drinking than adults and how to prevent that phenomenon for keep expanding? While several social theories had investigated the causal pathways of such behavior (Courtney & Polich, 2009), to our knowledge, no evolutionary theory has been used to build a prevention program against binge drinking. Based on the costly signal theory (Zahavi, 1975; Zahavi & Zahavi, 1975), we postulated that men tolerating alcohol sent signals to both potential mates and other male competitors. By doing so, they display their genetic quality to others, publically exposing their body to toxic substances and health consequences.

In order to backlash those signals, we proposed to send both men and women messages of an intoxicated men with different risk at play when drinking heavily: sexual impotence, cognitive impairment and long-term risks. By differentiating those signals, we predicted that the sexual signals sent to teenagers in an early stage of sexual maturity, should be the most impactful. On the other hand, short-term impairments (sexual and cognitive), in a high school

contexts in particular, may also be a none-mutually possible hypothesis that noise the signal sent to mate and male-male competitors.

Through an original prevention study in an ecological context (Study 1) and in an online replication (Study 2), we aimed at investigating if the different type of signals at play in a binge drinking prevention spots could influence a latter evaluation of an intoxication situation (an impression formation task). With the help of a professional film production company (<https://www.bproduction.fr/>), we realized a series of 3 different spots based on 3 type of signaling: a man binge drinking during a social gathering and ending up either sexually impotent, cognitively impaired or getting a long-term disease (cancers, cardiovascular troubles, etc.).

During the high school prevention action, we presented, in a between-subject design, the different spots to 269 students in 10th and 11th grades. After that, women were exposed to impression formation task of a man drinking during a causal date and not being able to tolerate the effects of alcohol. On the other hand, men were exposed to a man losing in a binge drinking game because of high intoxication. We displayed for both sexes low-tolerant men for ethical reasons since in a high school context, it would be highly contestable to show a tolerant man or to display any benefits from heavy drinking (but an online replication including the tolerant version must be run in the future to compare the effects of the spots).

Globally, the results were quite mixed. Among women, for instance, the sexual spots did have an effect on the latter impression task making them less willing to be in the same situation that the picturing man after viewing the sexual video when compared to the other spots. This effect did not show up for men but that was not the most surprising. Indeed, as our descriptive data mentioned, and as other studies had shown numerous times (Byrnes et al., 1999), young men engaged much more frequently and more intensely in binge drinking than do women. As a

results, whichever spots displayed to men may not affect their post-judgment in a formation impression tasks since they are more aware of the qualitative danger of such risky conducts. Similarly, in the second study, which tried to replicate the high school experiment, the effect on men were constantly far from reaching significance.

Women, on the contrary, being less exposed to binge drinking, might be particularly sensible to the sexually impotent signals if genetic quality is effectively what is being sent to them when a men is binge drinking. Another possible cognitive explanation might be that women, having a more subtle theory of mind since early ages (Baron-Cohen 2002), may be more able to take perspective on the situation and imagining themselves in Nicolas's position making the spots differently impactful on the impression formation tasks following.

Most surprisingly were the results about the reproductive success measures. None of the spots impacted more particularly the impression formation tasks among women. One possible explanation is that a floor-effect emerged since the man in the picture display low tolerance to alcohol then low genetic quality, whatever spot being pre-watched did not make any difference on the negative judgments women had over his reproductive success.

However, on the other hand, women did judged the target's attractiveness differently according to the type of spots they were been exposed to. Indeed, they evaluated Nicolas as less attractive after being exposed to the sexual risks spots when compared to the other spots (significant for study 1 and only marginal for study 2) but when compared to the cognitive spots only, the latter came out even more negatively impactful than the sexual one (only in study 1). The first explanation might be that attractiveness is a mediator of reproductive success evaluation and that the effect sizes displayed were not that large that they could impact a reproductive success evaluation. The scholar context again might explain why the cognitive spot

impacted the attractiveness judgement that much. One possible explanation is that, contrary to middle school (9th grade, where grades do not influence early adolescent peer popularity, see Boyatzis, Baloff & Durieux, 1998), in high school, having good grades and being cognitively fitted would be a real feature of attractiveness.

Regarding male participants, none of the spots impacted in either way the willingness to accept Nicolas as a potential teammate in a sportive competition. Either another floor effect emerged making the target unfit for any type of competition to play with. Indeed, when it came to face Nicolas in a sportive competition (so, this time, begin an adversary), the cognitive video made participants more willing to fight against Nicolas in a competition when compared to the sexual spot ($p = .01$), the other comparisons did not come out significant. Similarly, it is possible than the scholar context impacted in such a way that memory and concentration impairments make the target look weaker than just having sexual impotence.

We had a parallel, none mutually exclusive, hypothesis about short-term risks being evaluated as clear whereas long-term ones would be seen as ambiguous and more engaging than short-term ones (Tymula et al., 2012). However, only the women's willingness of being in Nicolas situation came out significant with women being less prone to be in Nicolas's case after being exposed to the short-term spots (cognitive and sexual) than after viewing the long-term diseases prevention video.

Limits

As in any prevention programs, our studies had limitations that must contribute to make further studies even more precise to attest transparency and replicability. First, since some of students of that particular high school participated as actors in our preventions spots, it was

ethically impossible to ask evaluations of them to other students. This goes against both research ethical standards (WHO, 2011) as well as appropriate academic-education cooperation. As a result, we had to create an impression formation task following the diffusion of our spots making the transfer of sexual and competitive evaluation much more difficult to evaluate than if we would have asked to judge directly the individual acting in the different videos. On the other hand, it can be a way to sidestep eventual experimental biases by transferring the spot influences over another task as it is common in social psychology.

Secondly, the ecological context, while being more representative of the way the teenagers behave, made it more difficult because of the school context. Knowing that the cognitive spot regularly came out as more impactful than the sexual post, we think it may be because of the importance of cognitive functions (memory, concentration, etc.) for school achievements at this particular stage (10th and 11th grades) and age ($M = 15.94$, $SD = 0.93$). While at the end of middle school, grades do not seem to influence student's peer popularity (Boyatzis, Baloff & Durieux, 1998), it is probably another story in high school where a selection had already been made and where students prepare for exams (the equivalent of the American SAT in France, the "Baccalauréat") that would largely determine their future professional careers.

Additionally, we did not test for the impact of the spot on attitude or consumption toward alcohol. We tested an indirect impression formation task after the exposure to a spot. The main interest here was to see how prevention signals could impact the way they judge a peer intoxicated during a social gathering. Showing that specific signals impact more their impressions than others could be of great help for the health and educational community and contributing more deeply to understand binge drinking as a multi-faceted phenomenon.

The main replication of this project may target young high school or university students outside of scholar context to see how much of the cognitive vs. sexual signaling really impact their impressions formations. One way to replicate this program would be a longitudinal online investigation to see right after, +1 week and +1 month after this exposure how much the different spots impact their attitude toward alcohol, how robust and strong is the effect. Another advantage of the online protocol is that, contrary to a classroom where data can get really noisy (student-student interactions, professor presence, scholar environment, etc.), the online version can be made isolated at home, similarly to the way they would be talking to their friend online or planning a social event.

On the other hand, doing a laboratory setting of our experiment, adding implicit or physiological measures might be a good way to correlate self-report post-impression to direct-in vivo implicit reactions and physiological changes. First, an eye-tracker study would permit to see which part of the different spots attract the most student's attention and pupil dilation would tell which moment is most impactful (either describing fear or excitement). Moreover, adding EMG (electromyography) measures to evaluate electrical activity produced by skeletal muscles (Weiss, Weiss & Silver, 2015) and distinguish, combined with eye-tracking measures, which part of the videos are the most stressful and how to develop future preventions programs that are both impactful and measurable. Evidenced-based policy must be evaluating scientifically on the long-term and, like any other bottom-up approach, health preventions must always be turned to measurable hypothesis-generating studies.

Finally, further research should include impression tasks including men tolerating alcohol's effect to see how this influence of the different signaling make vary the response to the task following. Indeed, one possible weakness in our spots is that the none-tolerant alcohol men

are sending, *de facto*, signals of low genetic quality to the participants. To that extent, possible floor-effects could have emerged making the target (Nicolas) unfit in whatever situations following the spots. Getting short or long-term signals, sexual or none sexual would in that case make no difference whatsoever about the target's capability. On the contrary, measuring the transfer of those signals upon a tolerant man would show probably higher variations between spots leading to more subtle measurements.

Chapter 5: Do Women Expose Themselves to More Health-Related Risks in Certain Phases of The Menstrual Cycle? A Meta-Analytic Review.

Over the past three decades, dozens of studies have reported evidence that the menstrual cycle influences many aspects of women's cognition, motivations, and behavior, including, for example, emotion recognition (Sundström Poromaa & Gingnell, 2014), mental rotation abilities (Broverman et al., 1981; Zhu, Kelly, Curry, Lal & Josph, 2015), verbal functions (Rosenberg & Park, 2002), mood (Maki, Rich, & Rosenbaum, 2002; Rubinow & Schmidt, 1995), empathy (Derntl, Hack, Kryspin-Exner, & Habel, 2013; Pfaff, 2012) and mate preferences (meta-analyzed by Gildersleeve, Haselton, & Fales, 2014; reviewed by Thornhill & Gangestad, 2008). Within this broad area of research, a growing literature has examined changes across the menstrual cycle in women's engagement in behaviors that could expose them to health-related risks, particularly sexual behavior, alcohol and cigarette consumption, and recognition and avoidance of potentially threatening people and dangerous situations. However, evidence in this area has been mixed. Furthermore, inconsistencies across study findings have been difficult to understand without a guiding theoretical framework or careful evaluation of differences in study methods (e.g., methods used to assess women's position within the menstrual cycle; different hormonal profile characterizations; within vs. between design).

Understanding how women's health-related risks change across the cycle could have important public health implications and may possibly lead to more accurate and individualized prevention programs. Studies of nonhuman animals in neuroendocrinology point to plausible physiological pathways through which women's position in the menstrual cycle could also influence such behaviors (e.g., through estradiol and progesterone receptors within the amygdala, hippocampus, hypothalamus and the frontal cortex, see Guerra-Araiza, Coyoy-Salgado, &

Camacho-Arroyo, 2002; Guerra-Araiza, Villamar-Cruz, Gonzalez-Arenas, Chavira, & Camacho-Arroyo, 2003; Kato, Hirata, Nozawa, & Yamada-Mouri, (1994). In addition, an evolutionary approach offers predictions regarding why women might engage in such risky behaviors within certain phases of the cycle (Bröder & Hohmann, 2003; Chavanne & Gallup, 1998; Fessler, Holbrook & Fleischman, 2014; Prokop, 2013). Therefore, an interdisciplinary evolutionary method is well suited to help organize and make sense of seemingly inconsistent findings within this literature.

In this review, we begin by providing a brief orientation to the physiological changes that occur during the menstrual cycle. We then define risk-taking and the key domains of risks examined within this meta-analysis. Next, we propose specific predictions regarding when, how (via what mechanisms), and why different forms of health-related risk-taking may change across the menstrual cycle. These predictions are informed by behavioral neuroendocrinology, studies of nonhuman animal species, and modern evolutionary theory. We then present a meta-analysis of 23 published and 4 unpublished studies (N=7,527) that examined changes in women's health-related risk-taking behaviors across the menstrual cycle, followed by a discussion of the implications of our findings for understanding the mechanisms underlying women's health risky behaviors.

Hormones across the Menstrual Cycle

Typically, the human female menstrual cycle lasts 28 days and is characterized by dramatic changes in ovarian hormones levels (Pfaff, 2012; Wilcox, Dunson & Baird, 2000). Menstruation marks the beginning of a new cycle and the start of the follicular phase, which extends from menstrual onset to ovulation and typically lasts approximately 10 to 14 days (Novak & Berek, 2007). As shown in Figure 23, in the early follicular phase, estradiol and

progesterone levels are low. At that time, the pituitary gland secretes two gonadotropins: luteinizing hormone (LH) and follicle-stimulating hormone (FSH). LH stimulates ovarian follicles (structures encasing microscopic egg cells) to produce androgens, while FSH stimulates the follicles to aromatize these androgens into estrogens (particularly estradiol) and also stimulates a cohort of several follicles to begin growing.

Eventually, one follicle becomes “dominant” and continues to secrete increasing amounts of estradiol, while the other follicles degenerate. A few days prior to ovulation, estradiol levels reach their peak. This triggers a surge in LH (Stricker et al., 2006), which causes the dominant follicle, now fully mature, to rupture and expel the egg (ovulation). Ovulation occurs around day 14 in an average cycle. The egg travels down the fallopian tube toward the uterus, and fertilization may occur if sperm are present. Women’s fertility – their likelihood of conceiving from unprotected sexual intercourse – is highest on the 5 days approaching ovulation and the day of ovulation itself, after which fertility declines precipitously (Wilcox, Dunson & Baird, 2000).

Ovulation marks the beginning of the luteal phase, which extends from ovulation to the next menstrual onset and lasts approximately 14 days (Novak & Berek, 2007; Prior, Vigna Schulzer, Hall & Bonen, 1990). Whereas progesterone levels were low throughout the follicular phase, in the luteal phase, the ruptured follicle — now called the “corpus luteum” — secretes large amounts of progesterone and a moderate amount of estradiol (Hall & Nieman, 2003). Together, these hormones prepare the endometrium (uterine lining) for possible pregnancy. If fertilization does not occur, the corpus luteum eventually degrades. The resulting drop in progesterone and estradiol causes the collapse and sloughing off the endometrium (menstruation), and the cycle begins again.

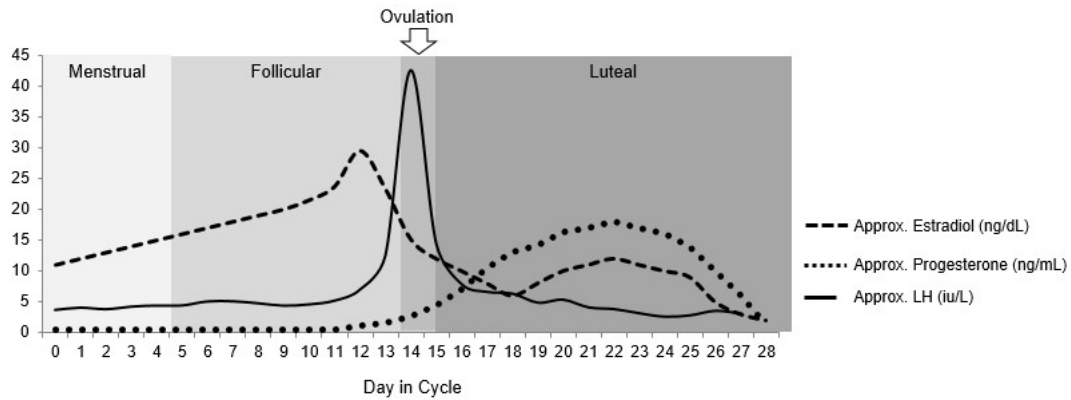


Figure 23. Estimated values of estradiol, progesterone and luteinizing hormone values across the phases in normal cycling women (based on Stricker et al., 2006).

Key Domains of Health-related Risk-taking

Risk-taking has been defined in a multitude of ways over time and across disciplines (Byrnes, Miller & Schafer, 1999; Hansson, 2010, 2014; Trimpop, 1994). In the present meta-analysis, risk-taking is defined as engaging in a behavior to obtain a reward, at the expense of exposing oneself to an elevated risk of undesired and negative health consequences. From a cost/benefit analysis perspective, risk-taking occurs when clear potential costs are outweighed by physiological or emotional benefits (Trimpop, 1994). For example, engaging in drug use, sexual behavior, gambling or other behaviors that enhance pleasure but are known to entail potential costs can be understood as risky.

As noted above, the domains of health-related risk taking that have been most widely studied in relation to the menstrual cycle to date are cigarette and alcohol consumption and sexual behavior. In addition, several studies have examined women's recognition and avoidance of threatening people and situations across the cycle. Although such studies do not assess risk-taking *per se*, they are relevant to understand how women's exposure to health-related risks may vary across the cycle. Here, we provide a brief overview of research on nonhuman animals and

on humans examining cycle shifts in each domain of health-related risk-taking and then outline our predictions based on insights from behavioral neuroendocrinology and evolutionary theory.

Alcohol and Tobacco Consumption

The long-term effects of both alcohol (ethanol) and tobacco consumption are well known and include upper aerodigestive tract cancers, lung cancer, cirrhosis and various cardiovascular and cerebrovascular accidents (WHO, 2014). Heavy drinking is common among college students and leads to short-term negative effects (Wechsler, Lee, Kuo, and Lee, 2000) but students also often report positive feelings such as mood enhancement, tension reduction or coping (Cooper, 1994; Cooper, Russell, Skinner & Windle, 1992). Tobacco initiation, on the other hand, may be due to self-image of maturity, sociability, independence, sexuality, weight control benefits with the highest rate among White girls and the lowest among African-American and Asians (French & Perry, 1995). Whereas the causes or correlates of alcohol and tobacco consumptions and maintenances are well studied, the biological mediators and their pathways remain largely unknown. This meta-analysis aims to evaluate whether certain hormonal profiles may play a role in those risky conducts.

State of the Evidence: Studies of Nonhuman Mammals

The relationship between smoking, alcohol consumption and hormonal profiles appears to be complex, based on studies of nonhuman mammals (Pfaff & Joëls, 2017). The study of human ovulatory cycle, despite differences with animals, still present many common patterns: pituitary gonadotropin luteinizing hormone (LH) and follicle-stimulating hormone (FSH), on the one hand, and estrogens and progesterone, on the other hand, play a necessarily role in regulating social behavior among mammals but little is known about whether the same patterns emerge at the human level (Fink, 2011; Thornhill & Gangestad, 2008; Pfaff & Joëls, 2017). More

specifically, human menstrual cycle differs from other animals on various points. Among rodents for instance, the cycle length is shorter than among humans and the estrogen and progesterone peaks demonstrate more overlapping. The four phases however (Proestrus, Estrus, Diestrus 1, Diestrus 2) largely match human's main phases in term of fluctuations in estrogen, progesterone, LH and FSH and may motivate to use the rat as a model (Staley & Scharfman, 2005, see figure 24 below). Moreover, the fact that the rat, as the primate, displays a diurnal change in LH secretion after the juvenile development can eventually restore his legitimacy as a model. However, non-human primates (NHPs) share even closer endocrine dynamics with human beings including a 28-days cycle in female macaques (Phillips et al., 2014) unlike many rodents that have a four-day estrus cycle (Steger and Peluso, 1987). They also share a similar menopause process, close responses to estrogen therapy and improvements in cognitive functions with estrogen (for a complete review, see Phillips et al., 2014).

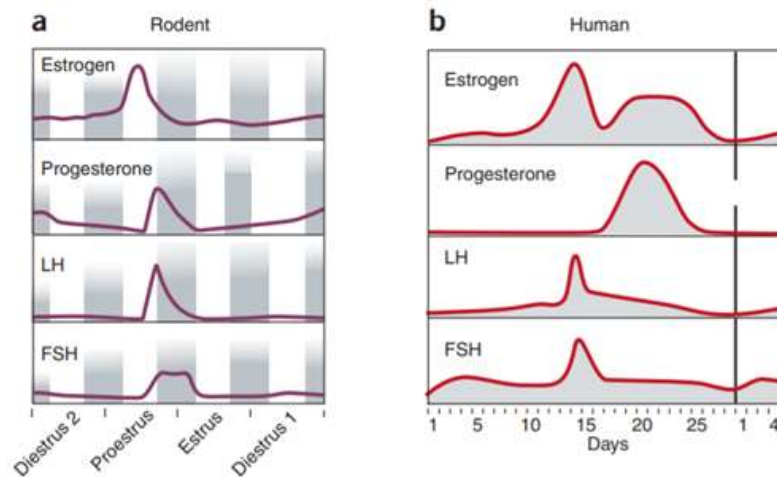


Figure 24. Comparison of the menstrual cycle of the human and the estrous cycle of the rat. (a) The estrous cycle of the rat is the 4-day long (gray bars represent the night, from 6 p.m. to 6 a.m.) with variations in estrogen, progesterone, luteinizing hormone (LH) and follicle-stimulating hormone (FSH). (b) The human menstrual cycle is, on the other hand, 28-days long but also presents major fluctuations of the above-mentioned hormones. Adapted from Staley and Scharfman (2005).

One of the leading challenges is the integration of multiple levels of analysis in experimental design to understand endocrine, neural and psychological influences on social behaviors (Pfaff & Joëls, 2017). Consequently, inter-species comparisons represent a powerful method to illuminate the behavioral changes occurring during the menstrual cycle since hormonal manipulations are not ethically possible in human (ovariectomy, estrogen supplements as stated down below in the last section). Those comparisons permit to elucidate the neuroendocrinology pathways leading to certain type of risky behaviors. In monkeys, for instance, alcohol consumption has been found to decrease during the menstrual phase when compared to mid-cycle or to the luteal phase (Ford, Eldridge, & Samson, 2002; Mello, Bree & Mendelson, 1986; Pfaff & Joëls, 2017). In rats with synchronized cycles, self-administration of alcohol has instead been found to decrease during estrus, the ovulatory equivalent phase among humans, and proestrus which hormonal pattern resembles a follicular phase (Forger and Morin, 1982; Ford, Eldridge, & Samson, 2002; Roberts, Smith, Weiss, Rivier, & Koob, 1998; Staley & Scharfman, 2005). The similarity between rodents and humans in the cycling levels of hormones in brain region make it a good candidate as an animal model but does not overlap completely the women's menstrual pattern (Staley & Scharfman, 2005). Still, other authors found no relationship between estrous cycle and ethanol consumption in Wistar rats (van Haaren & Anderson, 1994). On the other hand, the few studies that had previously investigated the relationship between ovarian cycles and nicotine self-administration among rats failed to find an effect of natural (unmanipulated) estrous cycle (Donny, 1999; Perkins, Donny & Caggiola, 1999).

State of the Evidence: Human Studies

The menstrual cycle has also been investigated as a potential source of day-to-day variation

in women's alcohol and tobacco consumption, with similarly mixed results. Some studies have found an increase in women's alcohol and tobacco consumption near the ovulatory phase (Pomerleau et al., 2000), whereas others did not find that pattern but instead found a decrease in alcohol and tobacco consumption during menses (Charette, 1989; Dumas, Calliet, Tumbling, & King, 1984; Pomerleau et al., 1994; Pomerleau et al., 2000). The overwhelming majority of women experienced discomfort (e.g. headaches, irritability, pain), to some extent, when approaching menstruation (Dickerson, Mazyck, & Hunter, 2003; Reed, Levin & Evans, 2008) and since these are also tobacco withdrawal symptoms (Hughes & Hatsukami, 1986), one could expect women to smoke more during this period to ease those symptoms. However, the results are quite unclear, and under laboratory conditions, some studies identify an increase numbers of cigarettes puffs during menses (Steinberg & Cherek, 1989) whereas others found slight decrease in smoking self-report during high-fertility when compared to the rest of the cycle (Allen, 1996; DeBon, Klesges, & Klesges, 1995; Pomerleau, Cole, Lumley, Marks, & Pomerleau, 1994).

Insights from Evolutionary Theory

Evolutionary psychology may give some insights to elucidate the relationship between menstrual phase and alcohol and tobacco consumption. One explanation is that women might have evolved in the context of alcohol to decrease use of toxic substances in order to avoid dangerous and coercive sexual situations around ovulation. Moreover, an additional explanation might be that women are more averse to certain risk-taking situations at that time of the cycle (e.g., go out dancing with friends), and this could decrease their alcohol and cigarette consumption because of less exposure to such cues (Bröder & Hohmann, 2003; Chavanne & Gallup, 1998). Another explanation may come from the cyclic changes in mood that induce change in women's social abilities, clothing style (Haselton et al., 2007; Schwarz &

Hassebrauck, 2008) along with enhance self-rated attractiveness that would eventually reduce the tendency to drink (Haselton & Gangestad, 2006; Schwarz & Hassebrauck, 2008).

The results are quite mixed when it comes to evaluate women's social activities (such as going out dancing, attending a concert, invite a man for dinner, etc.) across the cycle and if those activities could lead to higher substance use. Bröder and Hohmann (2003), for instance, replicated a study by Chavanne and Gallup (1998), where women had to fill a questionnaire on four occasion at 1-week intervals with a list of 40 activities (20 risky and 20 non-risky). They showed that naturally cycling women reduced risky behaviors such as "going out dancing with friend", "going to a party alone in the evening" or, more directly, "getting drunk while going out" during the ovulatory phase. However, many animal studies have shown an increase in locomotion at estrous so apparent that it can be used as one of the most reliable indexes of fertility (Fessler, 2003). As Bröder and Hohmann (2003) noticed, women might be more active during high-fertility days by increasing nonrisky activities over risky ones that would lead to change in a risky activities ratio.

An alternative, not mutually exclusive hypothesis involves the latter portion of the menstrual cycle. The early luteal phase, which is characterized by a hormonal profile that resembles early pregnancy, could also lead to avoid toxic substance in order to enhance the survival of the potential fetus (Fleischman & Fessler, 2011). Indeed, the highest level of progesterone is observed during pregnancy but also during the early luteal phase when the woman's body is getting prepared for conception and implementation of a potential fertilized egg.

Tracing back the physiological mechanisms may also reveal more direct links between risky activities and ovarian hormones through brain structures, including the hypothalamic-

pituitary axis. Moreover, brain areas that control risk sensitivity have likely been shaped phylogenetically and have genetic underpinnings. Recent twin studies revealed that heritability accounts for 29% to 55% of individual variations in risk-taking (Bell, 2009; Wang, Zheng, Xuan, Chen & Li, 2016). Inherited and environmentally response genes affecting risk-taking have orthologues (gene evolving from common ancestral gene) with common function in humans and other animals permitting inter-species comparisons through the HPA axis for instance (Cesarini, Dawes, Johannesson, Lichtenstein & Wallace, 2009; Stern, 2010).

Insights from Behavioral Neuroendocrinology

Indeed, the hypothalamic-pituitary axis plays a central key role in the regulation of alcohol and tobacco use both in human and non-humans mammals. The relationship between this axis and ovarian hormones is complex because chronic alcohol might influence the level of circulating estrogen, especially in dependent women. Ford, Eldridge and Samson (2004), instead, found that physiological doses of estradiol in rats increase ethanol consumption by 10% without increasing water consumption, indicating possible modulation by estradiol. Past drinking experience along with expectancies must also influence those complex patterns. Regardless of the type of drug, ovarian hormones appear to have an impact on psychoactive drug use and alcohol and cigarette consumption (Kuhar, 2011). For instance, in cocaine intake, ovariectomized rats that had estrogen supplements demonstrated the highest self-intake of drugs when compared to simply ovariectomized rats or compared to castrated males. A study run by Dluzen and Anderson (1997) showed that estradiol increased dopamine release in response to nicotine in female rats, implying that nicotine may be more rewarding when estradiol is high. In summary, whereas there are competing predictions based on the existing literature and evolutionary theorizing about humans, the non-human animal literature suggests that high

estrogen (which is associated with high fertility in both humans and non-humans) is associated with greater consumption of intoxicating substances. This meta-analysis aims to help identify associations between cycle phase and the use of drugs and alcohol in human females.

Prediction

The human and non-human literatures, taken together, revealed mixed results. On the one hand, the animal literature indicates that the mid-cycle phase will be associated with greater substance use due to higher concentration of estrogen at that time. Still, human data are unclear regarding whether the ovulatory or the early luteal phases increase or decrease alcohol and tobacco consumption. Therefore, there are competing predictions.

First, women may decrease drug and alcohol consumption at high fertility. This is possibly due to a selective pressure that makes women more attractive near ovulation. One of the possible by-product might be the enhance feeling of well-being and attractiveness at high fertility, which would decrease the craving or necessity of abusing such products.

Second, there could be an increase of drugs and alcohol consumption at menstrual and premenstrual phases because of lowered mood or increased discomfort due to premenstrual and menstrual symptoms. These two patterns – a decrease at high fertility and an increase premenstrually and menstrually – could lead to a cyclical change in alcohol and tobacco consumption.

Finally, an alternative hypothesis may come from the toxins avoidance pressure after ovulation, as progesterone rises. With a hormonal profile similar to pregnancy, counter-adaptation to toxic exposure could have led to decrease alcohol and tobacco consumption during the early luteal phase as compared to other phases except ovulation.

In summary, several different patterns are possible, a decrease in consumption at high

fertility, an increase premenstrually and menstrually, an increase at high fertility, and a decrease after ovulation as progesterone rises.

Sexual Behavior

Sexual contacts offer a variety of rewards (e.g., emotional and physical pleasure, relationship enhancement, and possible reproductive benefits) at the expense of an increased risk of incurring certain costs (e.g., pathogen exposure, possible reputational damage, viruses, etc.). Therefore, sexual behavior can be thought of as a form of health-related risk-taking or hazardous behavior¹². In our review and meta-analysis, we focus on frequency of allosexual activities specifically—rather than sexual desire or other forms of sexual behavior— because of clear and direct potential impacts on women’s health (STDs such as chlamydia, HIV, syphilis can also be transmitted during oral sex) and/or risk of conceiving. Allosexual behavior was operationalized as the frequency of intercourse, oral sex, or genital stimulation with a man or woman as those measures were most of the time mixed all together. We could not run analysis focusing specifically on frequency of heterosexual intercourses or unprotected sex, since not sufficient data were available.

State of the Evidence: Studies of Nonhuman Animals

Studies of nonhuman animals tend to find periods of sexual activity (estrous) clearly distinguishable from periods of sexual abstinence (diestrus; Balthazart, 2011; Thornhill & Gangestad, 2008; Pfaff & Joëls, 2017). Most mammals (dogs, rodents, etc.) and animals that possess estrus experience this increased sexuality at the only time conception can occur though

¹² One may criticize this standpoint as employing an overly broad definition of risk-taking. In general, sexual interactions that present potential risks is called “risky sex” and includes behavior that increase the likelihood of early sex initiation and pregnancy, multiple partners, unprotected sex, sex under the influence of alcohol or drugs (Donohew et al., 2000). Other distinctions include unsafe (having sex with a partner infected by STI without taking proper prevention measures) and hazardous sex (having unprotected sex with non-infected partner or having protected sex with infected individuals, see Slaymaker, Walker, Zaba & Collumbien, 2004). Since it is not possible to measure correctly those two latter categories, health experts usually use the “risky sex” definitions as a proxy.

the estrous cycle's length varies among species (4-5 days in rats or hamsters; 16 days in Guinea pigs; 28 days in rhesus macaques, see Brenner & Slayden, 2012). Behavioral estrus or heat can be defined as “a restricted period of proceptivity and receptivity characterized by mammalian females' behavioral readiness to mate, in addition to attractiveness to males, usually, though not invariably, coinciding with relatively high probability of conception” (Thornhill & Gangestad, 2008, p.184). Though usually described in mammals, a large portion of vertebrate taxa displayed hormonal, neural and physiological mechanisms that can be considered estrus, and phylogenetic analysis can help to clarify the origin of estrus. In female nonhuman Old World primates, mid-cycle patterns also appear to share similarities with estrus of other mammals (Dixon, 1998).

Nevertheless, some estrus-like patterns do not mean that females of all species will exhibit sexuality only during fertile phases and, on the contrary, some species do display extended female sexuality – having sex outside of the fertile period (Thornhill & Gangestad, 2008). Many species of birds (Birkhead & Møller, 1995) and nonprimate mammals (Fürtbauer, Heistermann, Schülke, & Ostner, 2011) copulate throughout the entire ovarian cycle. Many primate species, including humans, have extended sexuality and may engage in sexual intercourse on any day of the cycle (Pfaff & Joëls, 2017). However, women's extended sexuality is extreme: women are not only sexually proceptive and receptive throughout the cycle but also during other time points or conditions in which the conception is not possible, such as pregnancy, early lactation or anovulatory cycles (Grebe, Gangestad, Garver-Apgar & Thornhill, 2013).

State of the Evidence: Human Studies

In contrast with the nonhuman mammal literature, findings have been mixed regarding the existence and nature of shifts in women's sexual behavior across the menstrual cycle. Several studies have found an increase in women sexual activity during the high-fertility phase as

compared with the low-fertility remainder of the cycle (Adams, Gold, & Burt, 1978; Bullivant et al., 2004; Burleson, Trevathan & Gregory 2002; Harvey, 1984). However, patterns are not always consistent and this lack of stability could reflect the fact that sexuality is a complex social behavior, constrained and enabled by many factors, such as opportunities or leisure time (as revealed, for example, in the “weekend” effect, whereby people tend to have sex more on weekends as compared compare to week days, Ryan, Bernstein & Brown 2010). In sum, many social factors could moderate or obscure any effect of the menstrual cycle.

In addition, some studies reported an increase in sexual behavior at pre- and postmenstrual phases of the cycle; this pattern may reflect cultural taboos and restrictions on sexual activity during menses (Sanders & Bancroft, 1982). The increase in sexual behavior right before and after menses could reflect attempts to compensate for this reduction in sexual activity during menses.

Regarding the lack of a clear pattern in women’s sexual behavior across the cycle, individual studies may have lacked statistical power or used self-report measures of the menstrual phase (Adams, 1978; Bellis & Baker, 1990; Roney 2013). An evolutionary approach offers additional reasons why humans may differ from nonhuman mammals in patterns of sexual behavior across the cycle.

Insights from Evolutionary Theory

As discussed above, many primate species, including humans, have extended sexuality and engage in sexual intercourses on any day of the cycle (Gangestad & Haselton 2015; Thornhill & Gangestad, 2008; Pfaff & Joëls, 2017). Human female sexuality is relatively extreme among animals because they are receptive to sex (receptivity) and may actively seek sex (proceptivity) at any point within the menstrual cycle — even when they are not fertile. Scholars have proposed

several non-mutually exclusive explanations for why extended sexuality evolved in human females. For example, given an absence of obvious cues to ovulation (such as the bright red genital swellings that accompany the fertile window in nonhuman primates; Maestripieri & Roney, 2005), extended female sexual receptivity and proceptivity throughout the cycle may have made it difficult for males to discern when women were fertile. In turn, this may have enabled women to procure greater investment in offspring from putative fathers (e.g., if women have conceived with partners other than their primary social partner or through bi- or multiple-paternal care, see Gangestad and Thornhill, 2008; Hausfater & Hrdy, 1980; Hrdy, 1981; Rodríguez-Gironés & Enquist, 2001). Extended sexuality could also increase women's ability to choose long-term, investing partners, and decrease aggressiveness between males who might compete most aggressively for mating opportunities (Symons, 1979; for a brief summary of evolutionary explanations for extended sexuality in humans, see Haselton & Gildersleeve, 2011). Receptivity throughout the cycle could finally benefit women to promote investment from a pair-bonded mate and reduce polygyny, whereas selective proceptivity could favor conception with an extra-pair mate who possesses "good genes" that the main partner lacks (Gildersleeve, Haselton & Fales, 2014; Provots et al., 2008; Puts et al., 2012).

Importantly, extended sexuality does not necessarily imply no variation across the cycle in women's sexual desire or behavior. One of the most prominent and best-supported hypotheses regarding changes in women's sexuality across the menstrual cycle is the ovulatory shift hypothesis (Gildersleeve, Haselton, & Fales, 2014; Thornhill, & Gangestad 2008). This hypothesis proposes that, as heterosexual women get closer to ovulation (and their fertility rapidly peaks), they experience an increase in their sexual attraction to men who possess certain characteristics – namely, those characteristics that are thought to have historically reflected

beneficial heritable genetic qualities (e.g., good immune function). In other words, women experience an increase in sexual attraction to these men precisely when they are most likely to conceive and pass on the potential genetic benefits to their future offspring. Although the ovulatory shift hypothesis makes no predictions regarding general changes in women's sexual desire or behavior across the cycle, the proposed shift in women's mate preferences could produce a change in their overall frequency of sexual behavior depending on the social context. For example, women with access to sex partners possessing the characteristics they find particularly sexually attractive at high fertility might increase their sexual activity at this time.

Another hypothesis from an evolutionary perspective is that there will be a slight increase in sexual behavior at high- relative to low-fertility, *not necessarily because of an increase in women's desire*, but because of an increase in women's attractiveness. Evidence supports the existence of an ovulatory increase in women's attractiveness across multiple modalities (e.g., voice, appearance, movement, etc.), and both men and other women appear to be able to detect these "ovulation cues" and perceive them as attractive (Gildersleeve & Haselton, 2018).

Therefore, we might expect a slight increase in sexual behavior at high fertility because *women's partners might be more likely to initiate sexual behavior* at that time (Haselton & Gildersleeve, 2011).

Insights from Behavioral Neuroendocrinology

Because many brain regions involved in those sexual behaviors still present strong molecular and structural similitudes, phylogenetic inferences comparing different animal models can also help to make predictions for human beings. For instance, among ovariectomized rodents (rats, guinea pigs, hamsters and mice), although a treatment including only estradiol restore some part of female sexual behavior (Crowley, O'Donohue, & Jacobowitz, 1978; Mani, Blaustein, &

O'Malley, 1997), both estrogen and progesterone appeared necessary to restore the sexual behavior pattern that resemble the one observed during estrous (Beach, 1948; Edwards & Thompson, 1970). In most nonhuman primates (vervet monkeys, tamarins, and marmosets), females demonstrate sexual interest during the fertile phase (Gangestad & Thornhill, 2008). However, an extreme form of extended sexuality exist in blue monkeys, which have sex throughout the menstrual cycle well beyond the ovulatory period (Pazol, 2003).

Despite those behavioral differences, some structures play a key role in the regulation of female proceptivity and receptivity. The hypothalamic-pituitary axis, in particular, plays an active and retroactive role in many of these species. As a follicle matures during the first part of the cycle, it produces estrogen in greater quantity until a pulsatile surge in LH triggers ovulation. Estrogens surges right before ovulation has been regularly linked to lordosis in rodents via activation of several specific genes. More specifically, the preoptic area of the hypothalamus appeared to play a central role in the regulation of sexual behavior and sexual orientation (Balthazart, 2010; Dominguez, Gil, & Hull, 2006).

In sum, exploring the evolutionary history of estrus does lead to a clear picture of which pattern we should expect for women. Even though a vast majority of non-primate mammals' sexuality is related to estrogen fluctuations, the trend is more complicated for primates, with some species demonstrating dramatic extended sexuality, making it hard to predict an increase of heterosexual activity at mid-cycle.

Prediction: According to the literature above, we cannot with certainty predict a shift of women sexual activity at mid-cycle when compared to other phases. Extreme extended sexuality of women along with many confounding social effects (the weekend effect, the availability of the partners, religious beliefs, etc.) could weaken any existing effects. In particular, giving known

taboos about sexual intercourse during menstruation, we still expect to find an increase of sexual activity at mid-cycle as compared to menstrual days. Regarding the comparisons between the ovulatory phase and other phases (follicular and luteal), we expect a modest effects due to many confounding variables and external influences.

Risk Recognition and Avoidance

In addition to health-related risk-taking behaviors, a growing literature has examined variations across the menstrual cycle in women's ability to recognize cues of potential danger, emotion (fear and anger), as well as their tendency to avoid situations and people that could pose risks to their health. Given our objective of better understanding the role of the menstrual cycle in women's exposure to health-related risks, we included these studies in the meta-analysis.

State of the Evidence: Nonhuman Animal Models

While the nonhuman animals literature show that estrogen increases arousal in many circumstances, Morgan, Schulkin and Pfaff (2003) also revealed that under threatening environments, estrogen could similarly facilitate the increase of fear and avoidance responses. The non-human animal literature on this topic is inconsistent and complex (Pfaff, 2012). Animal models usually distinguish between active avoidance and passive avoidance. In active avoidance tasks, for example, rats avoided a mild presignaled shock by going into a secure location. In these tasks, females moved into the secure location more slowly on the days leading to ovulation (proestrus), indicating an impaired performance on associative learning or conditioning when estradiol levels are high (Diaz-Veliz et al., 1989). Moreover, in the same task and after ovariectomy, rats improved their avoidance response in laboratory whereas 17 β -estradiol injection damaged their performance (Alonso et al., 2006; Diaz-Veliz et al., 1989). In parallel, progesterone injections also slowed movement to the secure location in ovariectomized female

rats. In passive avoidance tasks, rats are trained to avoid a location where mild shock was experienced on a single training trial. Again, during estrous, females showed poorer performance with high level of estrogen and progesterone.

Other studies showed conflicting results with sometimes no effect of the cycle (Pfaff & Joëls, 2017). Morgan, Schulkin, & Pfaff (2004), on the other hand, found that mice treated with estradiol benzoate increase anxiety, fear learning and running wheel activity suggesting a general increase in arousal but depending on the environment. To go beyond those apparent inconsistencies, Morgan, Schulkin and Pfaff (2004) proposed a theoretical framework: the action of estrogens on motor activity and fear depend on context. While in a safe environment, estrogen would facilitate activity, in a threatening context, it will enhance fear, provoking a reduced activity. Estrogens effects would then depend on the environmental context during the behavioral tasks and would explain the apparent conflicting results in the literature. Thus, in safe context, estrogen would facilitate locomotor activity while under environmental threat, the same hormone would slow it down (Morgan, Schulkin & Pfaff, 2004). Second, the effect of estrogen would depend on the initial level of arousal and, according to Morgan and colleagues (2004), it must exist an optimal levels of arousal to facilitate courtship and mating responses in different context. Further studies are needed in that field to quantify this precise threshold.

State of the Evidence: Human Studies

In human females, several factors could lead to underestimating risks, including direct risk recognition, but also emotional recognition such as fear and anger that could lead to vital information pertinent to the survival of the individual (Bullivant, 2013; Derntl, Kryspin-Exner, Fernbach, Moser & Habel, 2008; Gasbarri et al., 2008; Sacher, Okon-Singer & Villringer, 2013). As in the non-human literature, inconsistencies are also present in the human literature: Pearson

and Lewis (2005), for instance, reported better fear recognition during high level of estrogen days and impaired judgment during menstruation when estrogen and progesterone levels are low. However, Guapo et al. (2009), reported, in contrast, that estrogen was negatively correlated with the accuracy of recognizing angry male faces, whereas Conway et al. (2007) found that progesterone levels were associated with greater precision at recognizing fearful and disgust faces. Concerning direct avoidance, a series of studies revealed that at high fertility, women evaluated men's sexual coerciveness (watching interview of men trying to attract other women) as more coercive than females in low-fertility days of the cycle (Garver-Apgar, Gangestad & Simpson 2007). Women in high-fertility phase were also more sensitive to snake detection (Masataka & Shibasaki, 2012), to sexual assault scenarios, measured by handgrip strength (Petralia & Gallup, 2002), had lower risk-recognition latencies (Walsh & DiLillo, 2013), and perceived a violent criminal as larger and stronger than a non-violent criminal control (Fessler, Holbrook & Fleischman 2014).

There is debate about whether ovulating young women are underrepresented in sexual assaults (Morgan, 1981; Rogel, 1977; Thornhill & Palmer, 2000). Fessler (2003) suggested that earlier supported findings were flawed. According to Fessler (Fessler, 2003), the data in one study showed that frequency of rape among women is at chance on day 14 and above chance on days 12 and 13 (Rogel, 1977).

Insights from Evolutionary Theory

To the extent that such phenomenon is real, however, a possible explanation might be that a counter-adaptation to rape would have made women more sensitive at mid-cycle to specific threats, such as situations or cues associated with sexual coercion (Bröder & Hohmann, 2003; Chavanne & Gallup, 1998). Given women's heavy investment in offspring and limited number

of total offspring in a lifetime, women are selective in their choice of mates (Trivers, 1972; Buss & Schmitt, 1993). Therefore, one would expect that women might be especially selective in choosing sex partners and especially cautious about avoiding sexual coercion when they are most fertile within the cycle (Gildersleeve et al., 2014).

Insights from Neuroendocrinology

The amygdala is an important brain region involved in emotional recognition and known to be influenced by ovarian hormones both in women (Derntl et al., 2008) and in mammalian females (Adolphs, 2002). Derntl et al. (2008), for example, showed greater amygdala activation during follicular phase and better performance at recognizing emotions. Other studies demonstrated stronger activation of those zones during mid-cycle compared to menstruation when women were passively viewing ambiguous or angry faces (Sacher, Okan-Singer & Villringer, 2013). However, Van Wingen et al. (2008) showed that single injection of progesterone in healthy young women increased amygdala activation to angry and fearful faces while another study showed a decrease in responses to faces in amygdala after the same single administration of progesterone dose (Van Wingen et al., 2007).

Prediction: In general, one might expect an increase in risk avoidance and recognition, along with better specific emotion recognition (fear and anger) accuracy on the fertile days leading up to ovulation when compared to all the other phases.

Method

Research strategy. In order to gather as many studies as possible that meet our criteria, we contacted every researcher whose publications were available to obtain the necessary data to compute effect sizes and any unpublished work that may fit the inclusion criteria of our current meta-analysis. We also sent requests for manuscripts and data via the listservs of associations

such as the Society for Personality and Social Psychology (SPSP), Society for the Psychological Study of Social Issues (SPSSI), Society of Experimental Social Psychology (SESP) and the European Association of Social Psychology (EASP).

We conducted a search for published and unpublished studies that fit our inclusion criteria until November 2017 through a search of specific terms in a logic of mutual inclusion on the main psychological databases: PubMed, PsychInfo, ScienceDirect, Web of Science, GoogleScholar, EBSCO, Dissertation Abstracts Online and ProQuest Dissertations & Theses. We searched the databases of word associations linking terms related to ovulation as, for example, "ovulat*" or "hormonal cycle" or "menstrual cycle" or "midcycle" or "high-fertility" or "luteal" or "follicular" or "estrogen" or "progesterone" or "estradiol" or "LH" or "FSH" with terms for the various types of risky conduct discussed in our analysis as "risk-taking" or "health" or "alcohol" or "drugs" or "sexual activity" or "sexual behavior" or "intercourse" or "sex" or "tobacco" or "cigarettes" or "addiction" or "risk recognition" or "fear faces" or "angry faces" or "risk avoidance" or "emotion". We also wrote to all the first authors' private mails in order to get additional and/or unpublished data.

Inclusion criteria.

Criterion 1. The most important criterion was the fact that the study contained data from naturally cycling women. Specifically, the study participants should not use any form of hormonal contraception at the time of the study. The ovulatory phase in women implies many hormonal variations that could result in a change of influence on some brain areas (hypothalamic-pituitary-ovarian axis in particular) affecting cognition and decision making in different ways. Pregnant and post-menopausal women have also been excluded from the analysis.

Criterion 2. The study needed to determine precisely the point in the cycle in which the participant was at the time of the experiment. The study must be able to determine the fertile window of the participants (including the few days leading up to ovulation and the day of ovulation itself – see below for further details on how fertility is defined in analyses) or follicular (early or late) or luteal (early or late) or menses. This could be achieved using methods that aim to pinpoint the day of ovulation, such as measures of urinary LH, basal body temperature, or salivary progesterone and estradiol (Godbert, Miro, Shreeves, Gnoth & Johnson 2015), or by using counting methods that estimate current cycle position based on last/next menstrual onset and average cycle length. This criterion was essential to be able to sort the studies according to the different measurement methods (see Table 1-4 in Appendices for menstrual cycle days included in the different studies). In the present meta-analytical review, the papers varied widely in their definition of the phases and what we referred to as “ovulatory phase” covered from day 6 (Bellis & Baker, 1990) to day 23 (Dumas, Calliet, Tumbling, & King, 1984) in a normal 28-days menstrual cycle.

Criterion 3. To estimate the effect size, and in particular the Hedges’*g*, we needed essential information such as variance and group averages. If the needed information was not available in the published report, we contacted the first authors to request that information. If we were unable to acquire the information, the study was excluded from our analysis ($K = 5$).

Computing Effect Sizes. The use of Hedges’s *g* was appropriate, given that the majority of studies in this literature have had small sample sizes and that Hedges’s *g* is a biased-corrected version of Cohen’s *d* (Borenstein, Hedges, Higgins, & Rothstein, 2009). The present meta-analysis compares different phases of the menstrual cycle through different types of risk-taking (alcohol and tobacco consumption, sexual activity, risk recognition and avoidance). Thus, *g*’s

represent the standardized mean differences between two particular phases (e.g., ovulatory vs. follicular). If, for instance, one particular comparison came out positive with a value of 0.2 in the sexual activity category between the ovulatory and the follicular phase, this would indicate a slight increase of allosexual behavior during high-fertile days when compared to the follicular phase of the cycle. Similarly, to Cohen's d , while a g of 0.2 represent a small effect, 0.5 and 0.8 represent respectively a medium and strong effect (Cohen, 1988). In case of substantial heterogeneity ($I^2 > 75\%$), and following van Aert's recommendations (van Aert, Wicherts and van Assen, 2016), we created (when possible) homogenous subgroups based on theoretical assumptions to estimate and compare effect sizes of this subgroup with the overall analysis.

The hormonal profile characterization really depended on the type of study. Substance use studies (alcohol and tobacco consumption) tend to use more rigorous methods, including within-women design, thus increasing statistical power for tests of associations with different hormonal profiles. This polychotomous characterization of the hormonal profile (in comparisons to binary conceptualization of the cycle such as high vs. low fertility days) enabled us to analyze alcohol and cigarettes consumption through menstruation, follicular, ovulatory, early luteal and premenstrual phases. When it was not possible, as in the case of sexual behavior and risk recognition and avoidance for instance, we had to take a more restrictive approach including fewer phases. Finally, we systematically excluded studies that contained a high- vs low-fertilty comparisons since we could not compare them to more precise phase specifications (as for Adams, Gold and Burt, 1978; Bröder and Hohmann, 2003; Prokop, 2013).

Coding Study Characteristics. We coded study for different characteristic when data were available (and contacted respective first authors if not). This included 1) relationship context of the sample (single, in relationship, both or not specified), 2) mean age of the sample, 3)

dependence to the substance for the alcohol and tobacco category only: high (more than 10 cigarettes a day or more than one drink a day for women and two drinks for men) vs. low (10 cigarettes a day or less or up to 1 drink per day for women and 2 drinks for men, Boulos et al., 2009; CDC, 2016), 4) study design (within-participants vs. between-participants), 5) cycle position estimation method (forward counting method vs. reverse counting method vs. average from forward and reverse counting methods vs. luteinizing hormone tests to attest ovulation vs. salivary method to verify impending ovulation or estrogen/progesterone levels vs. basal body temperature (BBT), noting for studies that used counting methods whether the benchmark date of menstrual onset was verified). 6) Type of measure: self-reported (women indicated the length of their cycle and date of their past or next menstruation) vs. physiological (urinary, blood sample for BBT charts, saliva sample to assess cycle position). Two researchers independently coded each study and then crosschecked their codes. In the case of discrepancies (which were rare), the researchers referred back to the paper or contacted the authors to verify the correct code. Thus, all codes were verified as correct.

Analysis

The modeling approach, used for every analysis ran in this meta-analysis, gave us the ability to include non-independent effects from the same pool of participants in a single analysis. We then weighted each effect by its inverse variance to reduce imprecision in our estimate of the overall effect size (Borenstein, Hedges, Higgins, & Rothstein, 2009). We conducted all analyses in Comprehensive Meta-Analysis (version 3.3.070) because it includes the most complete set of analytical features (Bax, Yu, Ikeda & Moons, 2007; Borenstein, Hedges, Higgins & Rothstein, 2009).

Following van Aert, Wicherts, & Van Assen (2016), we ran both fixed- and random-

effect models for all the analysis included. While the former is used to make inferences based only on the actual studies, the later is generally applied to generalize the results for an entire population (Borenstein, Hedges, Higgins & Rothstein, 2009). However, under strong publication bias, random-effect models (REM) can result in overestimate effect sizes since studies with small sample sizes get more weight compared to fixed-effect analysis (the reason is that REM estimate a mean of distribution of effects and a small studies give information than other studies do not give and we cannot, in that extent, give it a smaller weight; see Borenstein, Hedges, Higgins & Rothstein, 2009).

We then conducted different type of analysis for each category. The alcohol and tobacco consumption category contains tobacco and alcohol consumption regularly notified in a daily diaries confirmed in some studies by physiological controls (e.g., carbon monoxide, blood alcohol level). The “sexual behavior” category included allosexual behavior (behavior involving another individual through sexual intercourse, genital simulation with other, foreplay). The “risk recognition and avoidance” category combined the level of accuracy to recognize emotions such as fear and anger (which might be cues to possible threats), on the one hand but also the capacity to recognize direct risk when reading sexual coercive scenario or when confronted to a doubtful individual (a strange confederate with a big facial scarce as in Guéguen, 2012)¹³. Using meta-regression analysis (Borenstein, Hedges, Higgins, & Rothstein, 2009), we examined the following moderators: 1) whether the study used a self-report vs. physiological measure to assess cycle position or consumption markers (for all categories), 2) whether the sample came from dependent smokers or drinkers (in the alcohol and tobacco category), 3) the type of DV :self-reported vs. observed behavior (for the risk and recognition category), 4) the type of relationship:

¹³ Despite not being a risk “per se”, those capacities to recognize emotional cues and dangerous situations (sexual or not) can lead women to take faster and more accurate decisions on signals that can indicate potential risks.

paired, single, both or no information (for the sexual activity category), and finally 5) the mean age of the sample (for all categories).

We computed numerous effect sizes that may be really dispersed and variable from one study to another. This inconsistency statistically refers to “heterogeneity” (Del Re, 2015; Higgins and Thompson 2002). For example, consider hypothetically that the effect of the fertile window compared to the follicular phase of the menstrual cycle on tobacco consumption is medium according to Cohen’s standards (Cohen, 1992) but there is high variability between and within study. It is plausible those women might differ quite dramatically from each other on their cigarettes smoke per day and that this variability could affect the true effect size. On the other hand, between-study variability may also account for variation among the effect sizes in the population.

When there is strong heterogeneity, it might be crucial to identify which moderators may account for this variability. This analysis can be run when there is a theoretical or empirical justification, thereby helping to avoid Type I errors (Hunter & Schmidt, 2004). We systematically applied fixed-effect and random-effects models (REM) to compare both results following the Meta-Analysis Reporting Standards (APA, 2008, 2010). In case of massive heterogeneity ($I^2 > 75\%$), we create subgroups of interests based on theoretical and methodological considerations and ran both types of models, including the 3 estimates of between-study variances in REM, namely I^2 , Q and t^2 (van Aert, Wicherts, & Van Assen, 2016).

Beyond heterogeneity, difficulties to correctly evaluate effect sizes with few studies in meta-analysis may be due to low statistical power or to publication bias (the so-called “file drawer problem”; Rosenthal, 1979). With the overrepresentation of significant effects published in the literature, true effect sizes can be largely overestimated (Rothstein, Sutton, & Borenstein,

2005). When significance was reached, we consistently reported funnel-plots and p-curve estimates in effort to isolate any particular publication bias or signs of p-hacking (Simonsohn, Nelson, & Simmons, 2014). Publication bias can artificially inflate the average effect size and reduce heterogeneity across studies. In the present meta-analysis, we intended to use as much cautions as possible so results could be interpreted more realistically giving the actual state of the publication bias debate in the literature.

Results

As explained in detail above, the menstrual shift hypothesis posits that women experience specific cycle change for every type of behavior analyzed (alcohol and cigarette consumption, sexual behavior, risk recognition and avoidance). Specifically, certain phases of the cycle are expected to exhibit shift such as increase of sexual activity and better risk accuracy recognition during the fertile window compared to the rest of the cycle. Moreover, alcohol and cigarette consumption are expected to decrease at mid-cycle and early-luteal phases compared to the rest of the cycle.

The analysis examined cycle shifts in risky behaviors from a broad set of measures. This global analysis included 79 effects (figure 25 in the following page) from 27 studies (total $N = 7,527$). Here, we present results category by category, because a global effect of such diverse types of risk-taking behaviors would not be appropriate, particularly given that there are different sets of predictions for each type of risk. We limited our analyses to effects for which there were reasonable predictions (e.g., a precedent in the literature, or reasoning we outlined in our introduction, such as that informed by evolutionary thinking).

	Ovulatory vs. Follicular	Ovulatory vs. Luteal	Ovulatory vs. Late Luteal	Ovulatory vs. Menstrual	Early Luteal vs. Follicular	Early Luteal vs. Late Luteal	Early Luteal vs. Menstrual
Alcohol and tobacco combined	$g = -0.07$ 95% $CI [-0.18; 0.04]$ $SE = .06$ $p = .19$ $(k = 6, N = 731)$ $I^2/\tau^2 = 0, Q = 3.59,$ $p = .73$		$g = 0.01$ $[-0.14; 0.16]$ $SE = .08$ $p = .86$ $(k = 7, N = 787)$ $I^2 = 41.33,$ $\tau^2 = .02,$ $Q = 11.93,$ $p = .10$	$g = 0.01$ $[-0.08; 0.09]$ $SE = .04$ $p = .87$ $(k = 7, N = 742)$ $I^2 = 9.05, \tau^2 = .00,$ $Q = 7.70, p = .36$	$g = -0.15$ $[-0.31; -0.00]$ $SE = .08$ $p = .048$ $(k = 4, N = 530)$ $I^2/\tau^2 = 0, Q = 1.60,$ $p = .66$	$g = -0.09$ $[-0.23; 0.04]$ $SE = .07$ $p = .19$ $(k = 5, N = 586)$ $I^2/\tau^2 = 0, Q = 1.00,$ $p = .91$	$g = -0.02$ $[-0.16; 0.13]$ $SE = .07$ $p = .83$ $(k = 5, N = 541)$ $I^2/\tau^2 = 0, Q = .50,$ $p = .97$
Sexual activity	$g = 1.17$ $[-0.02; 2.37]$ $SE = .61$ $p = .054$ $(k = 7, N = 2075)$ $I^2 = 99.54,$ $\tau^2 = 3.31,$ $Q = 1731.00,$ $p < .001$	$g = 1.22$ $[0.34; 2.09]$ $SE = .45$ $p = .006$ $(k = 9, N = 4753)$ $I^2 = 99.48,$ $\tau^2 = 2.37,$ $Q = 2123.06,$ $p < .001$		$g = 1.69$ $[0.60; 2.78]$ $SE = .56$ $p = .002$ $(k = 6, N = 3306)$ $I^2 = 99.57,$ $\tau^2 = 2.75,$ $Q = 1837.34,$ $p < .001$			
Risk recognition and avoidance	$g = 0.28$ $[-0.21; 0.78]$ $SE = .25$ $p = .26$ $(k = 8, N = 742)$ $I^2 = 85.30,$ $\tau^2 = 0.38,$ $Q = 47.61,$ $p < .001$	$g = 0.40$ $[0.06; 0.74]$ $SE = 0.17$ $p = .02$ $(k = 10, N = 917)$ $I^2 = 76.63,$ $\tau^2 = 0.20,$ $Q = 38.51,$ $p < .001$		$g = 0.50,$ $[-0.20; 1.21]$ $SE = 0.36$ $p = .16$ $(k = 5, N = 351)$ $I^2 = 83.86,$ $\tau^2 = 0.51,$ $Q = 24.79,$ $p < .001$			

Figure 25. Table displaying all the main phases' comparisons for the three domains of health-related risks.

Alcohol and Tobacco consumption patterns. Ovulation vs. other phases.

We first analyzed the alcohol (ounces of alcohol per day) and tobacco consumption (number of cigarettes per day) throughout the ovulatory, the follicular, early luteal, late luteal and menstrual phases according to our theoretical framework.

Analysis comparing the *ovulatory* period to the *follicular* phase in REM revealed that the weighted mean g was null ($g = -0.07$, 95% CI [-0.18; 0.04], $SE = .06$) and not statistically significant ($p = .19$) indicating no difference of alcohol and tobacco consumption between those two phases of the cycle. The data revealed low heterogeneity ($I^2 = 0$, $\tau^2 = 0$, $Q = 3.58$, $p = .73$). A strong pre-post correlation for within-study design ($r = 0.75$) led, on the contrary, to small significant effects in both fixed and random models indicating a small protective effect of the ovulatory phase, $g = -0.09$; [-.17; -.00], $SE = .04$, $p = .047^{14}$ ($I^2 = 0$, $\tau^2 = 0$, $Q = 5.06$, $p = .54$). None of the moderator explained the effect ($Q = 3.13$, $p = .37$ for the full model including age, physiological control of the phases and dependent conditions – heavy smokers or alcoholics – of the participants).

When we compared the *ovulatory* period to the *late luteal period*, the REM analysis showed a null ($g = 0.01$, [-0.14; 0.16] $SE = .08$) and not statistically significant effect ($p = .86$) without influence of the pre-post within-study correlation. The data revealed small to medium heterogeneity ($I^2 = 41.33$, $\tau^2 = .02$, $Q = 11.93$, $p = .10$).

We finally compared cigarette and alcohol consumption between the *ovulatory* phase and the *menstrual* phase. This category revealed that the weighted mean g was null ($g = 0.01$, [-0.08;

¹⁴ No additional indications were inserted if the pre-post correlation threshold for within-study design ($r = 0.25$, 0.50 or 0.75) did not change the significance of the results.

0.09], $SE = .04$) and not statistically significant ($p = .87$) indicating no difference of consumption between those phases. The data revealed low heterogeneity ($I^2 = 9.05$, $\tau^2 = .001$, $Q = 7.70$, $p = .36$).

Alcohol and Tobacco consumptions patterns. Early luteal vs. other phases.

We then compared this behavior within *early luteal* phase to the *follicular*, *late luteal* and *menstrual* phases according to our theoretical framework.

During the *early luteal* phase, women consumed significantly less alcohol and tobacco than during the *follicular* phase. This category revealed a *small significant* effect ($g = -0.15$, $[-0.31; -0.00]$, $SE = .08$, $p = .048$) with low heterogeneity ($I^2/\tau^2 = 0$, $Q = 1.60$, $p = .66$). Both fixed and random-effect models gave exactly the same results (see Appendices, Table 2 for menstrual cycle categorizations and figure A1 for funnel plots that revealed no apparent publication bias). A weak pre-post correlation of $r = 0.25$, revealed a marginal effect ($g = -0.15$, $[-.30; .01]$, $SE = .08$, $p = .07$) while a strong one (i.e., $r = 0.75$) revealed a significant effect ($g = -0.17$, $[-.30; -.03]$, $SE = .07$, $p = .01$) with very low heterogeneity in both cases ($I^2/\tau^2 = 0$).

Finally, the comparisons between the *early luteal* phase and the *late luteal* phase and between the *early luteal* phase and the *menstrual* phase revealed a null effect ($g = -0.09$, $[-0.23; 0.04]$, $SE = .07$ and $g = -0.02$, $[-0.16; 0.13]$, $SE = .07$, respectively) not statistically significant ($p = .19$ and $p = .83$) with low heterogeneity ($I^2/\tau^2 = 0$, $Q = 1.00$, $p = .91$ and $Q = .50$, $p = .97$, respectively). Due to the low number of studies for these comparisons, it was not possible to run any meta-regression including the covariates of interest or to compute p-curve because all tests included $p > .05$.

Sexuality pattern. Ovulation vs. other phases.

An Evolutionary Approach On Binge Drinking

We analyzed the frequency of allosexual behavior to determine the difference between the *ovulatory* phase and the other phases of the menstrual cycle (see Table 4, in Appendices, for the cycle days including in those phases).

The comparison between the *follicular* phase and the *ovulatory* period produced a weighted mean g that was large ($g = 1.17$, $[-.021; 2.37]$, $SE = .61$) but only marginally significant ($p = .05$). The fixed-effect model also displayed a significant result with a large effect ($g = 0.76$, $[.69; .84]$, $SE = .04$, $p < .001$). However, the data revealed high heterogeneity ($I^2 = 99.54$, $\tau^2 = 3.31$, $Q = 1731$, $p < .001$) due to very strong effect sizes (from Caruso et al., 2014) that largely inflated the overall effect and produced publication bias (but no evidence of p-hacking, see figures S1a and P1a in Appendix). Not including them into the analysis produced a null and non-significant effect ($g = -0.04$, $[-0.22; .15]$, $SE = .09$, $p = .71$) with much lower heterogeneity compared to the full analysis ($I^2 = 70.09$, $\tau^2 = .04$, $Q = 20.06$, $p = .003$, see figure S1b in Appendix) leading to think that the true effect must be close to zero (the fixed-effect analysis even resulted in changing the direction of the effect, $g = -0.10$, $[-.18; -.004]$, $SE = .05$, $p = .04$).

We then compared data between the *ovulatory* and the *menstrual* phase and established that the weighted mean g was large ($g = 1.69$, $[.60; 2.78]$, $SE = .56$) and statistically significant ($p = .002$) indicating more pronounced sexuality during the *ovulatory* phase when compared to the *menstruation*. The fixed-effect model also revealed a significant results with a medium to large effect ($g = 0.67$, $[.60; .74]$, $SE = .04$, $p < .001$). The data again revealed very high heterogeneity ($I^2 = 99.57$, $\tau^2 = 2.75$, $Q = 1837.34$, $p < .001$) with apparent publication bias but no sign of p-hacking (see figures S3a and P1c in Appendix). Again, the data from Caruso et al. (2014) displaying abnormally high effect sizes, an analysis excluding those data were re-run

leading to a small significant effect in both fixed- and random-effect models ($g = 0.17$, [.10; .24], $SE = .04$, $p < .001$) with no apparent heterogeneity ($I^2 / \tau^2 = 0$, $Q = 5.50$, $p = .48$) or evidence of publication bias (see figure S3b in Appendix).¹⁵

We finally compared the *ovulatory* period to the *luteal* phase and established that the weighted mean g was large ($g = 1.24$, [0.32; 2.16], $SE = .47$) and statistically significant ($p = .008$) indicating higher frequency of sexual activity around *ovulation* when compared to the *luteal* phase (the fixed-effect model, however, revealed a more modest effect, $g = 0.33$, [.27; .39], $SE = .03$, $p < .001$). Since the heterogeneity was substantially high ($I^2 > 75\%$), we again ran an analysis excluding two inflated effects (from Caruso et al., 2014) and found no significant effect either in random-effect ($g = 0.06$, [-.04; .16], $SE = .05$, $p = .27$) or fixed-effect model ($g = 0.005$, [-.06; .06], $SE = .03$, $p = .88$) with a much lower level of heterogeneity ($I^2 = 50.04$, $\tau^2 = .01$, $Q = 16.01$, $p = .04$; see figures S2a, S2b and P1b for sign of publication bias and p-hacking analysis).

Risk recognition and avoidance pattern. Ovulation vs. other phases.

The third category of risks included sexual and non-sexual risk avoidance along with emotional cues that can lead to avoid potential risks (recognition of fear and anger). We first computed this risk recognition to compare the *ovulatory* and the *luteal* phase. Consistent with theorizing in this literature, this analysis revealed that the weighted mean g for the REM was small to moderate ($g = 0.40$, [.06; .74], $SE = .17$) and statistically significant ($p = .02$) indicating better risk recognition accuracy around *ovulation* when compared to the *luteal* phase of the

¹⁵ There were not enough studies to run a meta-regression including the covariates of interest (age, relationship status and physiological controls). A weak pre-post correlation ($r = 0.25$) led to a significant results in both FEM and REM ($g = 0.17$, [.09; .25], $SE = .04$, $p < .001$) while a strong pre-post correlation ($r = 0.75$) led to a significant results of the same amplitude ($g = 0.18$, [.11; .25], $SE = .04$, $p < .001$).

cycle. The fixed-effect model also revealed a significant results ($g = 0.25$, [.11; .39], $SE = .07$, $p = .001$) with evidence of a small amount of publication bias, but no apparent indications of p-hacking (figure R3 and P2 respectively, in Appendix). Meta-regressions analysis did not reveal any significant effects (the full model explaining 34% of the total between-study variance). Since the heterogeneity was still substantially high ($I^2 > 75\%$), we followed van Aert and colleagues' recommendations (2016) by analyzing subgroups of interest. The subgroup of interest, based on theoretical assumptions, were sexual risks (excluding emotion recognition studies) and revealed a small to large significant effect in both random-effects ($g = 0.55$, $SE = .27$, [.02; 1.08], $p = .04$) and a small effect in fixed-effect model ($g = 0.25$, $SE = .08$, [.09; .41], $p = .002$) still leading to non-trivial heterogeneity ($I^2 = 88.70\%$).

When we compared the *ovulatory* against the *follicular* phase, we found that the weighted mean g was small ($g = 0.28$, $SE = .25$, [-.21; .78]) but not statistically significant ($p = .26$) indicating no difference at risk recognition accuracy during the *ovulatory* compared to the *follicular* phase of the menstrual cycle (the fixed-effect model revealed a null effect, $g = -0.06$, $SE = .08$, [-0.23; .10], $p = .44$). Large heterogeneity ($I^2 > 75\%$) led us to re-analyze our data based on sexual risk recognition studies and found no significant effect in both REM and FEM analysis ($g = 0.32$, $SE = .33$, [-0.33; 0.97], $p = .34$ and $g = -0.10$, $SE = .09$, [-0.27; .07], $p = .25$ respectively). This second analysis also led to substantial evidences of heterogeneity ($I^2 = 91.06$, $\tau^2 = 0.47$, $Q = 44.74$, $p < .001$).

We finally compared the *ovulatory* and the *menstrual* phases. This category revealed that the weighted mean g was moderate ($g = 0.50$, $SE = .36$, [-.20; 1.21]) but not statistically significant ($p = .16$) with high heterogeneity ($I^2 = 83.86$, $\tau^2 = 0.51$, $Q = 24.79$, $p < .001$). The

fixed-effect model also yield a non-significant result ($g = 0.03$, $SE = .11$, $[-.18; .25]$, $p = .77$).

The funnel plots revealed that, while the alcohol and tobacco set of studies did not display any apparent bias, the other categories were inconsistent. In both risk-recognition and sexuality studies, there seemed to be an underrepresentation of studies in the lower part of the plot (with smaller standard errors) and generally one or two studies outside the plot (with g 's > 1). According to Egger, Smith, Schneier, & Minder (1997), such apparent publications bias could be due to delayed publication or locations biases; selectively reported outcomes or analysis; fraud or simply chance. Sterne et al. (2011) later expressed some concerns over the direct association between funnel plot asymmetry and publications biases in particular when visually inspected funnel plots alone. Comparing fixed and random effect models is also a way to explore possible bias when funnel plots are asymmetrical in meta-analysis with substantial between-study heterogeneity. In both risk recognition and sexual activity studies, fixed effects models eventually revealing significant effects to the same extent of random-effect models.

In addition, while our set of alcohol and tobacco studies did not have enough significant studies to run adequate p -curves (a good sign of absence of p -hacking), the two others categories revealed no evidence of p -hacking with high power and good fit between expected and observed p -values (Simonsohn, Simmons & Nelson, 2015; see Appendices for details). Since data revealed moderate-to-large heterogeneity (for the risk recognition and sexual activity categories), we also followed van Aert and colleagues (2016) by doing subset analysis when possible. Approached based on selections methods, such as the one developed by Hedges (1992), presents less sensitivity to heterogeneity, and may lead us to extra-caution in interpreting results with moderate-to-large heterogeneity (McShane, Böckenholt & Hansen, 2016).

Discussion

Overview. This meta-analysis provides the first attempt to describe health-risks pattern across the ovulatory cycle. The three main categories of risk-taking behaviors assessed include alcohol and tobacco consumption, sexual behavior, and risk recognition and avoidance. The last one analyzed both the accuracy at recognizing emotions that could indicate threat (fear and anger), as well as behavioral responses to potentially dangerous situations. All of those behaviors are of important concern for the health community. Understanding them, through different levels of organization (hormonal, social, and behavioral) represents both a scientific challenge and an important new way of thinking about women's health.

Surprisingly, the data revealed that the ovulatory phase was not associated with a reduction in alcohol and tobacco consumption when compared to the rest of the cycle. Those effects were close to null and the between-study variability due to heterogeneity rather than sampling error was null to medium ($0 < I^2 < 42$) due either to consistent measures and methods between studies and/or because our sample of studies was too small to estimate true heterogeneity. On the other hand, only the *early luteal* versus *follicular* comparison revealed a small reduction of consumption of these toxic substance during the post-ovulatory phase (women consuming less alcohol/tobacco at early luteal when compared to the follicular phase). Those general results may seem counterintuitive since the late luteal phase, in particular, is subject in some women to premenstrual syndrome, a common condition (involving depression, mood lability, abdominal pain, headache among others) that could lead to more alcohol and tobacco consumption (Dickerson, Mazyck & Hunter, 2003). Since our data did not reveal any relationship between the late luteal phase and substance use, this may indicate that as

menstruation approached, withdrawal symptoms might increase but not necessary alcohol or tobacco consumption per se (see the meta-analysis by Weinberger et al., 2015).

The sexuality results did not match the same patterns observed in many non-human species. Despite an apparent conflicting literature and remaining debate and the evolution, existence, and function of estrus (Thornhill & Gangestad, 2008), the data revealed an increase in allosexuality around ovulation compared to the menstrual phase but the other comparisons did not hold when excluding extreme effects (from Caruso et al., 2014). One possible confounding might be that sexual activity in general (masturbation, foreplay, etc.) varies across the cycle and that some specific behaviors (e.g., intercourses) weighted more than others did.

Another mediator that could partially explain the inconsistency observed in the allosexual behavior shift would be the increase in women's attractiveness. Gildersleeve & Haselton (2018), for instance, reviewed evidence for an ovulatory increase in the attractiveness of women's voices, appearance, and even body movements. As a result, women's partner might be more likely to initiate sexual activity at that time. It is unclear, however, whether women are driving this effect or if factors behind their control, such as partners' advances or availability play a role and to what extent. One thing to also consider is the target of women's attractions and sexuality. Past research has shown that increases in women's attraction to their own (primary) partners vs. other men is associated with the sexual attractiveness of their primary partners (reviewed in Larson, Pillsworth, & Haselton, 2012). Women partnered with less sexually attractive partners, on the other hand, tend to show increases in attraction to other men when fertile (see also Gangestad, Thornhill & Garver-Apgar, 2005; Thornhill & Gangestad, 2008). Controlling for the attractiveness perception of the participants and his/her partner could clarify this potential

sexuality shift.

Another hypothesis that we did not investigate is the role of women's luteal phase in their sexual receptivity (i.e., acceptance of male sexual initiation) and proceptivity (i.e., women's initiation of sexual activity). Even though the luteal phase did not seem to display higher frequency of allosexual behavior than the ovulatory period, it's worth noting that recent data show an increase of sexual activity with primary partners when comparing the luteal phase to the follicular phases, particularly for women who feel that their partner's investment in the relationship lags behind their own (Grebe, Gangestad, Garver-Apgar & Thornhill, 2013). This hypothesis (that extended sexuality promotes sexual activity in the luteal phase to encourage investment from male partners) is subject to controversy as recent works failed to replicate this effect (Roney & Simmons, 2016). In all, however, it remains plausible that women's sexual motivations are influenced by hormonal fluctuations (such as estrogen peak before and at ovulation) and that extended sexuality is influenced by social factors (such as week-end timing) that we did not assess in our present work (Roney & Simmons, 2016).

Along with the ovulatory shift in sexuality, researchers have predicted that a counter-risk mechanism may have evolved to protect women against environmental threats (including sexual assaults) specifically during the most fertile days. Whereas there is still an ongoing debate about whether women ovulating are underrepresented among victims of rape (Fessler, 2003), we found a shift on risk recognition when comparing the *ovulatory* and the *luteal* phases. However, the other phases comparisons did not reach significance. This could be due to a low statistical power or to the substantial between-study heterogeneity (concepts and methods use differed largely across studies). It is also possible that the risk recognition capacity encompasses larger skills sets

toward at reducing risk of sexual coercion that the present studies did not include.

Limitations. The results of this meta-analysis presented somewhat mixed findings. On the one hand, there were some increases in sexual activity and risk recognition capacity during the ovulatory period as compared with other low-fertility phases (menstrual and luteal respectively). However, the alcohol and tobacco consumption analysis showed inconsistent results, which contrasted with results observed in the animal literature. Despite a relatively coherent methodology for the substance use portion of the analysis, with longitudinal design, physiological characterization of the menstrual cycle, low heterogeneity, only the analysis comparing the early luteal versus the follicular phase displayed significant small effect.

Studies were methodologically heterogeneous. Therefore, all results should be cautiously interpreted. In the alcohol and tobacco category, data coming mostly from medical studies, represented high methodological standards with longitudinal studies design and LH measures. The very low heterogeneity and the good quality of measures would be optimal if there were not such small samples sizes and too many parameters (one or two independent variable with multiples modalities). Therefore, one should be cautious in interpretation these findings.

Sexual behavior also showed an increase during the fertile period when compare to other phases but only the ovulatory vs. menstrual comparison resisted the exclusions of the inflated effects (Caruso et al., 2014). This particular shift may be largely explained by the tendency to avoid sexual activity at menstruation because of physical discomfort or social taboos. It is also possible that male partners could be driving some of this effect because of their increase interest in women displaying estrus cues. The very few numbers of intercourses-only variable made impossible the analysis of that specific behavior. While the high vs. low fertility shift would

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include specifically higher frequency of sexual intercourses around ovulation, the shift might include a wider range of sexual activity when other phases are targeted. For instance, when comparing the luteal to the follicular phases, it might be plausible to see more non-reproductive sexuality at luteal phases (including masturbation, oral sex, etc.) when fertility is the lowest.

Along with sexual activities, some evolutionary theorists have argued that women will be better at recognizing emotions and cues of dangerous (sexually coercive) situations when fertile. Caution is again warranted in interpreting these findings. First, it is not clear that the emotion recognition is directly related to danger avoidance but we chose to include them because in an ancestral context, seeing anger or fear in someone else's face might be a cue to potential danger in the near environment. Second, studies of reaction sensitivity to sexual assault scenario and threatening situations were highly heterogeneous. Finally, the only robust effect seemed to be the ovulatory vs. luteal comparisons with women participants more accurate at recognizing risk at high fertility compared to the luteal phase. One possible explanation is that our comparisons were too specific and a more general high vs. low fertility mechanism is at play. Again, those studies revealed large heterogeneity with or without subgroup analysis as illustrated by funnel plots (see Appendices).

A limitation of the funnel plot approach includes the fact that the shape of the funnel plot is largely determined by the way of building the plot. The other main problem with that technique is that publication bias, in both social and medical sciences, largely occurs through significance and not effect sizes (Simonsohn, Nelson & Simmons, 2014). This can happen, in particular through p-hacking by data peeking, selectively reported DVs or excluding outliers (van Aert, Wicherts & van Assen, 2016). Since journals tend to report only significant findings, this can

lead to largely inflate the effect sizes in the available literature (Ioannidis, 2005). Simonsohn and colleagues (2014) then decided to create p-curve stated that “because only true effects are expected to generate right-skewed p-curves — containing more low (.01s) than high (.04s) significant p values — only right-skewed p-curves are diagnostic of evidential value” (Simonsohn, Nelson & Simmons, 2014, p.534).

Contributions of the present research and directions for the future. This meta-analysis represent to our knowledge the first attempt to determine the combined effect of menstrual cycle on health-related risk-taking behavior for those specific categories of effects. Through 27 studies and 79 effects, we have been able to assess multiple analysis in an effort to examine risk behaviors across the cycle. We also used several procedures to determine whether observed statistically significant cycle shifts appeared to result from bias in researchers’ measurement of menstrual cycle phases (through meta-regressions) or variations across relationship context or physiological controls (but the lack of power make it hard to strongly based our analysis on such inferences).

In the future, researches should seek to identify the hormonal mechanisms underlying cycle shifts in women’s risky behavior. Previous research has suggested several possible candidates for hormonal mediators of the cycle shifts observed in this meta-analysis. Estrogen seems to play a role in the regulation of dopamine during alcohol and tobacco use for instance. However, the exact pathway and the causal direction of this effect remains unknown and may contribute to make more systematic interdisciplinary projects leading to the evaluation of those biomechanics. Those biogenesis, proliferative, ovulatory, luteal and pre-menses) is the most appropriate experimentally.

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Second, research in some area has focused on testing for the presence of cycle shifts in women's risky behavior primarily in Western samples of educated young women. That was the case of the risk and avoidance category mainly ran on psychological students. Those samples are usually overrepresented in psychological research and this bias is a real problem that need to be addressed (Henrich, Heine, & Norenzayan, 2010). However, the alcohol and tobacco dataset and the sexual behavior studies were largely run on non-undergraduate, community women allowing for conclusions that are more generalizable. Nonetheless, future research should consider varied samples of women to see if cultural context might affect cycle shifts. For example, menses is interpreted differently in non-Western societies and be more subject to taboo in certain part of the world. This could dramatically affect women's sexuality dynamic by either reducing even more their activity at that time or promoting stronger effects when compared to other phases (Agyekum, 2002; Costos, Ackerman & Paradis, 2002).

Lastly, from a methodological standpoint, the study of menstrual cycle does not have yet a standard procedure across disciplines to precisely determine women's position on the cycle. In general, different methods with various reliability are available for that procedure. The strongest one consist at measuring the LH level of the women either in a cross-sectional design (between-study design) or along the cycle (within-study design or longitudinal). Other physiological tools permit to determine women's position cycle such as the BBT charts but many studies in psychology are still using self-report measures (backward and forward counting methods) that present weaknesses and imprecisions compared to the methods described above. It could be the case that medical studies, like those represented in the alcohol and tobacco category, have better measures of hormonal profiles and so lower heterogeneity as compared to psychological studies.

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In order to get an optimal understanding of those health-risk behaviors, inter-disciplinary studies and multi-methodology still represent the best option to understand risky behavior and provide insights into health applications and policy programs. On the other hand, we chose in this meta-analysis to make comparisons between different phases instead of using a dichotomous (high- vs low- fertility days). Future meta-analysis should also aim at analyzing high- vs. low- fertility on risky behaviors and compare it to phases analysis.

Chapter 6: Binge Drinking Frequency and Intensity across the United States (2007-2016): a Multilevel Modeling of Life-History Theory and Risky Drinking.

The excessive use of alcohol or binge drinking (drinking at least 4/5 standard drinks in 2 hours for women and men respectively) is a costly risky conduct from both health- and socioeconomic point of views (CDC, 2017). The Behavioral Risk Factor Surveillance System (BRFSS) survey reported that, in 2013, more than half of the American adult population had been drinking alcohol in the past 30 days and that, among them, 17% admitted having at least binge drinking once. The Center for Disease Control and Prevention, through its application ARDI found that, between 2006 and 2010, binge drinking caused an average of 88,000 deaths per year and costed \$249 billion just for the year of 2010 (about \$807 per person per year), most of this due to economic loss of productivity (72%) and health care expenses (11%).

Between 1993 and 2001, the National Survey on Drug Use and Health (NSDUH), a household-based survey, had shown an overall increase in binge drinking rates in the US from 12.1 to 18.6 percent. More than a quarter of the 12- to 20 years old reported drinking alcohol in the past 30 days (27.1%) with a median age of 14.22 years old (Chen, Yi & Faden, 2011). While at this age, nearly 10% of men reported drinking in the month, 20 years old males are more than 60% (65% among non-Hispanic Whites) admitted experienced alcohol. There is a constant gender gap in risky drinking with men always consuming more frequently and with higher intensity compared to women in both US descriptive data (Chen, Yi & Faden, 2011) and meta-analysis (Byrnes, Miller & Schafer, 1999).

Among the myriad of other factors involved in binge drinking patterns, numerous of social factors regularly emerged in the literature: being part of fraternities, party-centered life-style, peer pressure, disrupted families, impulsivity or even sensation-seeking (Courtney &

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Polich, 2009; Weschler, Dowdall, Davenport, and Castillo, 1995). Fraternities, for instance, are famous for widespread use of drinking games and 81.1% of fraternity or sorority residents in the US are binge drinkers (Wechsler et al., 1998; Wechsler, Davenport, Dowdall, Moeykens & Castillo, 1994). Another strong predictor is the marital status of the individual. When controlling for other demographic variables, the status of “never married” was a strong predictor of binge drinking (see Weschler, Dowdall, Davenport, and Castillo, 1995; Wechsler, Lee, Kuo & Lee, 2000; Schulenberg et al., 1996). Chassin, Pitts and Prost (2002) evaluated binge drinking trajectories from adolescence to emerging adulthood in a high-risk sample. They found that family structure was a good predictor in particular for early heavy drinkers: adolescents from disrupted families (where one or more biological parents is absent) were more likely to be involved in risky drinking activities than their counterparts from united families (where both biological parents are present).

On the other hand, drinking intensity is correlated to various cognitive processes (seek-excitement, self-control) that put adolescent and young adults at heightened vulnerability to risk. This is the case, in particular, when personality traits such as impulsivity or sensation-seeking are noticeable among the individual (Cyders, Flory, Rainer & Smith, 2009).¹⁶ However, the other major biological components appeared to be the age with major decrease in binge drinking when one gets older (Wilsnack, Wilsnack, Kristjanson, Vogeltanz-Holm & Gmel, 2009).

Thus, from a general standpoint, while engaging in binge drinking in the first place and maintaining frequent drinking risky activities tend to be more influenced by social and

¹⁶ The frequency of the short allele (S) in the serotonin transporter (5-HTT) was correlated to higher ethanol tolerance among adults 26 years old and older. In term of racial differences, the gene that codes for alcohol metabolizing enzymes, the aldehyde dehydrogenase gene (ALDH2), possess an allele (ADLH2*2) that inactive a major metabolizing enzyme for alcohol. Among Chinese and Japanese, 25 and 40% respectively possess this allele which is much higher than among Caucasians (resulting in flushing and nausea after alcohol consumption, see Higuchi et al., 2004; Plomin & DeFries, 2013).

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situational factors, drinking intensity (the amount of alcohol consumed in a single occasion) may be more influenced by biological factors that goes beyond one's control. The life-history theory (LHT) framework tried to understand behavior development across factors that shape one's development and human evolutionary strategy. For instance, the intensity of reproductive competition is one factor triggering risk-taking (Hill & Chow, 2002) interacting with the environmental characteristics mentioned above.

We predict that, across 10 years' data, being a male will be the strongest predictor of binge drinking intensity and that an interaction will emerge with age (a younger male being more vulnerable to such conduct than an older one). On the frequency of binge drinking, we predict that situational factors such as employment (student), marital (never married) or economic status (high household income) will moderate the association between gender (male) and risky drinking. While the data are nested among US States and imposed a multilevel analysis, we do not have specific predictions for that second-level and then assume than the trend described above will repeatedly occur across space (53 US States and territories) and time (2007-2016).

5.1. Life-history theory and risky drinking

Risk-taking has long been thought to be a stable personality traits among social psychologists (Wang, Kruger & Wilke, 2009). Some individuals would be particularly risk-seekers while others, more risk-averse, would tend to avoid situation that put themselves, their financial or their surrounding belongings in danger. However, Johnson and Wilke (2006) have found that risky-taking behaviors tend to vary considerably between domains (e.g., some individuals may be particularly inclined at engaging into physical risks, like bungee jumping, but at the same time risk averse concerning financial investments). Risk-taking has been considered domain-specific by evolutionary psychologist (Cosmides & Tooby, 1996) when they are

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pertinent in regard to ancestral situations updated a in modern context (e.g., risky drinking could have taken the form of drinking enema among Maya but as drinking games in contemporary societies, see Diamond, 1992).

Life-history theory (LHT) addresses the binge drinking problematic by differentiating development stages and frame it into a global life-strategy perspective (Kaplan & Gangestad, 2004). Competition to capture energy in ancestral environment (foraging, hunting, etc.) involved trade-offs (costs/benefits) to allocate it to reproduction and survival-enhancing activities. Those activities take form through mating, parental investment, within-group competitions and so on (see Wang, Kruger and Wilke, 2009). LHT usually distinguishes between fast and slow life-history strategies (figure 24 below). Risky drinking typically fit into a fast life-history strategy corresponding to adolescent/young adulthood: causal and more frequent matings, lower investment in parenting, higher impulsivity, lower trust in others, etc. Hill and Chow (2002) are the first, to our knowledge, having used life-history theory model to compare it to actual data (Ontario Health Survey and Epidemiological Catchment Area in 1995). They found that young males (18-29 years old) tend to drink more than female and that single, childless and low income individual were also more willing to engage in binge drinking. However, those data covered only one year and were not enough spatially spread to observe the dynamic of the phenomenon.

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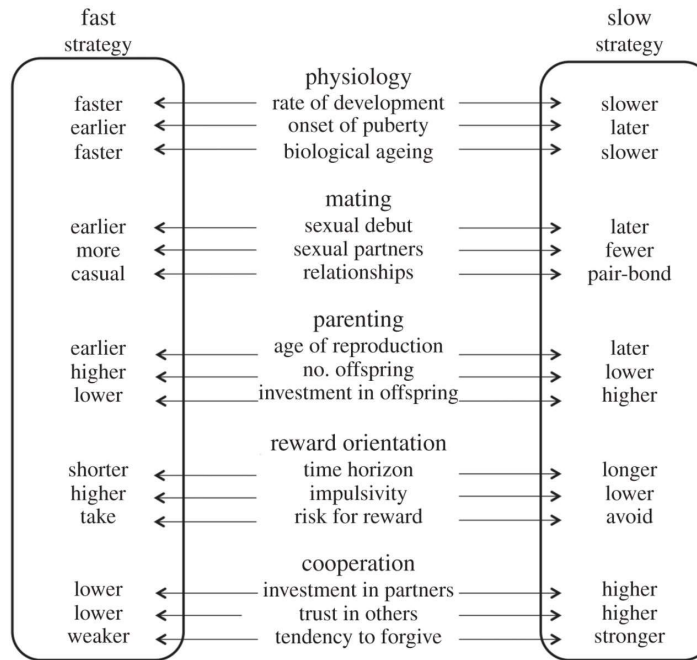


Figure 24. Life-history theory (from Griskevicius et al., 2013).

In general, LHT modeling of binge drinking also predicts such patterns. However, we disagree with the socioeconomic level influences on binge drinking. Indeed, alcohol display can be associated with demonstration of wealth as the Boston Bruins did after their 2011 Stanley Cup victory where they spent \$156,679.74 total on alcoholic beverage (“Their Stanley Cup Overfloweth”, 2011). According to the national Gallup survey (2001), more than 80% of individuals making more than \$75,000 admitted drinking alcohol while only 46% of those making less than \$20,000 reported drinking. In Australia, among 50 neighborhoods in Melbourne, participants with lower education or households income were less likely to consume alcohol regularly compare to higher household income (even though low income individuals drank less frequently, they tend to consume in greater quantities when they do, see Giskes, Turrell, Bentley & Kavanagh, 2011). Using data from the National Longitudinal Survey of Adolescent Health (AddHealth), Humensky (2010) showed that both higher parental educational level and income were associated with higher binge drinking rates.

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This is not surprising as higher income families can more easily integrate their children to college and university campuses where fraternities/sororities are particularly famous for binge drinking games (Courtney & Polish, 2009; Wechsler, Dowdall, Davenport, & Castillo, 1995). Our study drew on a much larger sample (4 million of participants) over 10 years (2007-2016) across 53 states and territories of the United States. We used data starting from the late 2000s because this is when public opinion and policy expert defined binge drinking more precisely as heavy intoxication in a single occasion (usually connected to public disorders from youth; for a social history of the concept, see Berridge, Herring & Thom, 2009).

We predict that binge drinking frequency, while largely explained by gender differences, should display interaction with the employment status such as male students binge drinking more often than other professions. Moreover, we expect that marital and economic status should also interact with gender such as men who had never been married as long as rich males should also display higher binge drinking patterns. On the other hand, the drinking intensity (the total number of drinks per occasion) will be largely explained by the sex and the age with young men consuming more than women due to physiological and intrasexual competition aspects (LaBrie, Ehret & Hummer, 2013; Marsh and Kibby, 1992).

5.2. Current Study

5.2.1. Methodology.

The Behavioral Risk Factor Surveillance System (BRFSS) published every year a collaborative project between all of the states in the United States. It aims at measuring behavioral risk factors among noninstitutionalized adults aged 18 years or older and currently living in the United States. The idea is to collect uniform space-specific data to monitor health practices across space time in an adult population. In 2015, for instance, the 53 states and

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territory used the Computer-Assisted Telephone Interview (CATI) systems to collect data during each month (on different participants every month). The questionnaire lasted 18 minutes on average and are being monitored by experienced telephone surveys interviewers. Data were weighted to ensure the total number of cases to equal population estimates for each geographic area¹⁷.

5.2.2. Participants.

In total, over 10 years (2007-2016) and across 53 states and US territories, 4,595,452 adults individuals participated in the BRFSS Survey (M = 459545.20, SD = 30213.54 per year). After excluding those who did not answer the binge drinking frequency question, the drinking intensity question as well as those who conveyed inconsistent responses (e.g., reported binge drinking 30 times in the past month but drinking, on average, only 1 drink anytime they drank¹⁸), we ended up with 2,120,906 participants (M = 212090.60, SD = 16536.89). Among them, 15.97% were between 18 and 34 years old (N = 338,702), 2.17% reported being students at the time of the survey (N = 46,052) and 46.59% of participants were men (N = 988,138).

¹⁷ “When data are unweighted, each record counts the same as any other record. Unweighted data analyses make the assumption that each record has an equal probability of being selected and that noncoverage and nonresponse are equal among all segments of the population. When deviations from these assumptions are large enough to affect the results from a data set, weighting each record appropriately can help to adjust for assumption violations. In the BRFSS, such weighting serves as a blanket adjustment for noncoverage and nonresponse and forces the total number of cases to equal population estimates for each geographic region, which for the BRFSS sums to the state population. Regardless of state sample design, use of the final weight in analysis is necessary if users are to make generalizations from the sample to the population. Following is a general description of the 2015 BRFSS weighting process. Where a factor does not apply, processors set its value to one for calculation. In order to reduce bias due to unequal probability of selection, design weighting is conducted. The BRFSS also uses iterative proportional fitting, or raking, to adjust for demographic differences between those persons who are sampled and the population that they represent. The weighting methodology, therefore, comprises two sections—design weight and raking.” (OVERVIEW: BRFSS, 2015, p. 9).

¹⁸ We applied a general rule for those inconsistencies. For instance, someone reported having binge drinking 6 times in the past month should reported, on average, drinking at least 1 drink per occasion (6 (to 11) binge drinking events x 5+ drinks = 30+ (55+) drinks a month thus at least 1 (≈ 1.83 , rounded to the lower = 1) drink per drinking event; 20 binge drinking events x 5+ drinks = 60+ drinks a month thus at least 2 drinks per event, etc.). Inversely, admitting not having any binge drinking episode in the past month but drinking 76 standard drinks a month is possible if the individual drinks chronically (typically 2-3 drinks a day).

5.2.3. Measures.

The model was built upon 7 variables. The first main outcome was binge drinking frequency (counts) drawn from the question “Considering all types of alcoholic beverages, how many times during the past 30 days did you have 5 or more drinks for men or 4 or more drinks for women on an occasion?”. The other main dependent variable was drinking intensity per day drunk (“During the past 30 days, on the days when you drank, about how many drinks did you drink on the average?”).

Based on our model, we extracted four sociodemographic variables for the binge drinking frequency pathway from the BRFSS: employment (students vs others), income (1 = \$10,000 or less to 8 = \$75,000 or more), marital status (married, divorced, never married) as well as sex of the participants (male vs. female). Regarding the drinking intensity analysis, we only use the sex, the drinking counts outcome and the age of participants (from 1 = 18-34 to 8 = 65+ years old). Depending on the year, the BRFSS data included between 41 and 53 US States and territories (see Appendice). We did not have specific predictions for this second level of analysis but included it as a random-factor as recommended elsewhere (Gelman & Hill, 2007).

5.2.4. Descriptive results.

Binge drinking frequency per gender. The percentage of binge drinkers among men and women have increased through the recent years in the United States. While in 2007, 29.95% of binge drinkers were males (n = 26,388) and 18.35% were females (n = 20,211), in 2016 those numbers raised to 30.89% (n = 34,933) for men and 19.37% for females (n = 22,624, see figure 25). However, the gender gap observed in other countries was also confirmed in our American data with men always having at least a 10% edge over women regarding binge drinking frequency.

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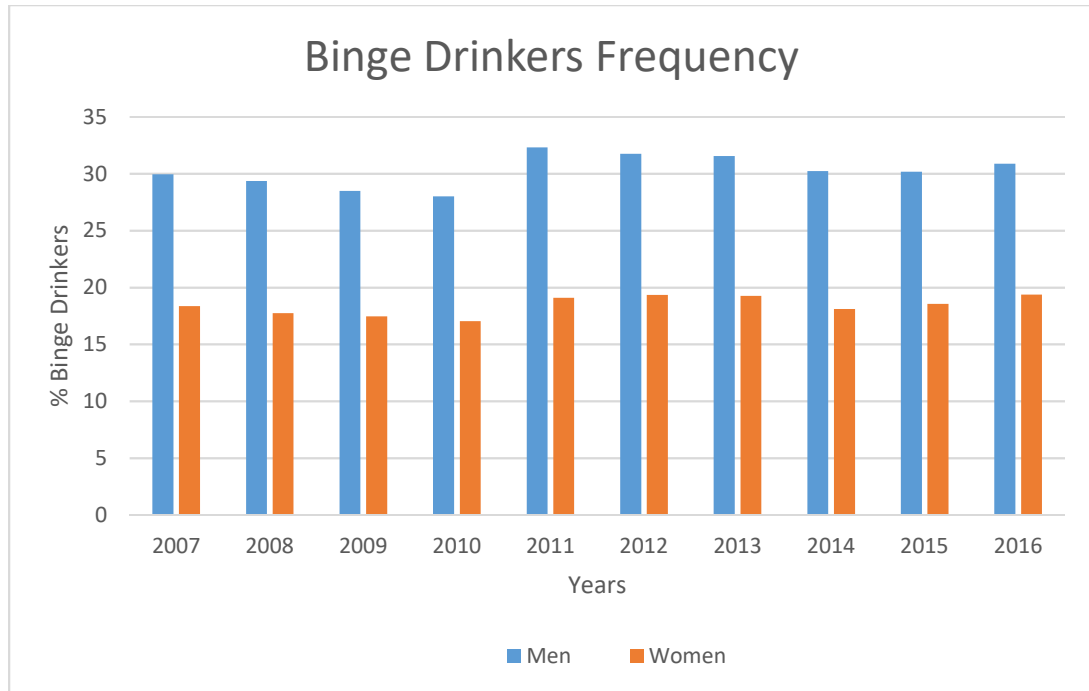


Figure 25. Binge drinkers frequency per gender from 2007 to 2016 in the US (BRFSS).

Binge drinking frequency per age groups. Regarding the frequency of binge drinkers among age groups, patterns close to the literature came out with 18-24 years old having between 43.86% (2010) and 54.47% (2011) of that range group admitting having had at least one binge drinking episode in the last 30 days. The second age group, 25 to 34 years old, had experienced more than 15 per cent increase between 2007 (24.42%) and 2016 (40.16%) making it the second most vulnerable group after the 18-24 years old as can be seen in the figure 26 below. Quite surprisingly, while the 18-24 years old is very stable since 2007 (around 50% with small variations across years), all the other age groups had experiences small and progressive increase. Interesting projections might be to predict how closer the runner-up 25-34 years old group is going to get to the 18-24 years old group in the coming years (and which factors might help reduce this demographic gap).

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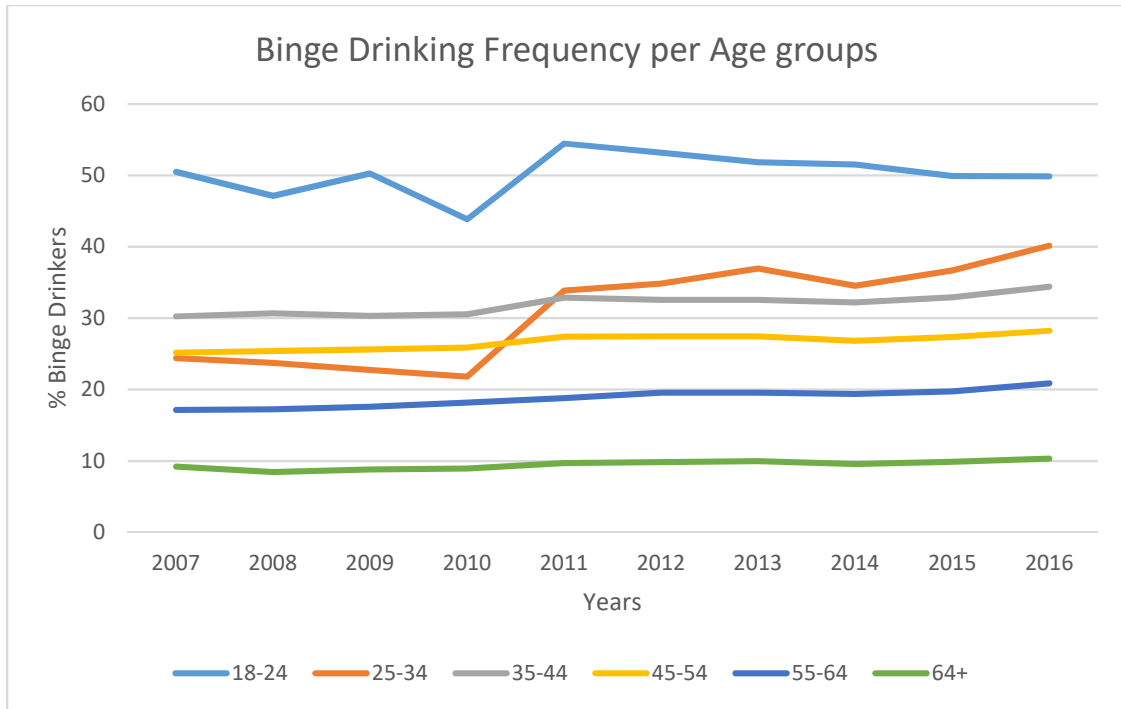


Figure 26. Binge drinkers frequency per age groups per years in the US (BRFSS)

Binge drinking frequency per States. On the State level now, the trend emerging is that northern-middle States displayed the highest binge drinking prevalence in 2010 (see figure 27, CDC, 2010). For instance, Illinois (21.4%), North Dakota (21.9%) and Montana (21.5%) all displayed binge drink rates superior to 20% for the population while the national average was at 17.1% this same year. On the contrary, California (16.5%) and states at the South-East of the country showed the lowest rates. In 2015, the prevalence of binge drinkers in North Dakota (24.9%) or even Wisconsin (24.4%) kept rising while Montana remained stable (21.3%, in dark red figure 28 below, CDC, 2015). More concerning is that California, Florida or Louisiana now all displayed prevalence rate superior to 16%. Since Texas or Arizona remained stable, it thus possible that the larger college enrollments in two major educational states such as California or Florida had participated in the global increase in binge drinking practices.

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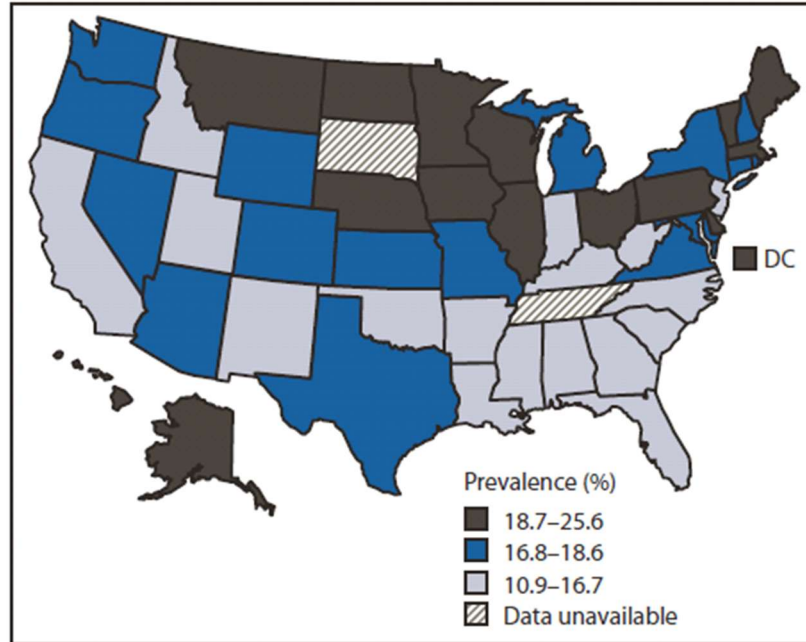


Figure 27. Prevalence of binge drinking among US adults, 2010. Retrieved from <https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6101a4.htm>.

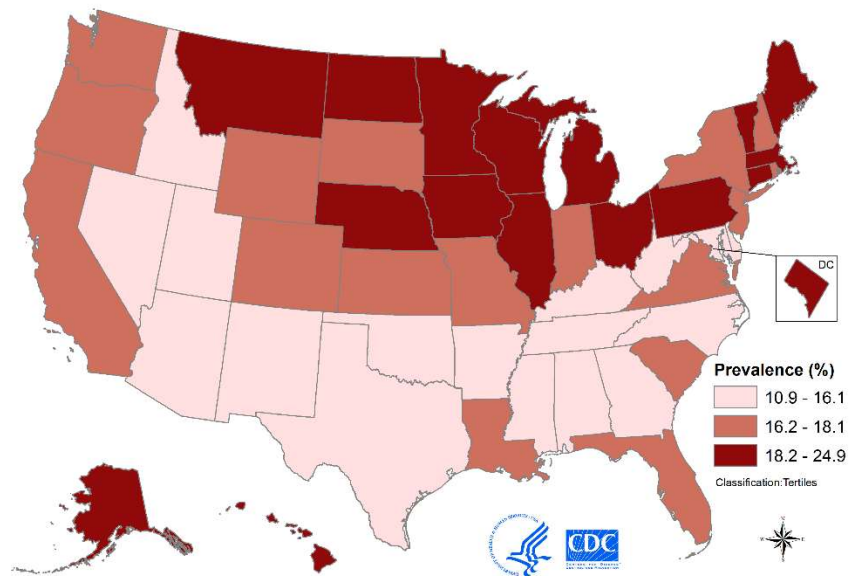


Figure 28. Prevalence of Binge Drinking Among US Adults, 2015. Age-adjusted to the 2000 US Census standard population. Retrieved from <https://www.cdc.gov/alcohol/data-stats.htm>.

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Drinking intensity per gender. Men also reported drinking in higher intensity than women across the 10 years of the BRFSS Study (see Figure 29). Since 2007 (4.48 drinks per occasions on average), men's average drinks per occasion slightly decreased to get down to 4.41 drinks. However the overall ten years study indicated a pretty stable pattern, in particular, when comparing to women who reported having decrease their drinking amount to 3.09 drinks per occasion in 2016. Those results indicate that men are close to the 5+ binge drinking standards at every occasion they drink.

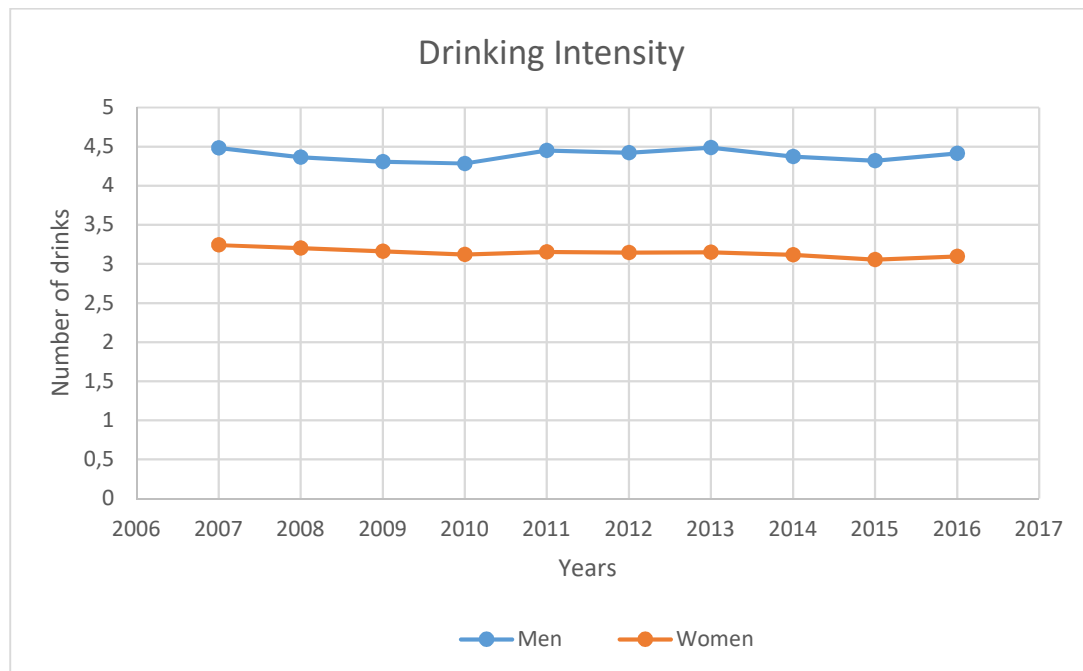


Figure 29. Drinking intensity (number of drinks per occasion) for US Adults (BRFSS).

5.2.5. Inferential results.

As far as binge drinking phenomenon is concerned, there is not a definitive answer about which type of models make the best predictions and fits the most adequately the data. Massive Structural Equation Models (SEM) may possibly overfit the data making difficult any

generalization while, on the other hand, a mathematical approach might simplify the process to a point to introduce biases (Kelloway, 2014; McElreath & Boyd, 2008).

A variety of tools had been used recently to understand this phenomenon including analytical (Giacobbe, Mulone, Straughan & Wang, 2017; Mulone & Straughan, 2012), or agent-based modeling (Gorman, Mezic, Mezic & Gruenewald, 2006; Lamy, Perez, Ritter & Livingston, 2011). While we are aware of the limits of our choice, we proposed to use multi-level modeling because we have clear idea of the pathway we want to test and also because of the nested nature of the data we based our analysis on.

Multilevel Modeling.

The data were analyzed, year per year, using the *lme4* package on *R* (for multilevel modeling) and the *MuMIn* package to assess Akaike information criterion (AIC). The categorical independent variable was binary coded (1 = Male, 2 = Female) while the Independent variables were counts (treated using log-likelihood Poisson distribution). The moderators were either pseudo-continuous (age from 1 = 18-24 years old to 6 = 65+ years old; annual household income from 1 = less than \$10,000 to 8 = \$75,000) or binary coded (student status: 1 = Student, 0 = non-Student; Marital Status: 1 = Never married, 0 = others). We checked in every analysis for potential statistical outliers following the studentized deleted residual (SDR) technics indicating that a level greater than 4 is consider as outliers (see McClelland, 2014). Due to the very large amount of data (more than to 200,000 participants in 2016 for instance), the SDR method largely cut off more than thousands of participants for every year but this did not pose problem for our theoretical framework and analysis, quite the contrary¹⁹.

¹⁹ This a choice that makes sense not only statistically but also theoretically. The results converged to the trend that SDR deleted most of the participant reporting drinking more than 20 drinks per occasion or binge drinking more

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Model justifications. We analyzed both frequency and intensity drinking pathways separately. For each pathway, there were two models: a simple one (with the nested main effect) and a full model (with all the moderators nested into States). As a categorical variable including 53 levels, the States factor should be treated as random physical spots representative of a population (and thus as a random factor in a model). Moreover, the theoretical model we proposed does not specify particular variations between such large spaces and thus cannot suggest that any particular states will display specifically stronger effects or pathways than other particular locations. On the other hand, random effect as measure, in the same data, from different space location can help as a remedy against pseudoreplication (i.e., incorrectly modeling randomness in a particular dataset, see Millar & Anderson, 2004 for other remedies against pseudoreplication involving challenging analysis such as state-space models or geostatistics).

Frequency model. The Frequency model involved the regression of binge drinking event counts (Y) on sex (X, categorical) moderated by age (A, continuous) with all the dataset nested across US States and territories. Two random intercept models can be written: the basic one including only X and Y as fixed effect and the States as random effect (1) and, a second one, including age (A) as a continuous moderator between X and Y (3).

$$y_{ij} = \beta_{0j} + x_{ij}\beta + x_j\gamma + \epsilon_{ij} \quad j = 1, \dots, J \quad i = 1, \dots, n_j \quad (1)$$

$$\text{avec } \beta_{0j} = \beta_0 + \alpha_j \quad (2)$$

$$y_{ij} = \beta_{0j} + x_{ij} \beta_1 + A_{ij}X_{ij}\beta_2 + x_j\gamma + \epsilon_{ij} \quad (3)$$

than 8 times a month. While ones could argue that this rhythm is possible (binge drinking more than twice a week is quite current among students) it is generally considered both per practitioners and researchers that such a regular amount referred to a substance use disorder (DSM-V).

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We analyzed the model that includes the product terms (SexXAge) against the one that does not include it and compare their explained variance ($R^2_{(3)} - R^2_{(1)}$). Moreover, we also compared the Akaike information criterion (AIC) criteria between the model 3 and 1. In that particular estimator of the quality of statistic model, having too many parameters is penalized, discouraging overfitting. The model displaying the lowest AIC would be the better fitted (if the two models are pretty much equals, that would mean that the Age moderator does not give particular additional information compared to the only-sex model).

Intensity model. The Intensity model involved the regression of drinking counts per day drinking (Y) on sex (X) moderated by employment (S, Students vs. non-Students), marital (M, Never married vs. others) and economic status (H, household income, continuous) nested across US States and territories. Again, at least two random intercept models can be written: the basic one including only X and Y as fixed effect and the States as random effect (4) and, a second one, including employment, marital and economic status (6).

$$y_{ij} = \beta_{0j} + x_{ij}\beta + x_j\gamma + \epsilon_{ij} \quad j = 1, \dots, J \quad i = 1, \dots, n_j \quad (4)$$

$$\text{avec } \beta_{0j} = \beta_0 + \alpha_j \quad (5)$$

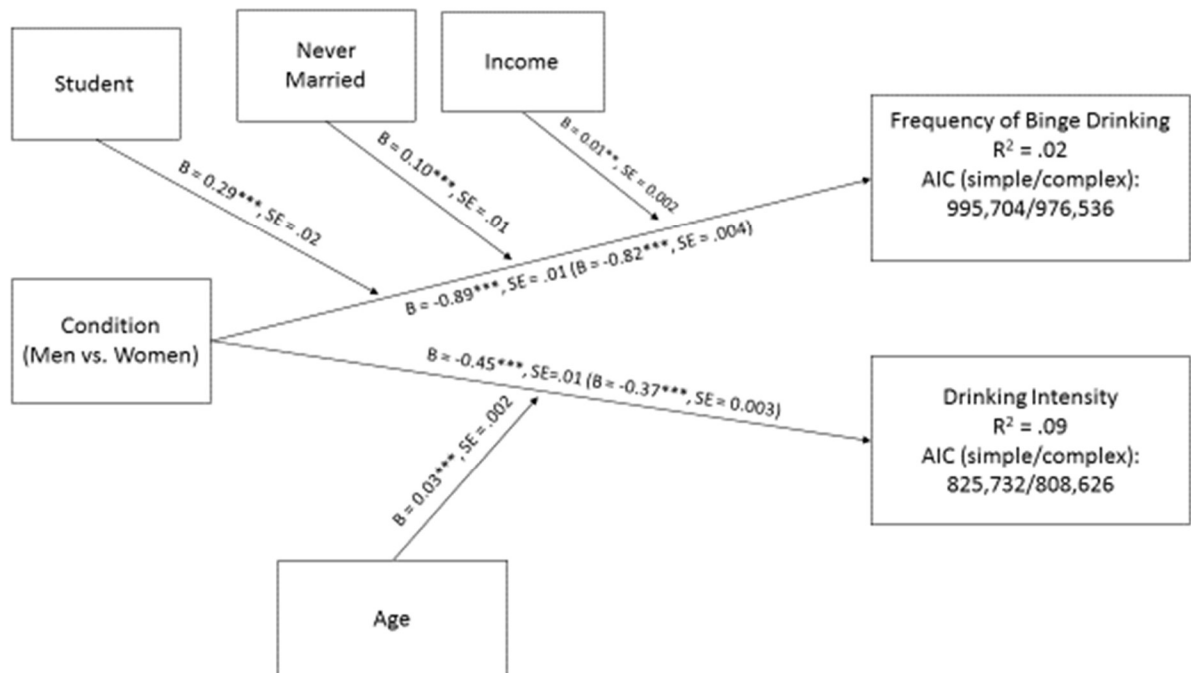
$$y_{ij} = \beta_{0j} + x_{ij} \beta_1 + S_{ij}X_{ij}\beta_2 + M_{ij}X_{ij}\beta_3 + H_{ij}X_{ij}\beta_4 + x_j\gamma + \epsilon_{ij} \quad (6)$$

Results. For parsimony reasons, we only present here the results for the year 2016 and 2007 to give an overview of the tendency and consistency of our model across those years but the models for the 10 years are available down below (Appendices).

Drinking Intensity (2016). We found that, for the year 2016, the basic model indicates that the Sex variable was negatively related to Drinking intensity with males drinking more

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during drinking occasion when compared to females ($B = -0.37, SE = .003, p < .001$; see figure 30 below). The full model showed the effect of male gender was even stronger when taking into account the age as moderators ($B = -0.45, SE = .01, p < .001$) while the Sex-Age Interaction gave an almost null effect ($B = 0.03, SE = .002, p < .001$; it goes without saying that with that amount of participants, the p value can be classified as “poorly reliable”). The AIC for the full model (AIC = 808,626) was only a bit smaller than the simple model (AIC = 825,732) indicating that the full model was only slightly better fitting than the simple one. The R^2_m for the full model was .09 and the $R^2_c = .11$ If we subtract the $R^2_{m/full\ model} - R^2_{m/simple\ model} = 0.05$. The moderation component still explained about 5% of the variation in the drinking intensity (Nakagawa & Schielzeth, 2012²⁰). Across all US States and territories, the trend was the same with men drinking with more intensity during drinking occasion when compared to women (see figure 31).



²⁰ Please note that due to the more complex binge drinking frequency model, we were unable to materially run this type of analysis and only reported the conditional R -squared (though the AIC criteria are still all from generalized linear mixed-effects models).

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Figure 30. Full Model for the 2016 dataset.

5.2.5.1. Binge Drinking Frequency (2016).

The second pathway treating binge drinking frequency (counts, Poisson distributed) also revealed that the male sex was a strong positive predictor of such risky conducts ($B = -0.89$, $SE = .01$, $p < .001$). The student status positively moderated this main pathway and being in college campus increase your likelihood of frequently binge drinking though the effect is more than three time smaller than the gender one ($B = 0.29$, $SE = .02$, $p < .001$). Never having being married increase slightly the chance to binge drink regularly ($B = 0.10$, $SE = .01$, $p < .001$) while your economic status or household income does not interact with the Sex condition ($B = 0.01$, $SE = .002$, $p = .005$). In term of modeling selection process, it appears that the full model was only slightly a better fit than the simple one regarding AIC criteria (respectively 976,536 vs. 995,704). This indicates that the full model does not add much information in comparison to the numerous quantity of parameters it imposes. For the frequency of binge drinking events, the gender effect though was much more variable across States (see figure 32 below). While in most states men still surpassed women on risky conducts, the distributions were much more uniform than for the intensity of drinking. Moreover, some states (e.g. Virgin Islands of the US) even displayed an inverse pattern with more women engaging in binge drinking.

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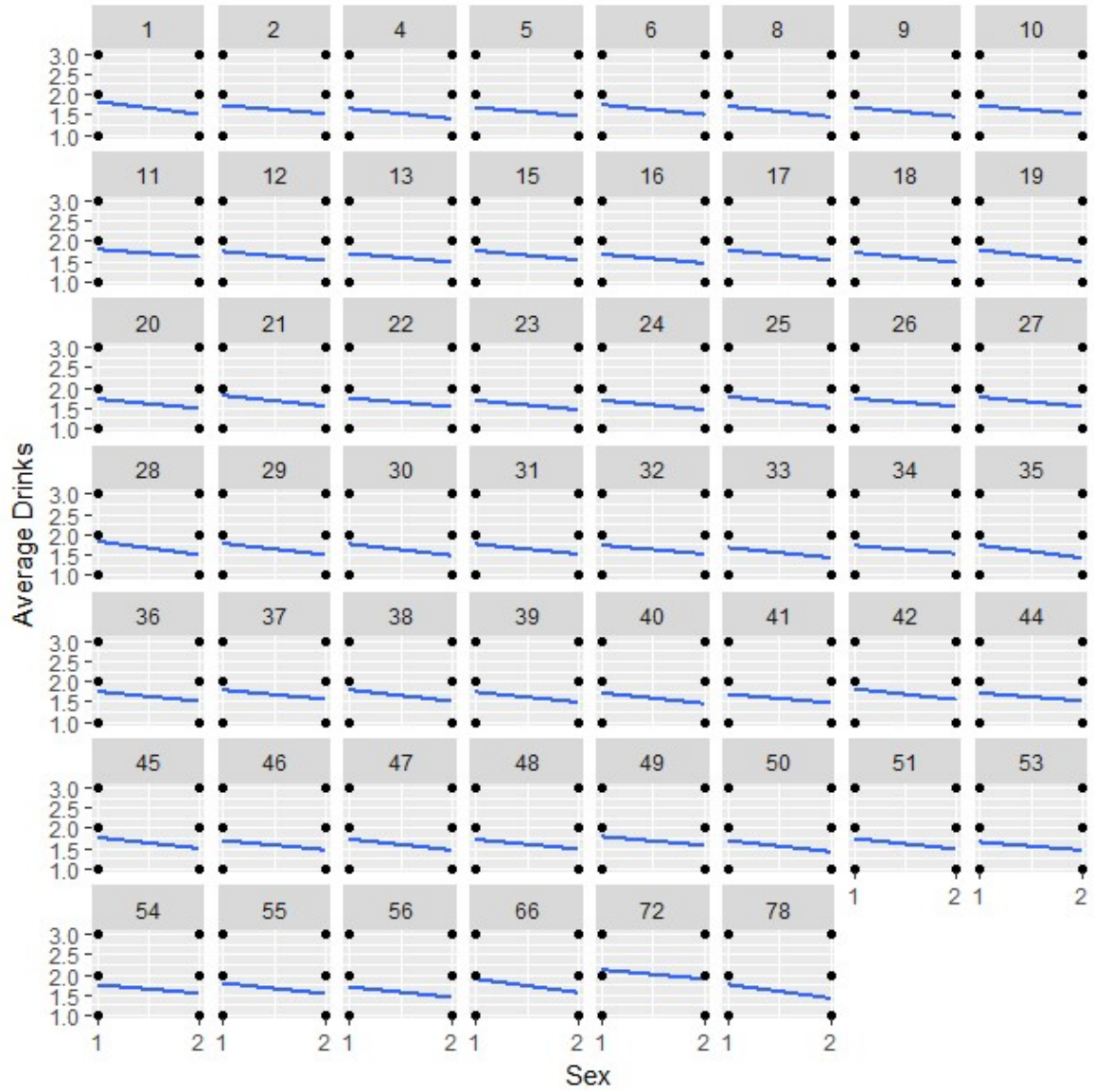


Figure 31. Drinks consumed per occasion per Sex across 58 US States and territories in 2016 (1 = Alabama..., 78 = Virgin Islands of the US, complete list of codes and figures in Appendices).

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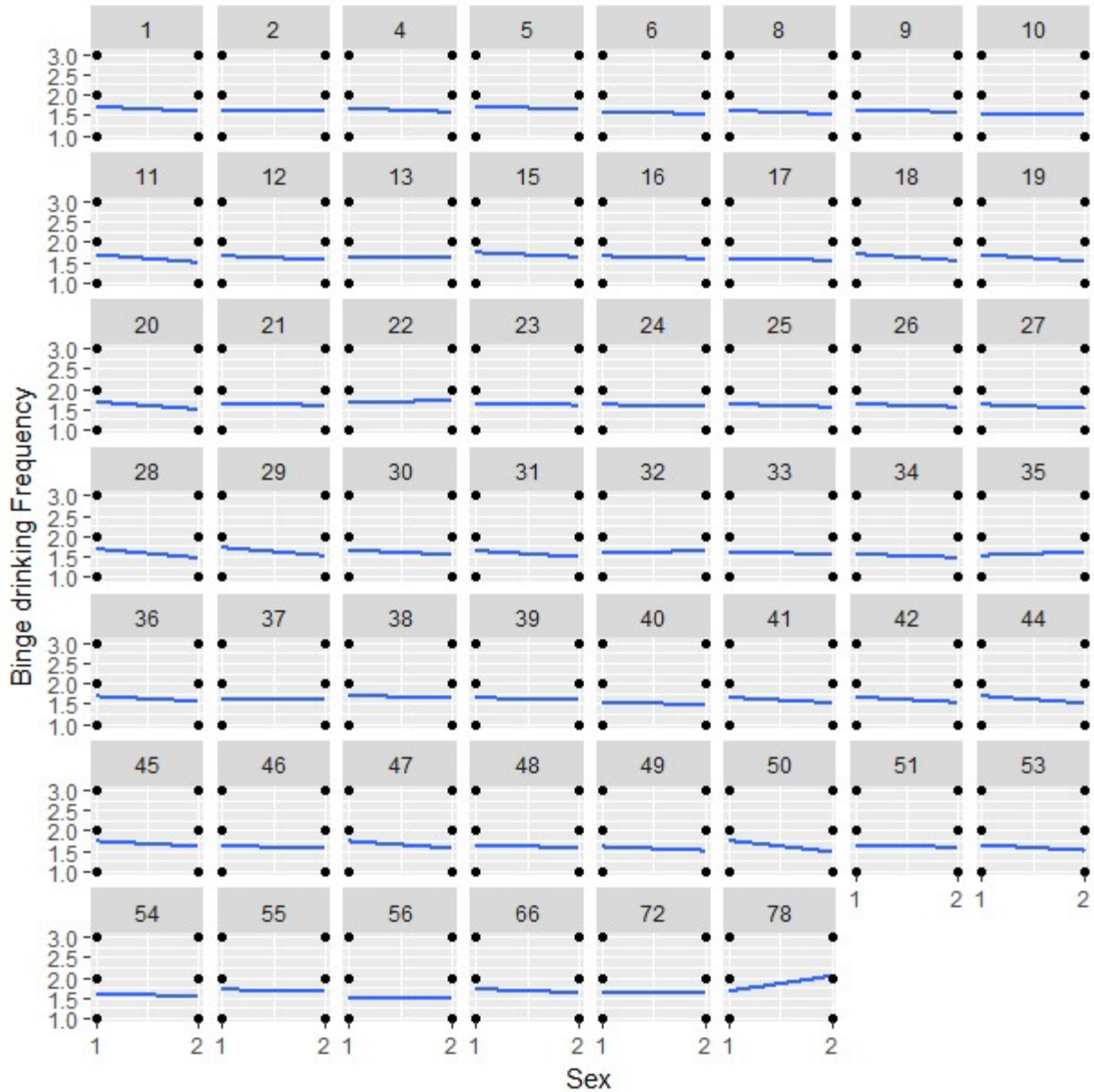


Figure 32. Binge Drinking Frequency per Sex across 58 US States and territories in 2016 (1 = Alabama..., 78 = Virgin Islands of the US, complete list of codes and figures in Appendices).

5.2.5.2. Drinking Intensity (2007).

We found again that the male gender was strongly related to the intensity of drinking (though to a larger extent than in 2016; $B = -0.32$, $SE = .01$, $p < .001$) while the interaction with the age was almost null ($B = .01$, $SE = .002$, $p < .001$) as in the 2016 data. That indicates that the age does not interact with gender in the process of drinking intensity. Regarding selection model, the

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conditional model (including the random) only explained 1% more variance than the marginal one (with only fixed-effects) since $R^2_{m/full\ model} - R^2_{m/simple\ model} = 0.01$. As we can observed, this confirms the descriptive results that we displayed here State by State (figure 34). The model comparison with and without the moderators revealed that the AIC criteria for the full model was only slightly better fitted than the simple one (AIC = 590,792 vs. 602,654 respectively); this is not substantial enough to discard the basic model as Gender explained almost all the variance in that model (figure 33).

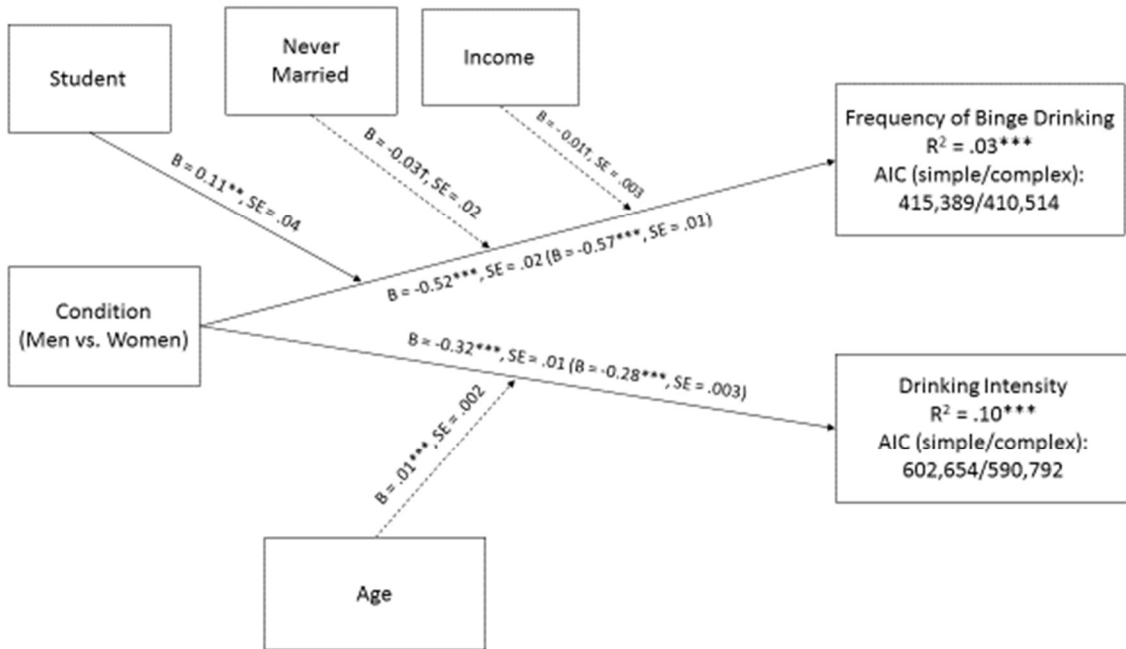


Figure 33. Full model for the year 2007 (BRFSS).

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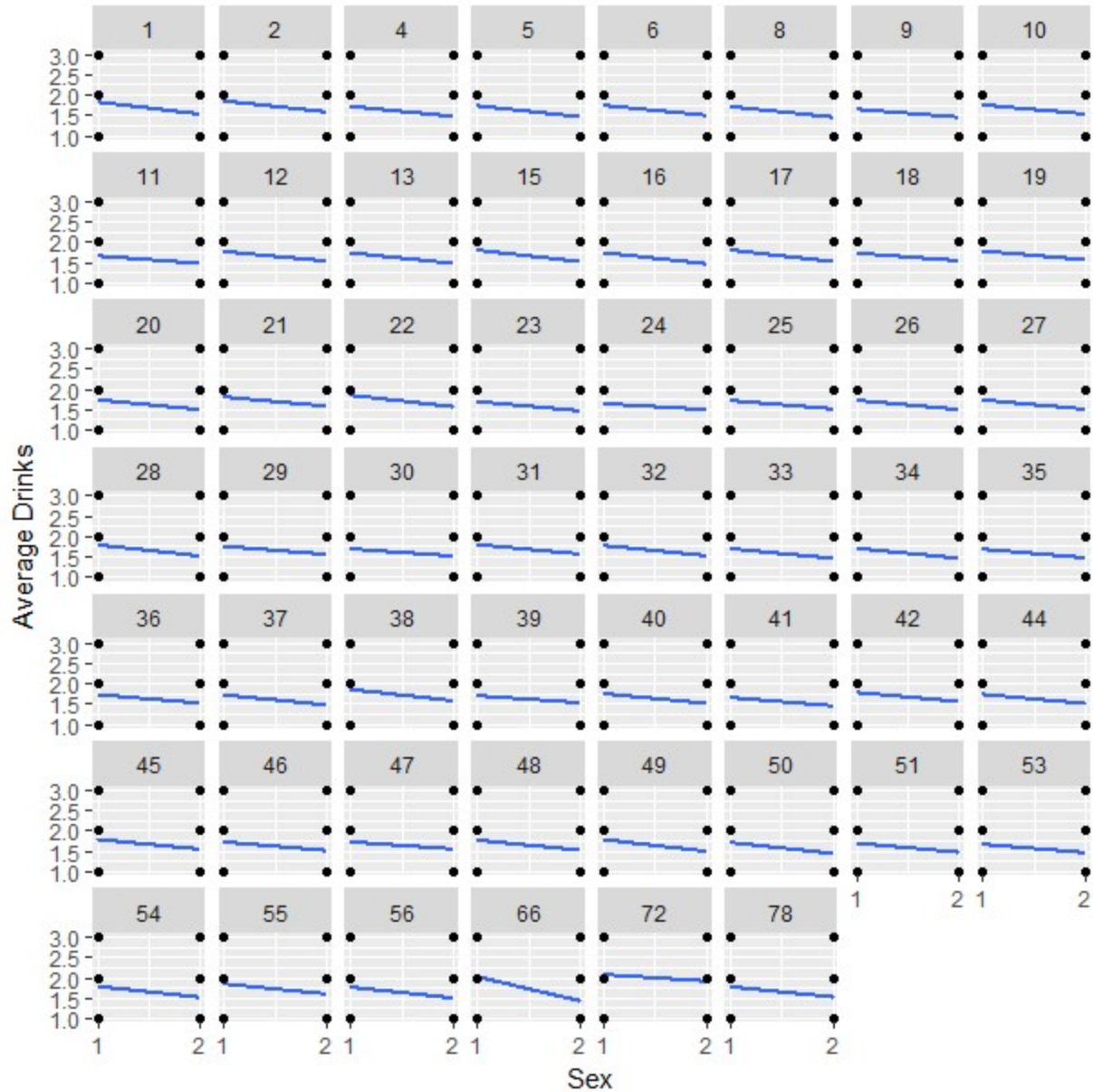


Figure 34. Drinking intensity per Sex across 58 US States and territories in 2007 (1 = Alabama..., 78 = Virgin Islands of the US, complete list of codes and figures in Appendices).

5.2.5.3. Drinking Frequency (2007).

Finally, we replicated the same trend regarding the relation between male and binge drinking frequency than the one found in 2016 to a lower extent though (figure 33). Men tend to participate more to risky drinking activities on a monthly basis compared to women ($B = -0.52$, $SE = .02$, $p < .001$), the effect being almost the same in the simple or full model. The marital and

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economic status moderators displayed null effects (respectively $B = -0.03$, $SE = .02$, $p = .07$ and $B = -0.01$, $SE = .003$, $p = .08$). However, the full model only explained about 3% of variation in binge drinking frequency and was only slightly more informative ($AIC = 410,514$) than the basic model without moderators ($AIC = 415,389$). Though weaker than for frequency, the tendency across States was still in favor of men except for few exceptions (e.g. Arizona = 3) where the gender gap was filled.

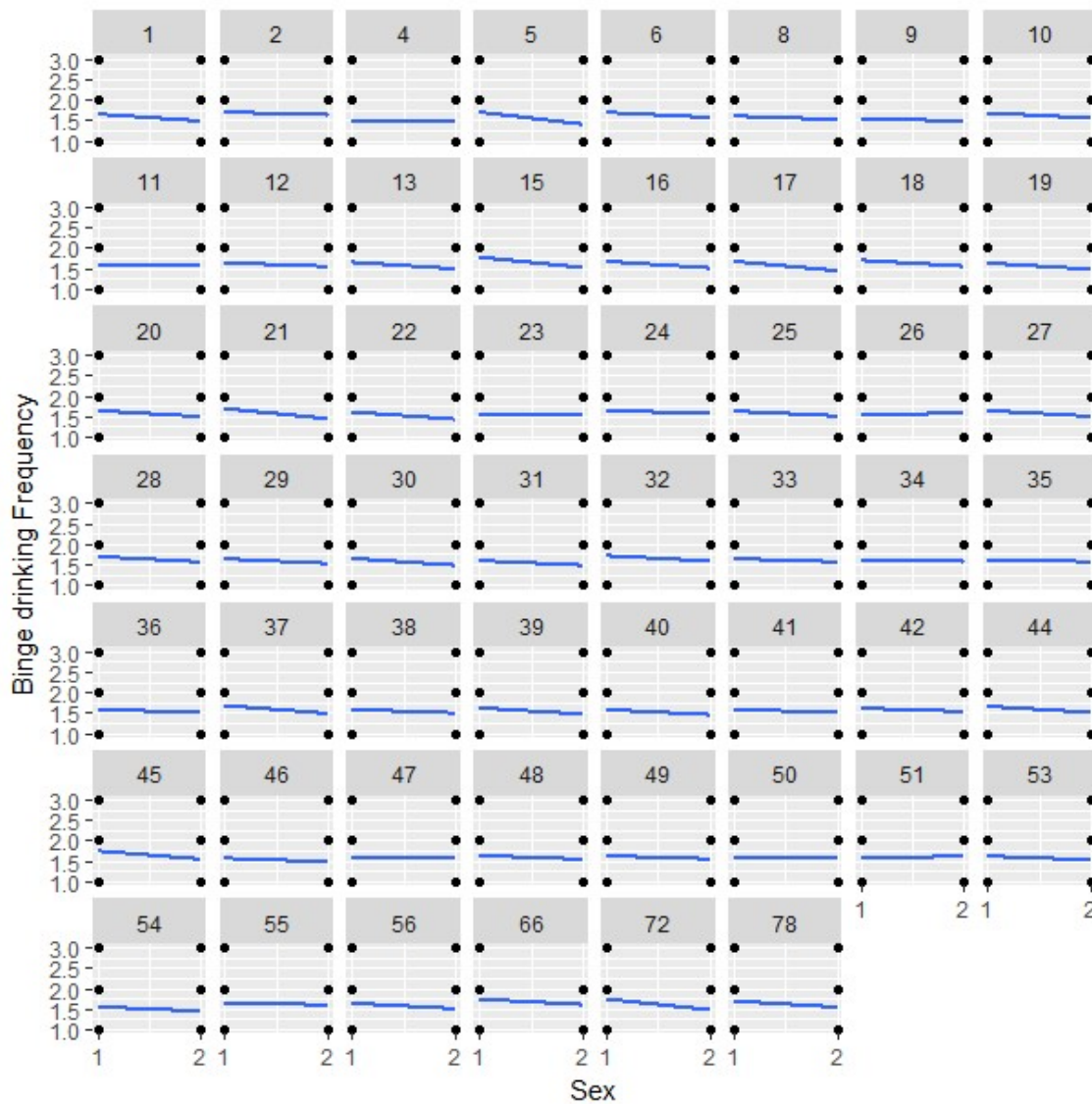


Figure 35. Drinks consumed per occasion per Sex across 58 US States and territories in 2007 (1 = Alabama..., 78 = Virgin Islands of the US, complete list of codes and figures in Appendices).

5.2.6. Discussion.

The present project intended at analyzing data based on an evolutionary predictions framework about binge drinking behavior through a cross-sectional 10 years study extracted from the CDC database in the US (BRFSS, 2007-2016). Past studies on binge drinking had revealed a myriad of factors potentially involved in binge drinking frequency and intensity. In particular, a constant gender gap has been observed across different countries and years both on drinking frequency and intensity with young men being particularly sensitive to binge drinking practices compared to females (Byrnes et al., 2009; Courtney & Polish, 2009). Other moderators appeared to influence this relation, notably being part of fraternities/sororities, or to a larger extent, to a student groups; never being married and having a high household income (> \$75,000 per year).

An evolutionary framework, such as the life-history theory (LHT), proposes to analyze risky drinking through the lens of energy attribution and allocation (Hill & Chow, 2002). According to this theory, young male entering the sexual competition would tend to have a faster life-history strategy meaning that they would take risks to get more mates, earlier in their development, and would discount further gains over short-term rewards (among other things, see Kaplan & Gangestad, 2004 for a complete description of the theory). This would then explain why young single men seem to be so involved in drinking games and alcohol abuse in social context when compared to other categories of the population. However, to our knowledge, no studies had tried to implement a global LHT model and compare it to long-term data across such a wide area.

Descriptive statistics confirmed the gender gap across 10 years with men constantly drinking to higher extent when compared women but also more regularly. About 50% of the 18-24 years old group declared having binge drinking the last month of the survey and almost 40% of the 25-

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34 admitted doing the same. The 18-34 years block described by the LHT theory (Hill & Chow, 2002) is confirmed descriptively but ones might wonder how this could moderate the gender effect. On a State level, the prevalence of binge drinking seem to be constantly higher in the northern-mid belt of United States and our analysis was also able to tell if a multi-level model could either helped explain this difference or discard the gap between those states and the rest of the territory.

Our multi-level analysis revealed that the gender gap existed across years and space through the entire American territory. However, the intensity gap was more consistent across States in comparison to the binge drinking frequency which geographical variation was much higher. The binge drinking intensity, whereas largely explained by the fact of being male, was also moderated by the Status student and, to some extent, by the fact to never having being married. However, the socioeconomic status, which according to conflicting literature is either a protective (Hill & Chow, 2002) or a reinforcing factor (Giskes, Turrell, Bentley & Kavanagh, 2011), constantly displayed a null effect on binge drinking frequency. One reason could be that male students, independent of their family economic status, are able to get regularly access to alcohol through social gathering organized on the campus and financed either by fraternities or by local social groups.

On the other hand, the drinking intensity pathway revealed, quite surprisingly, than the age did not moderate the male gender effect. Even though, the male effect is not as strong as for the binge drinking frequency model, it was regularly found across the 10 years and different States and territories. Regarding the absence of age effect, like our descriptive results showed, it is quite possible than, while a majority of young individuals (18-34 years old), and in particular young males, are involved in binge drinking activities, their age ranges did not moderate the amount of

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alcohol they drink per occasion. This is somehow a hard blow for our theory because we predicted that young male should be the more sensitive to the amount of drinking ingurgitated per drinking occasion. One possible explanatory analysis to be made, is to look only at male admitting binge drinking and see if, among those, the age has some influence.

Limits.

As any sort of analysis of this dimension, it contains several major flaws. The first one that both weaken our analysis and inclusion is the cross-sectional nature of the survey. Following participants on the long-term does not only reinforce a possible causal model, but from an epidemiological point of view, allow you to detect when binge drinkers maintained their risky behaviors and when they go back to a non-binge drinking state (Gorman, Mezic, Mezic, & Gruenewald, 2006). Also with the multitude of questions asked in a single interview, it is possible than participants misevaluated their drinking patterns or even over- or under-estimated it (the gender of the interviewer could have modulated this effect too). One could argue that the lack of physiological control (e.g. BAC) might be a real weakness here but past studies tend to show than self-reports of substance use is generally coherent with physiological reports (Polich, 1982).

Nevertheless, one of the main concern here is to discriminate binge drinkers from problem drinkers. While high SDR was usually related to substantial problem drinkers (like the ones admitting binge drinking 50 times a week), no clear distinction were made on the survey that address this crucial difference. Having alcoholics in our sample can affect the results in a multiple ways. First, since we know the prevalence of men is important among chronic drinkers, their presence in the sample can artificially pull up the mean reinforcing the gender gap in our binge drink frequency and intensity analysis. Second, the way a healthy social drinker and a

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substance use individual respond to questions about alcohol might differ substantially and this could help explain those strange patterns of individual admitting binge drinking 50 times a month but drinking only 1 drink per occasion. Finally, this might interfere also with all the moderators included in our models since chronic drinkers tend to be older, non-student and with different income levels than social binge drinkers. All in all, the CDC and BRFSS should implement questions to distinguish more precisely binge from chronic-problematic drinkers if we want to draw strong inferences from such data.

Further research

The model, methodology and analysis could be substantially increased with simple changes. First, as we noticed before, medical questions could be asked to distinguish alcoholics from regular binge drinkers. This would help both the modeling and the analysis parts. Second, the model we proposed here is far from being perfect and the social vs. biological pathways could be improved in different ways.

The direct influence of ALDH2 allele on drinking effect might also impact really powerfully drinking intensity rate of individuals. Since 20% of Chinese and 40% Japanese individuals carry the short-version of this allele, they are particularly vulnerable to alcohol's effects. One possible proxy would be to incorporate a binary (Asian vs others) racial variable in the drinking intensity pathway and see how this modulate the gender effect.

Moreover, our model proposed a too strong distinction between the two pathways. Not only many cognitive components (AEs, DRSE, Sensation-seeking, Intrasexual Competition, etc.) influence those pathways but the two outcomes itself may be largely related in a sense that binge drinking regularly produce an obvious amount on intensity and vice-versa. The literature is still

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not completely clear about which variable is the most crucial to explain this behavior but future studies should take into account more subtle pathways and interactions.

Chapter 7. Conclusion

Binge drinking is a global phenomenon that costs the community billions of dollars every year. Its impact is multiple since, in addition to directly affecting health, excessive alcohol abuse is linked to a set of harmful behaviors that endanger surrounding people. While chronic alcohol consumption is declining in developed countries, binge drinking is a trend that develops and is particularly popular among young students. Developing a theoretical framework that makes sense of this practice, inferring experimental hypotheses and testing them were the primary objectives of this thesis.

In Chapter 1, I tried to show that this multi-faceted phenomenon revealed a three-fold nature: biological, psychological and sociological. To my knowledge, no theory proposes to integrate several levels of explanation and current theories only investigate horizontal vectors of analysis. So I suggested, through an evolutionary approach of the costly signal theory, a vertical line of attack that can make experimental predictions by linking different levels of explanation. A series of hypotheses emerged from this theoretical framework that constitutes the experimental chapters, body of this doctoral work.

Indeed, Chapter 2 was focused on explaining how an expensive signal is necessarily honest and thus reflects the genetic quality of the signaler. As a result, the receiver (women in this case) should perceive the man tolerating alcohol' harmful effects as more attractive than other men in competition. Through an unprecedented experimental approach (dating website), I recruited a series of women and exposed them to profiles of men describing different levels of tolerance to alcohol. Eye-tracking and physiological measurements have shown that women had more interest in alcohol tolerant profiles without being able to assert a particular link with the level of attraction for the target. A parallel hypothesis of expensive signal theory is that one can send

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messages to multiple targets. The other main targets are same-sex individuals (here men) who compete with the tolerant one for resources or potential mates. Nevertheless, the tolerance male profiles was not evaluated by male participants as particularly competitive when compared to male profiles with lower level of alcohol tolerance.

One possibility to explain these lack of effects is that men do not necessarily evaluate another man in face-to-face confrontation but form an impression of a scene in ecological context and, based on that, decide what to do. In Chapter 3, I recruited online hundreds of men and exposed them to situations where other men described their level of tolerance in contexts of competitions and mating. I observed that despite the different contexts of the situations presented, men tended to rate tolerant men as having higher reproductive success compared to men who were less tolerant to alcohol. I have therefore tried to develop a model of multiple mediations integrating a path from the perceived level of competitiveness to the reproductive success evaluation (but only one study had clearly established this path).

To implement this theory of the expensive signal, I organized with the help of a local French High School, a prevention study consisting, through original prevention spots, to send precise negative signals of alcohol's effects on certain evolutionary skills (sexual, cognitive or resistance to diseases). I found that women were particularly sensitive to messages indicating the negative effect of binge drinking on sexual skills (in the classroom as well as in the online replication study). However, the cognitive risks associated with alcohol also appeared to be important and it is possible that alternative explanation of short. vs. long-term risks might lead to better understanding of those results.

To build a vertical analysis of binge drinking incorporating several levels of explanation, one possible path aimed at exploring the relationship between certain hormones and risky

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behaviors such as binge drinking. Through a meta-analysis incorporating numerous studies from the 80s until today, I found that women tend to consume more alcohol and smoke more cigarettes right after ovulation (in the early luteal phase) than during the rest of the cycle. One hypothesis that I suggested is the protective effect that this moment of the cycle might have on the ingestion of toxins at a time when hormonal dynamics closely resemble those of early pregnancy (and which the body cannot distinguish properly). I also observed a stronger positive effect, more robust this time, between ovulation and sexual activity and ability to recognize relevant emotions (fear, danger) and coercive sexual situations. Non trivial heterogeneity on the sexual and risk recognition category calls for other study with longitudinal designs.

The final chapter highlighted the importance of modeling the dynamics of binge drinking on a large scale. Through a temporally and spatially massive set of data, I sought to test an evolutionary model (life history theory) that makes precise predictions about the effect of gender, age and marital and economic status of an individual on his/her propensity to engage in risky drinking. Contrary to predictions, I found that socio-economic status did not affect the frequency of binge drinking and that marital and student status explained little variance compared to only being a male. Likewise on drinking intensity where the sex accounted for most of the effect compared to age.

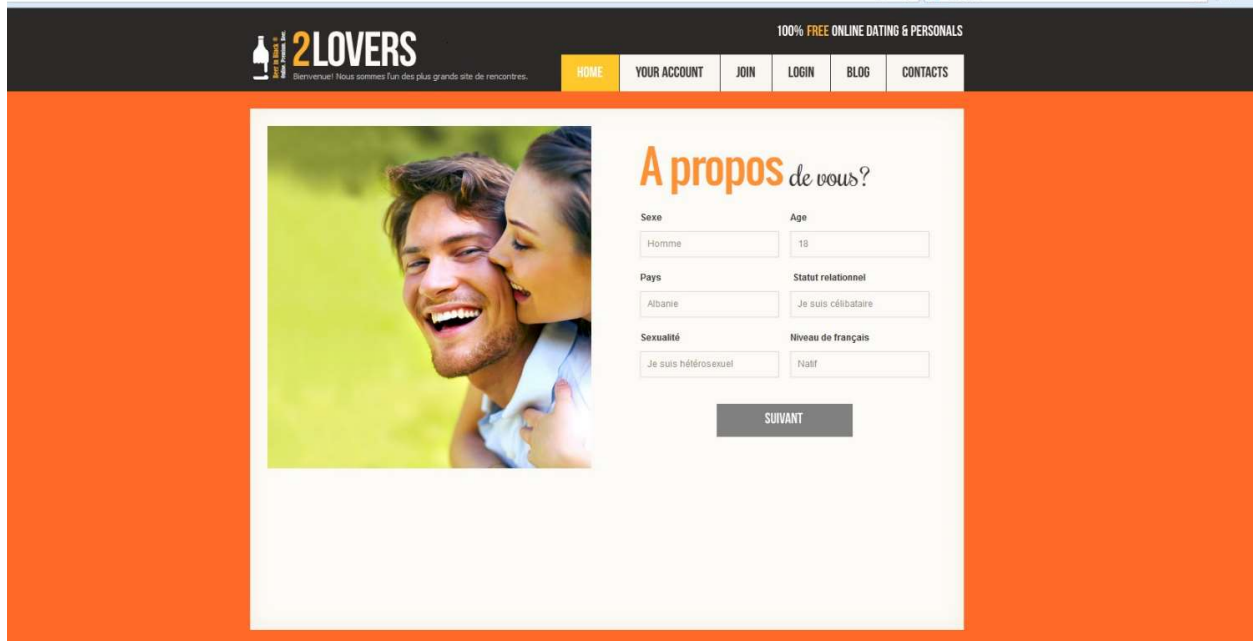
I hope I have partially shown in this thesis that the explanatory gap between evolutionary biology and psychology are still wide. Both theoretical and mathematical chasms between the two disciplines make it difficult to apply theories such as that of Zahavi's. In addition, ethical and experimental limits related to human being make the conditions of data collection particularly delicate. In the future, interdisciplinary collaborations are needed so that works can

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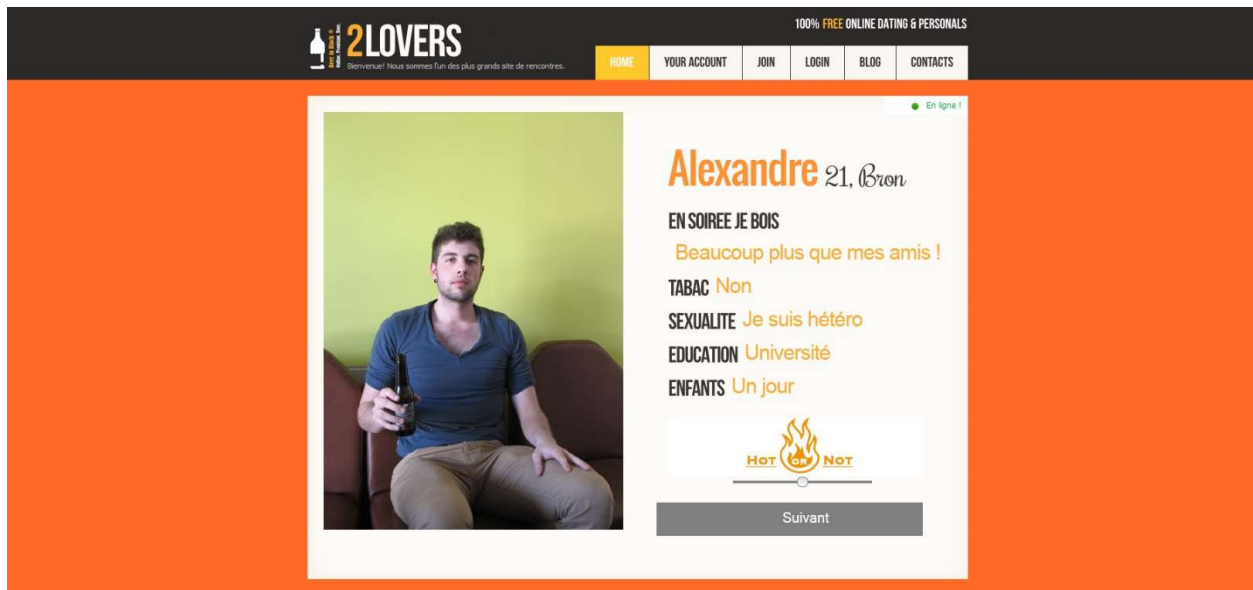
be created that integrate different levels of analysis and thus make it possible to deal with real and deep causes.

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ANNEX CHAPTER 2

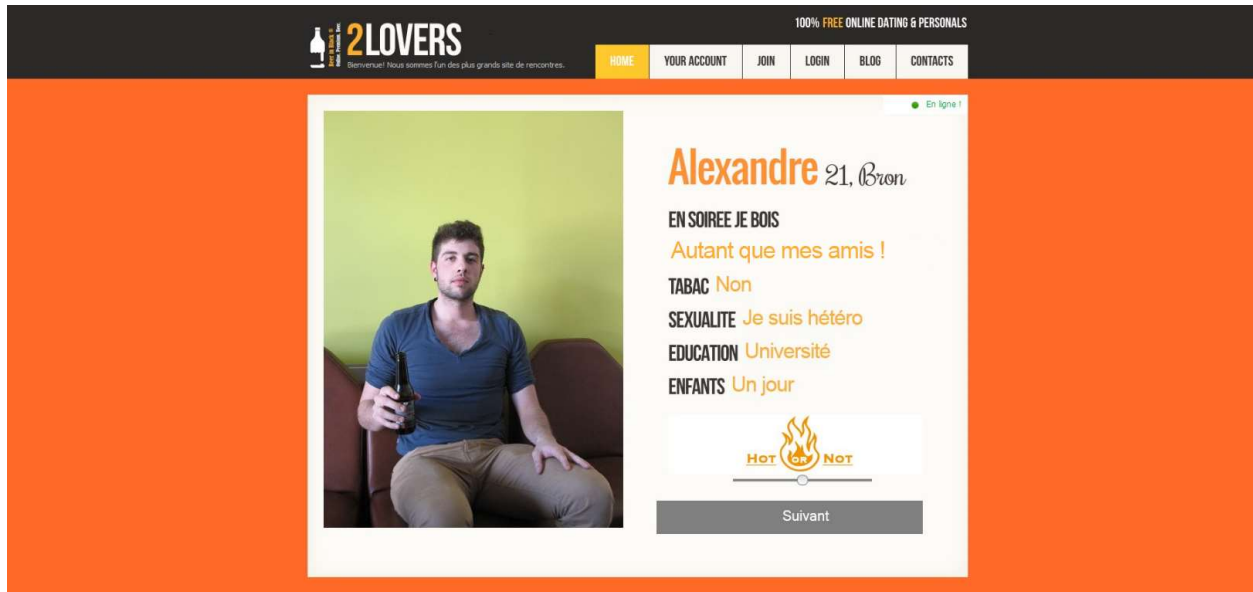


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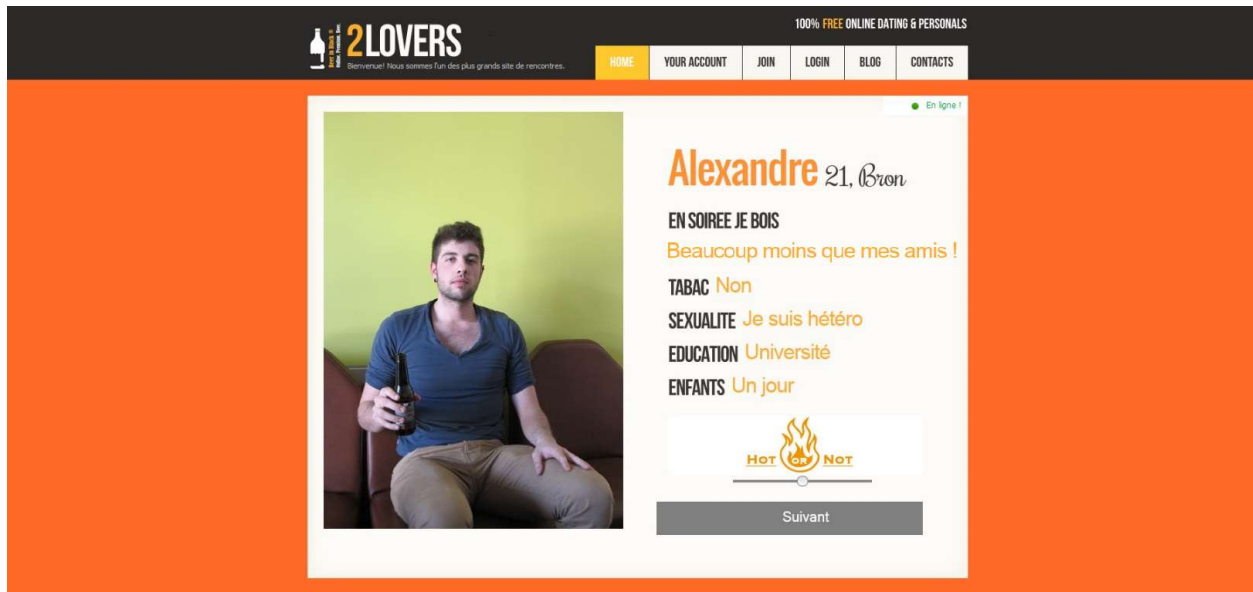


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Page 3b of Study 1.



Page 3c of Study 1.

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2LOVERS
Bienvenue! Nous sommes l'un des plus grands site de rencontres.

HOME YOUR ACCOUNT JOIN LOGIN BLOG CONTACTS

Vous avez presque terminé!

Religion: Salaire annuel:

Activité: Quel était le but de l'étude?:

Etes-vous enceinte?: Utilisez-vous des contraceptifs hormonaux? (ex, pilule):

SUIVANT

Pre-last page of Study 1.

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2LOVERS
Bienvenue! Nous sommes l'un des plus grands site de rencontres.

HOME YOUR ACCOUNT JOIN LOGIN BLOG CONTACTS

Merci à vous!

Vous venez de participer à une étude à propos du lien entre les hormones et la séduction. Nous essayons de voir s'il existe un lien entre le comportement social et différents hormones.

Par conséquent, il nous manque une **information cruciale à propos de votre cycle hormonal**. Cela nous permettra d'estimer votre position dans le cycle et de voir l'impact de votre niveau d'œstrogène sur votre comportement.

Merci d'indiquer la date du premier jour de vos précédentes menstruations.
Février 1 2014

A quel point êtes-vous certaine de l'information que vous venez de donner? Très certaine

Durée de votre cycle: Si vous savez que votre cycle dure plus ou moins de 28 jours, merci d'ajuster le nombre ci-dessous.
28

A quel point êtes-vous certaine de l'information que vous venez de donner?
Très certaine

Quel est votre numéro de sujet? (donné en début d'expérience)

Quel est votre e-mail? (Nous pourrions vous informer des résultats globaux de l'étude)

Merci de cliquer sur fin puis d'appeler l'expérimentateur.

FIN

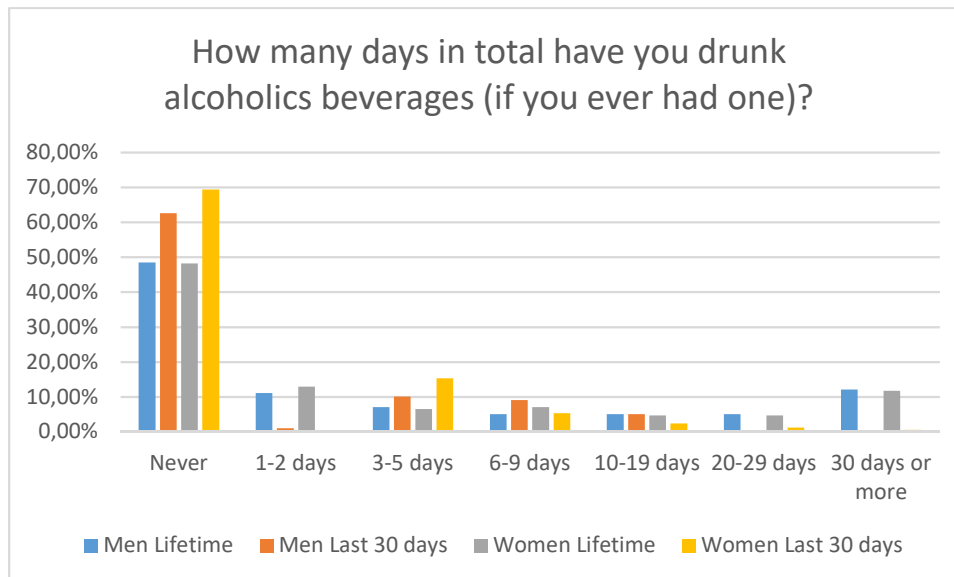
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ANNEX CHAPTER 4

<i>How many <u>days</u> in total have you drunk alcoholic beverages (if you ever had one)?</i>	MEN		WOMEN	
	In your lifetime	In the last 30 days	In your lifetime	In the last 30 days
<i>Never</i>	48,48%	62,63%	48,23%	69,41%
<i>1-2 days</i>	11,11%	1,01%	12,94%	0,00%
<i>3-5 days</i>	7,07%	10,10%	6,47%	15,29%
<i>6-9 days</i>	5,05%	9,09%	7,06%	5,29%
<i>10-19 days</i>	5,05%	5,05%	4,71%	2,35%
<i>20-29 days</i>	5,05%	0,00%	4,71%	1,18%
<i>30 days or more</i>	12,12%	0,00%	11,76%	0,59%

Table 1 of Study1.



Graph. 1 of Table 1.

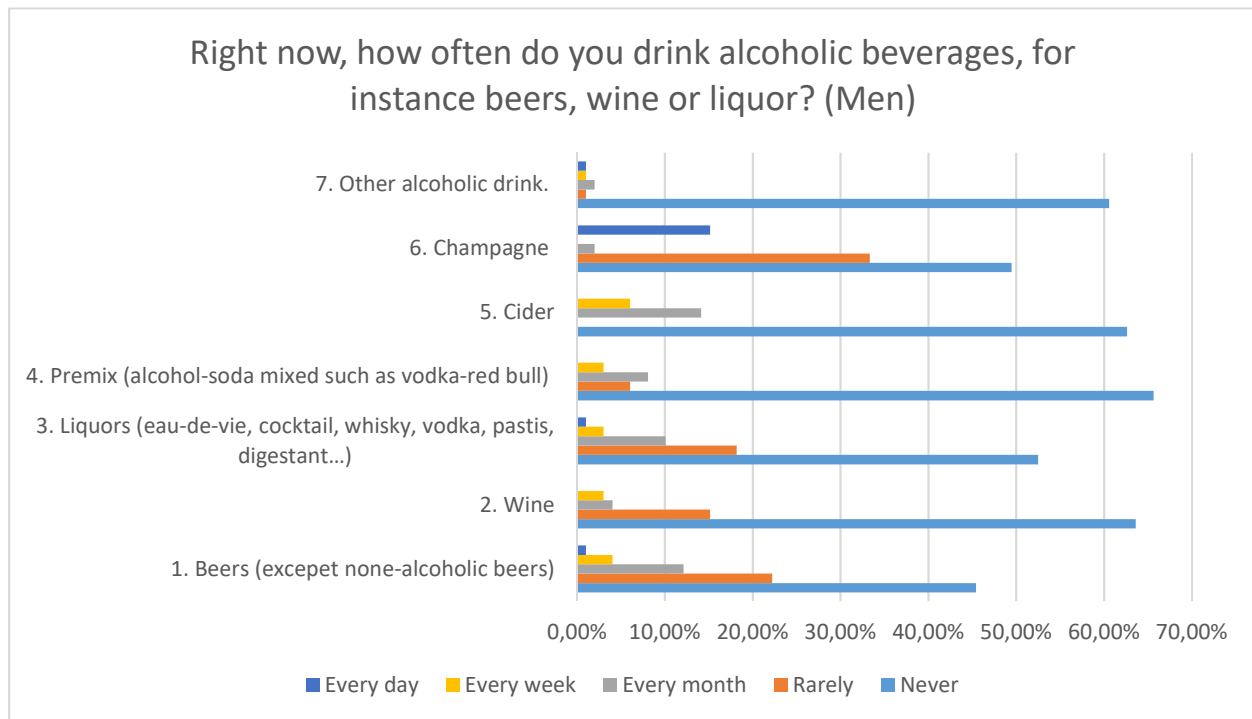
Right now, how often do you drink alcoholic beverages, for instance beers, wine or liquor? Try to count even small quantities.

	Never	Rarely	Every month	Every week	Every day
1. Beers	45,45%	22,22%	12,12%	4,04%	1,01%

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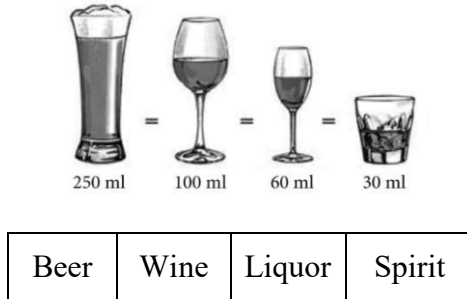
(except none-alcoholic beers)					
2. Wine	63,63%	15,15%	4,04%	3,03%	0%
3. Liquors (eau-de-vie, cocktail, whisky, vodka, pastis, digestant...)	52,52%	18,18%	10,10%	3,03%	1,01%
4. Premix (alcohol-soda mixed such as vodka-Red Bull)	65,65%	6,06%	8,08%	3,03%	0%
5. Cider	62,62%	0%	14,14%	6,06%	0%
6. Champagne	49,49%	33,33%	2,02%	0%	15,15%
7. Other alcoholic drink.	60,60%	1,01%	2,02%	1,01%	1,01%

Table 2 of Study 1 (men only).



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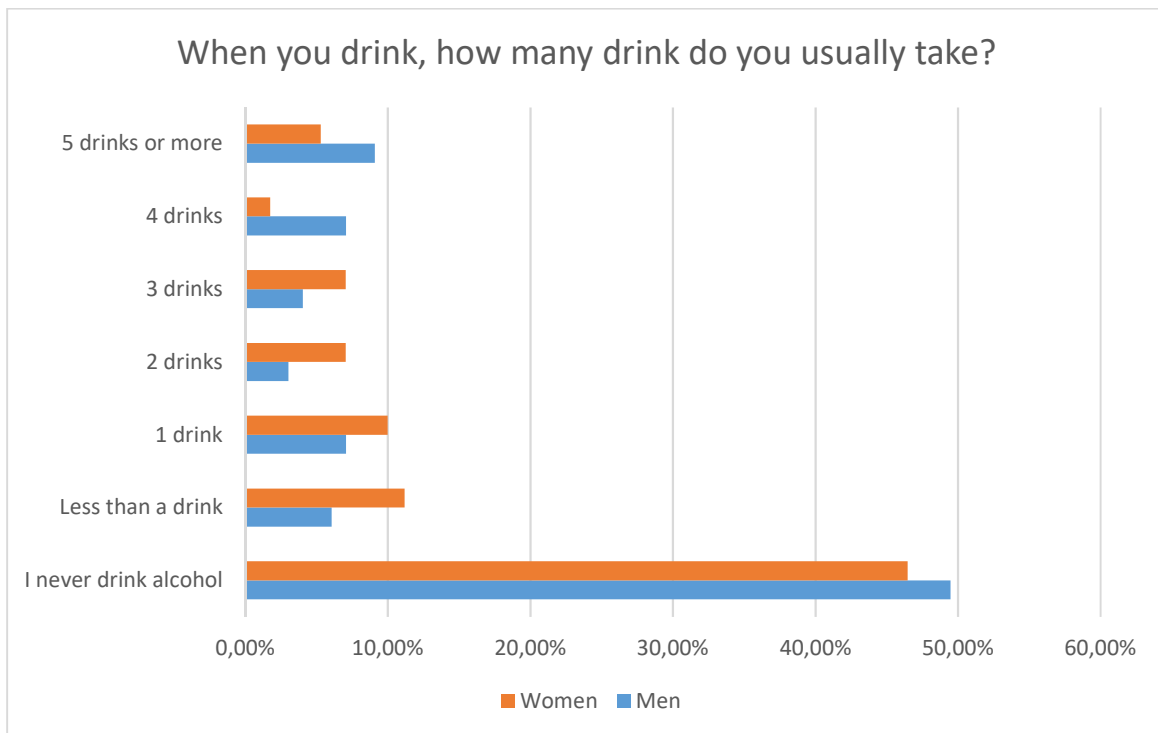
Graph 2 of Table 2.



When you drink, how many drink do you usually take?

	Men	Women
I never drink alcohol	49,49%	46,47%
Less than a drink	6,06%	11,18%
1 drink	7,07%	10,00%
2 drinks	3,03%	7,05%
3 drinks	4,04%	7,06%
4 drinks	7,07%	1,76%
5 drinks or more	9,09%	5,29%

Table 3 from Study 1.

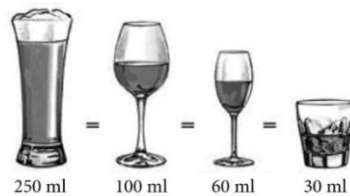


An Evolutionary Approach On Binge Drinking

Graph. 3 from Table 3.

<i>How many <u>days</u> in total have you drunk alcoholic beverages (if you ever had one)?</i>	MEN		WOMEN	
	In your lifetime	In the last 30 days	In your lifetime	In the last 30 days
<i>Never</i>	3.53%	9.41%	2.52%	18.24%
<i>1-2 days</i>	1.18%	12.94%	2.52%	18.24%
<i>3-5 days</i>	1.18%	25.88%	4.40%	27.04%
<i>6-9 days</i>	5.88%	20.00%	6.29%	16.35%
<i>10-19 days</i>	1.18%	23.53%	6.92%	16.98%
<i>20-29 days</i>	2.35%	3.53%	7.55%	1.26%
<i>30 days or more</i>	84.70%	4.71%	69.81%	1.89%

Table 1 from Study 2.



Beer	Wine	Liquor	Spirit
------	------	--------	--------






When you drink, how many drink do you usually take?

	Men	Women
I never drink alcohol	5.88%	6.29%
Less than a drink	0.00%	4.40%
1 drink	8.24%	15.72%
2 drinks	25.88%	30.82%
3 drinks	25.88%	21.38%
4 drinks	12.94%	11.95%
5 drinks or more	21.18%	9.44%

Table 2 from Study 2.

ANNEX CHAPTER 5

Table 1. Menstrual phases definitions and effect sizes for alcohol and tobacco studies (Ovulatory vs. Follicular/Late Luteal/Menstrual phases)

-  Menses (all bleeding days) and Follicular (end of menses to beginning of the ovulatory phase)
-  Ovulatory days
-  Menses
-  Late Luteal
-  Follicular

STUDY	EFFECT	CYCLE DAYS DEFINED AS “MENSES”, “FOLLICULAR”, “OVULATORY” AND “LATE LUTEAL”																												
		28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1 ← RCD	
		FCD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
		→																												
DEBON ET AL. (1995)	Cig./phase																													
RONEY & SIMMONS (2013)	% days alcohol consumed																													
POMERLEAU ET AL. (1994)	Drinks and cig./day																													
POMERLEAU ET AL. (2000)	Alcohol oz/day and cig/day																													
DUMAS (1984)	Alcohol ounces/day																													
CHARETTE (1989)	Alcohol ounces/day																													

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Table 2. Menstrual phases definitions and effect sizes for alcohol and tobacco studies (Early luteal vs. Follicular/Late Luteal/Menstrual phases)

- ☒ Menses (all bleeding days) and Follicular (end of menses to beginning of the ovulatory phase)
- ☐ Early luteal
- ▨ Menses
- Late Luteal
- ▤ Follicular

STUDY	EFFECT	CYCLE DAYS DEFINED AS “MENSES”, “FOLLICULAR”, “OVULATORY” AND “LATE LUTEAL”																											
		28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1 ← RCD
	FCD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
		→																											
DEBON ET AL. (1995)	Cig./phase																												
RONEY & SIMMONS (2003)	% days alcohol consumed																												
POMERLEAU ET AL. (1994)	Drinks and cig./day																												

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POMERLEAU ET AL.
(2000)

Alcohol
oz/day and
cig/day



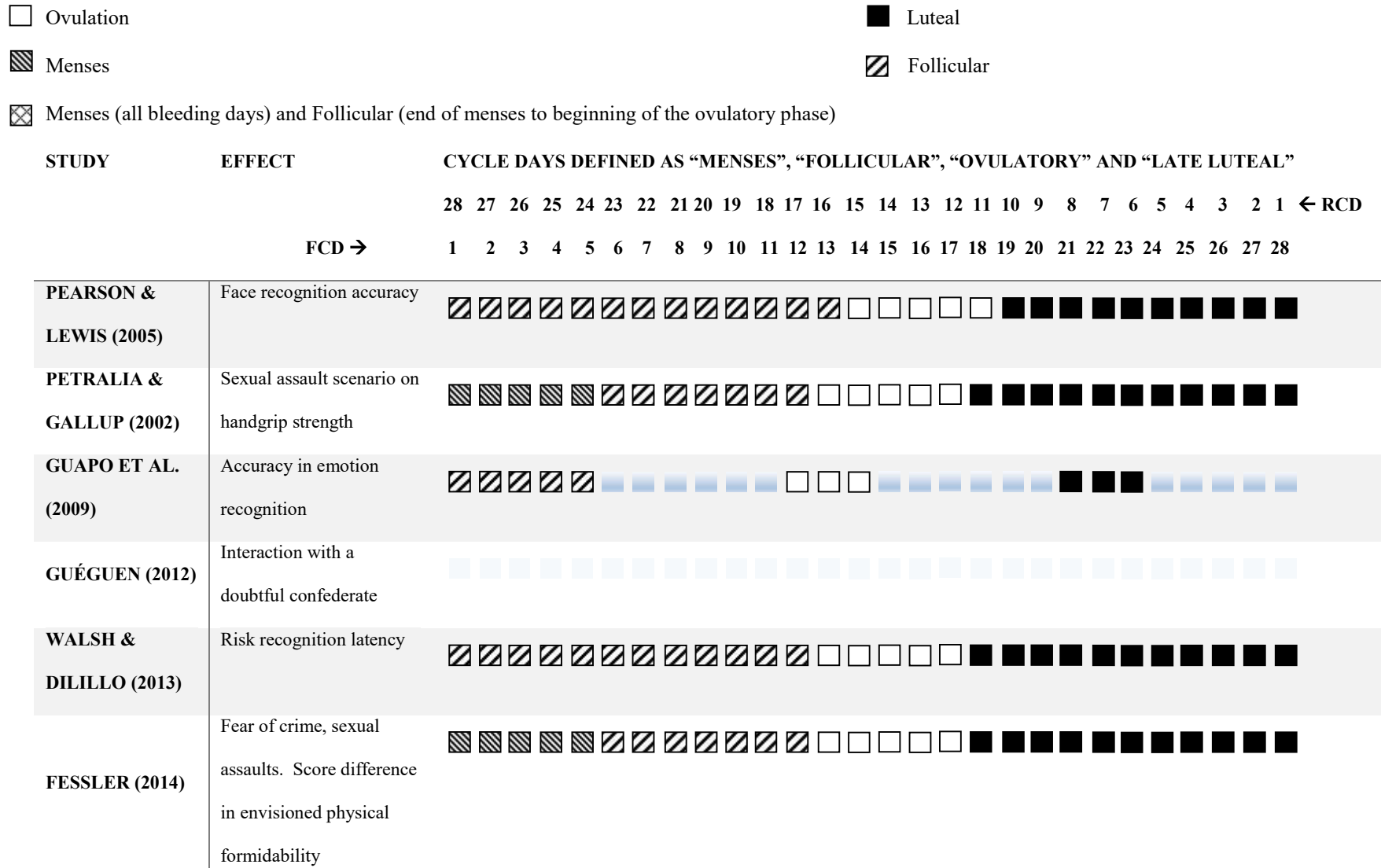
DUMAS (1984)

Alcohol
ounces/day



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Table 3. Menstrual phases definitions and effect sizes for Risk Recognition and Avoidance studies (Ovulation vs. Follicular/Luteal/Menstrual)



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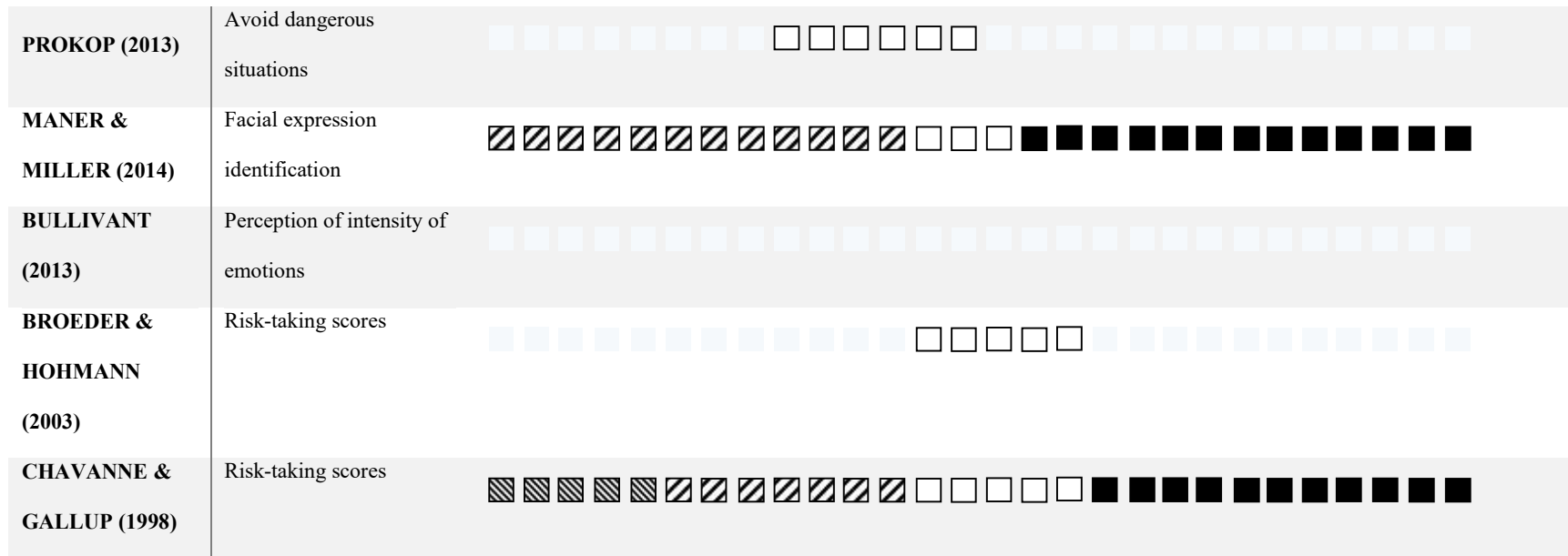
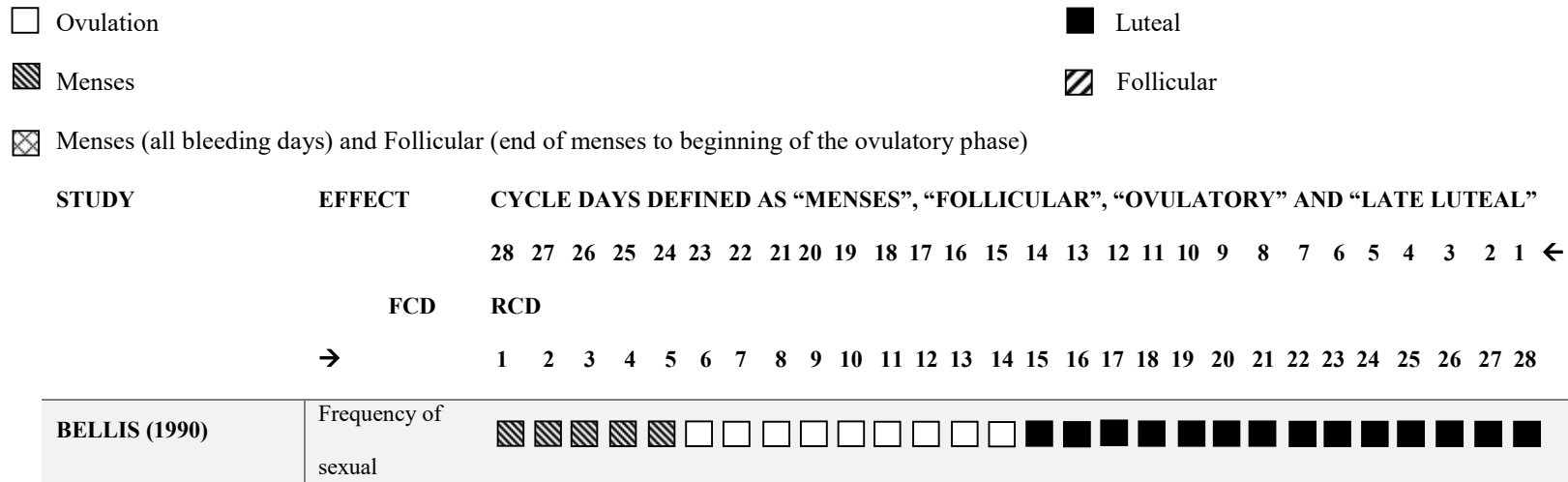


Table 4. Menstrual phase definitions and effect sizes for Sexual Activity studies (Ovulation vs. Follicular/Luteal/Menstrual)

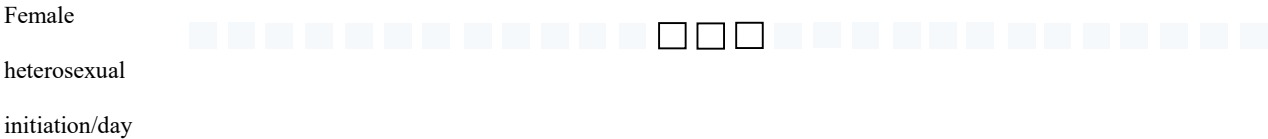


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ADAMS (1978)



PRASAD (2014)



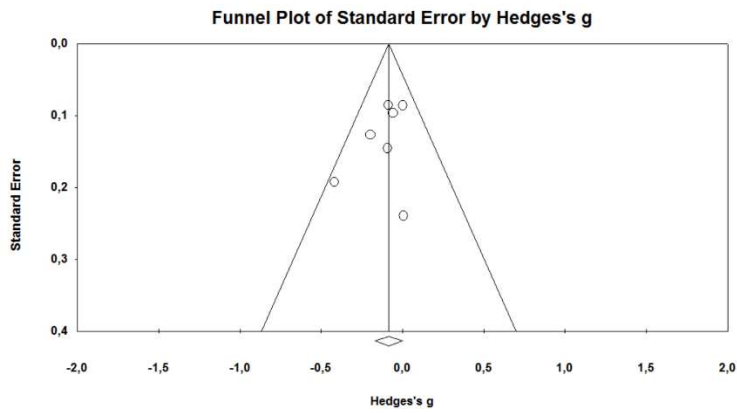
Table 5	Ovulatory vs.	Ovulatory vs.	Ovulatory vs.	Ovulatory vs.	Early Luteal vs.	Early Luteal vs.	Early Luteal vs.	
	Follicular	Luteal	Late Luteal	Menstrual	Follicular	Late Luteal	Menstrual	
Alcohol and tobacco use (combined)	g= -0.07 95% CI [-0.18; 0.04] SE=0.06 p=0.19 (ks=6, Ns=731) I ² /τ ² =0, Q=3.58, p=.73		g=0.01 [-0.14; 0.16] SE=0.08 p=0.87 (ks=7, Ns=787) I ² =40.83, τ ² =0.02, Q=11.83, p=.11	g=0.02 [-0.08; 0.12] SE= 0.05 p= 0.71 (ks=7, Ns=742) I ² /τ ² =0, Q=4.41, p=.73	g= -0.15 [-0.30; -0.00] SE=0.08 p=0.049 (ks=4, Ns=530) I ² /τ ² =0, Q=1.60, p=.66	g=-0.08 [-0.22; 0.06] SE=0.07 p=0.26 (ks=5, Ns=586) I ² /τ ² =0, Q=.62, p=.89	g= -0.01 [-0.15; 0.13] SE=0.07 p=0.85 (ks=5, Ns=541) I ² /τ ² =0, Q=.53, p=.97	
Alcohol use	g= -.07, [-.17; .04], SE=.06, p=.23, (same ks, Ns than above), I ² /τ ² =0, Q=5.07, p=.54		g=.04, [-.11 ; .20], SE=.08, p=.58 (ks=6, Ns=757), I ² =40.18, τ ² =0.02, Q=10.03, p=.12	g=.06, [-.05 ; .17], SE=.06, p=.28 (ks=6, Ns=712), I ² /τ ² =0, Q=4.15, p=.66	g= -0.14 [-0.29; .02] SE=0.08 p=0.077 (ks=4, Ns=530) I ² /τ ² =0, Q=1.86, p=.60.	g= -0.11 [-.26; .04] SE=.08 p=.15 (ks=4, Ns=556) I ² /τ ² =0, Q=.99, p=.80	g= 0.02 [-.14; .17] SE=.08 p=.84 (ks=4, Ns=511) I ² /τ ² =0, Q=2.65, p=.45	
Tobacco use	ks < 3		g= -.06, [-.35 ; .22], SE=.14 (ks=3, Ns=59), I ² =19.62, τ ² =0.01, Q=2.49, p=.29	g= -.14, [-.39 ; .10], SE=.13, p=.26 (ks=3, Ns=59), I ² /τ ² =0, Q=0.97, p=.62	ks < 3	g= -.02 [-.26; .23] SE=.12 p=.90 (ks=3, Ns=59) I ² /τ ² =0, Q=.07, p=.97	g= -.07 [-.31; .18] SE=.13 p=.60 (ks=3, Ns=59) I ² /τ ² =0, Q=0.5, p=.78	
Sexual activity (all)	g=0.14 [-0.007; 0.28] SE=0.07 p=0.06 (ks=8, Ns=2130) I ² =81.53, τ ² =0.039, Q=54.13, p < .001	g=0.15 [0.04; 0.26] SE=0.06 p=0.009 (ks=10, Ns=4808) I ² =80.69, τ ² =.029, Q=67.31, p < .001		g=0.27 [.15; .40] SE=.06 p<.001 (ks=8, Ns=3373) I ² =79.50, τ ² =.030, Q=53.66, p < .001				

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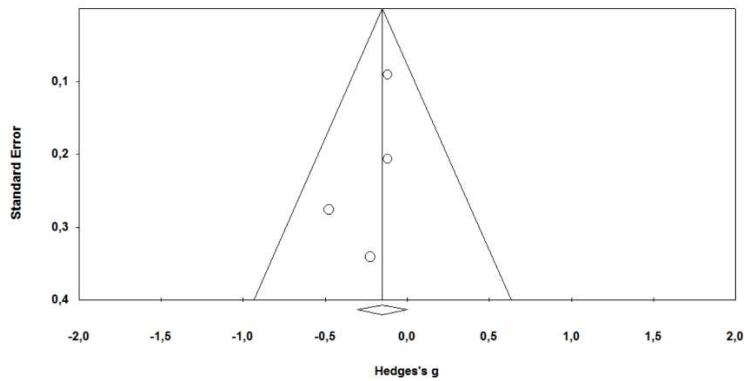
Sexual intercourse	ks < 3	g=.06 [-.09; .21] SE=.08 p=.40 (ks=3, Ns=2440) I ² =53.13 τ ² =0.01, Q=6.40, p=.09	ks < 3				
Risk recognition and avoidance	g=0.45 [0.06; 0.83] SE=0.20 p=0.02 (ks=10, Ns=1309) I ² =86.98, τ ² =0.29, Q=69.14, p < .001	g=0.31 [0.04; 0.57] SE=0.13 p=0.02 (ks=12, Ns=1353) I ² =74.84, τ ² =0.14, Q=43.72, p < .001	ks < 3	g=.46, [.07; 0.85] SE=0.20 p=0.02 (ks=8, Ns=919) I ² =82.41, τ ² =0.23, Q=39.80, p < .001			
Avoidance of sexually threatenin g situations	g=0.49 [-.08; 1.05] SE=.29 p=.089 (ks=4, Ns=1087) I ² =92.62, τ ² =0.35, Q=54.22, p < .001	g=.33 [-.26; .92] SE=.30 p=.27 (ks=4, Ns=1038) I ² =88.23, τ ² =0.30, Q=25.48, p < .001	ks < 3	g=.57 [-.03; 1.16] SE=.30 p=.06 (ks=4, Ns=806) I ² =89.91, τ ² =0.30, Q=29.74, p < .001			

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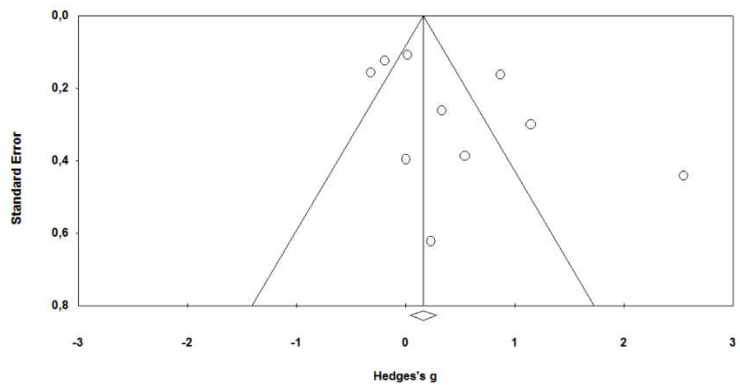
A0. Alcohol/Tobacco (Ovulation vs. Follicular, pre-post correlation = .75)



A1. Alcohol/Tobacco (Early luteal vs. Follicular)

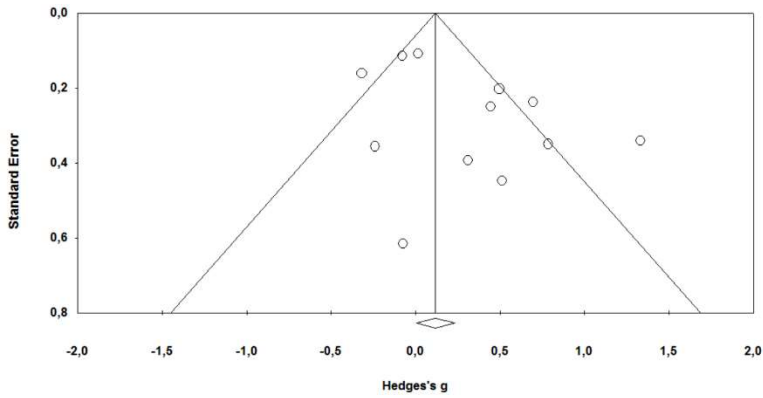


A2. Risk recognition and avoidance (Ovulation vs. Follicular)

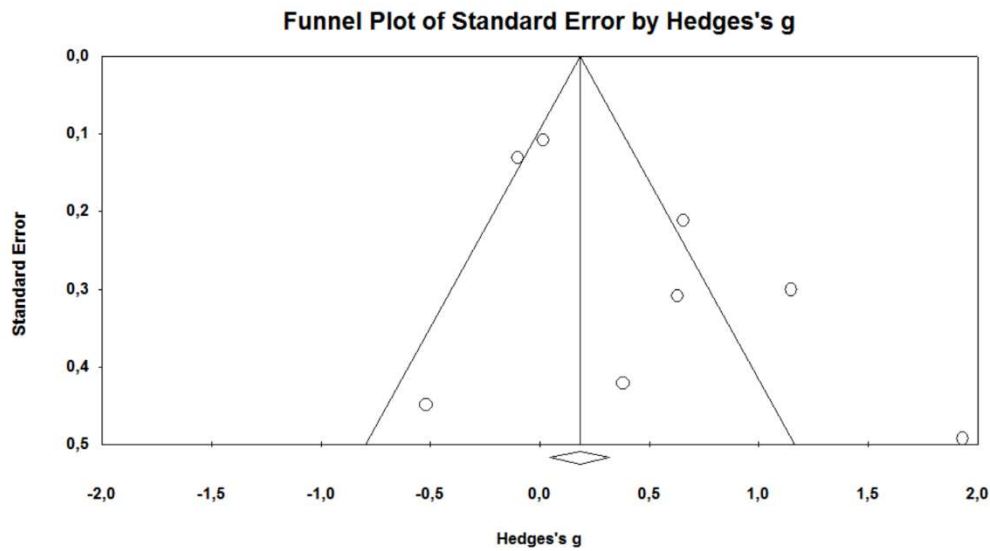


A3. Risk recognition and avoidance (Ovulation vs. Luteal)

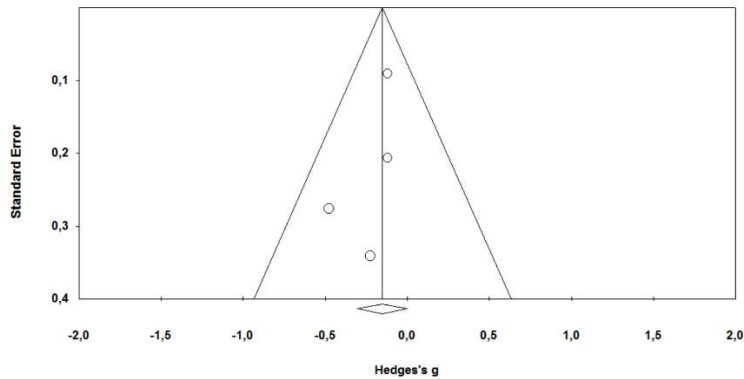
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A4. Risk recognition and avoidance (Ovulation vs. Menstrual)

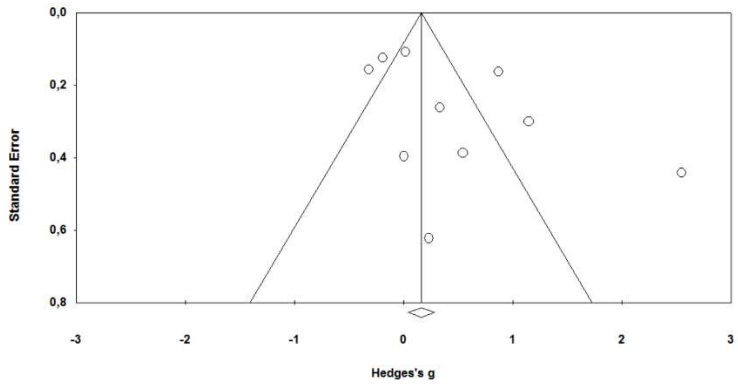


A5. Alcohol/Tobacco (Early luteal vs. Follicular)

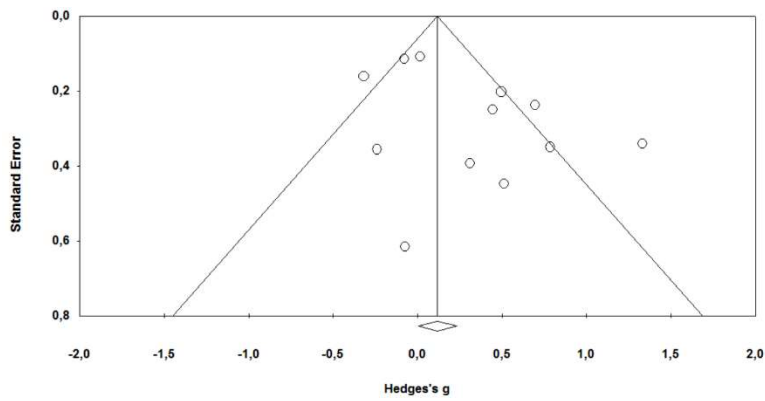


A6. Risk recognition and avoidance (Ovulation vs. Follicular)

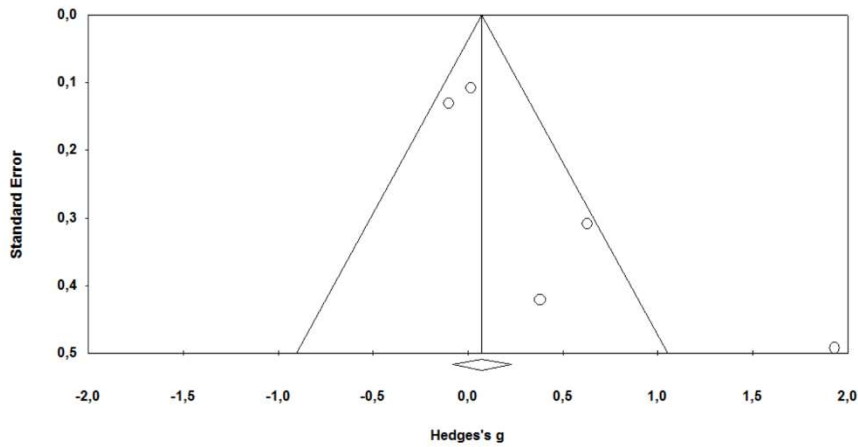
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A7. Risk recognition and avoidance (Ovulation vs. Luteal)

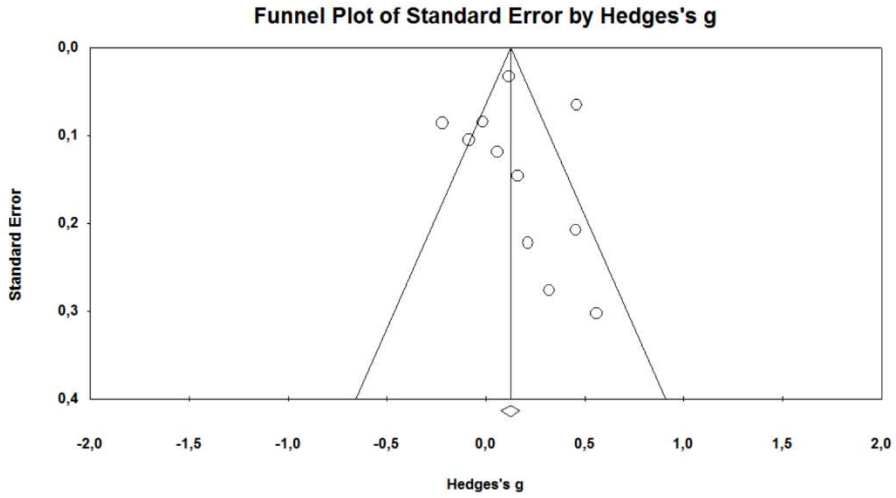


A8. Risk recognition and avoidance (Ovulation vs. Menstrual)

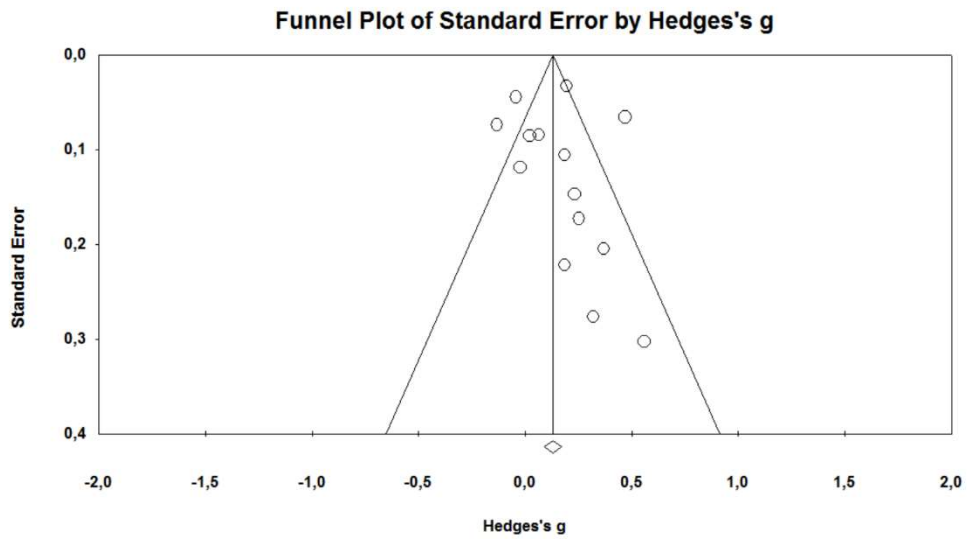


S1. Sexual activity (Ovulation vs. Follicular)

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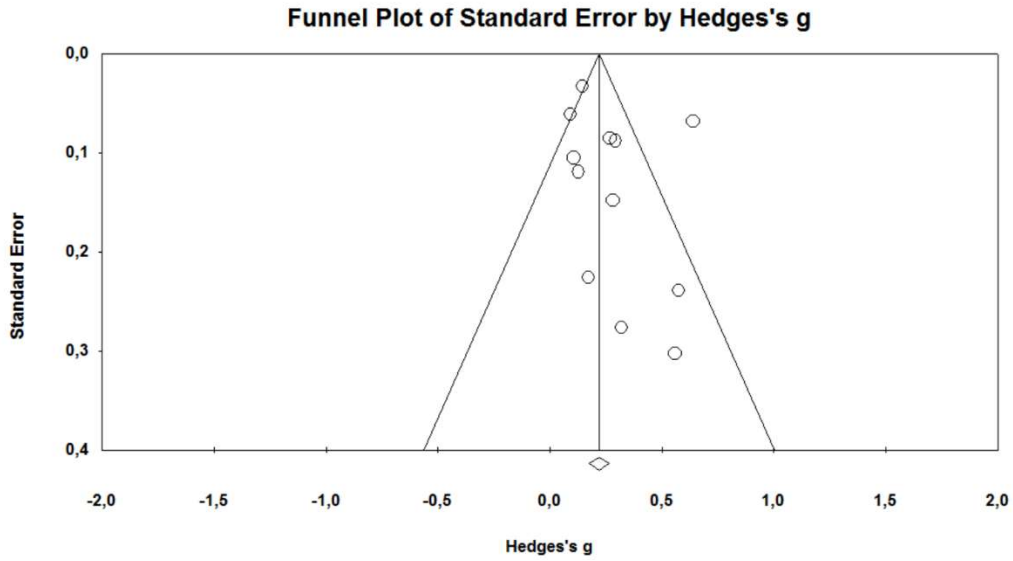


S2. Sexual activity (Ovulation vs. Luteal)

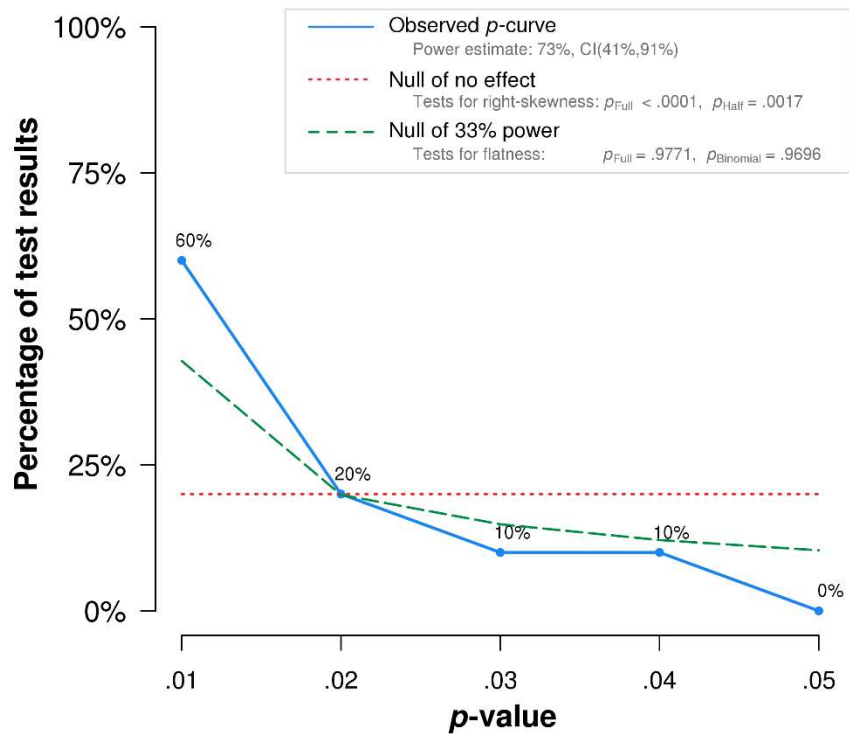


S3. Sexual activity (Ovulation vs. Menstrual)

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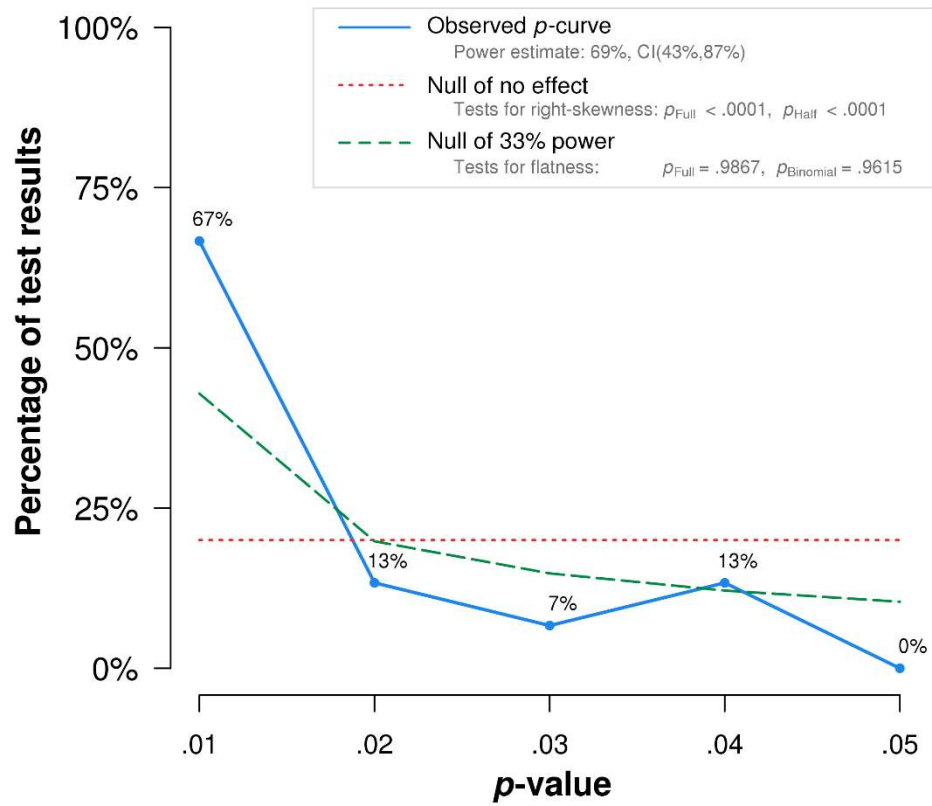
B2. P-curve for Risk-Recognition/Avoidance studies, Ovulatory vs. Follicular phases



Note: The observed p-curve includes 10 statistically significant ($p < .05$) results, of which 9 are $p < .025$. There were 4 additional results entered but excluded from p-curve because they were $p > .05$.

B2. P-curve for Risk-Recognition/Avoidance studies, Ovulatory vs. Luteal phases

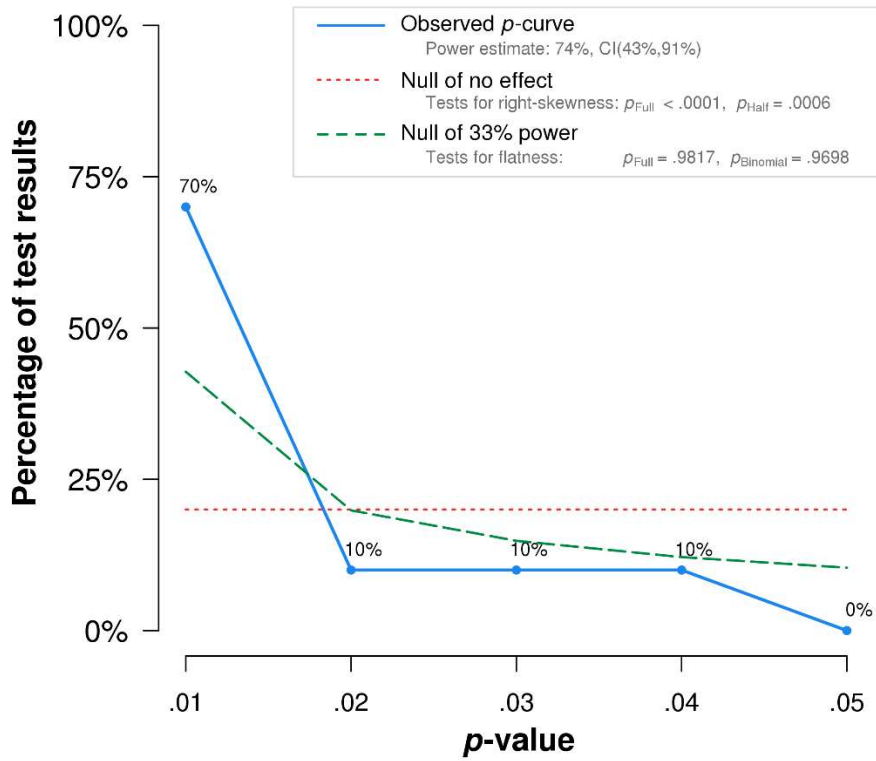
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Note: The observed p -curve includes 15 statistically significant ($p < .05$) results, of which 13 are $p < .025$. There were 7 additional results entered but excluded from p -curve because they were $p > .05$.

B2. P-curve for Risk-Recognition/Avoidance studies, Ovulatory vs. Menstrual phases

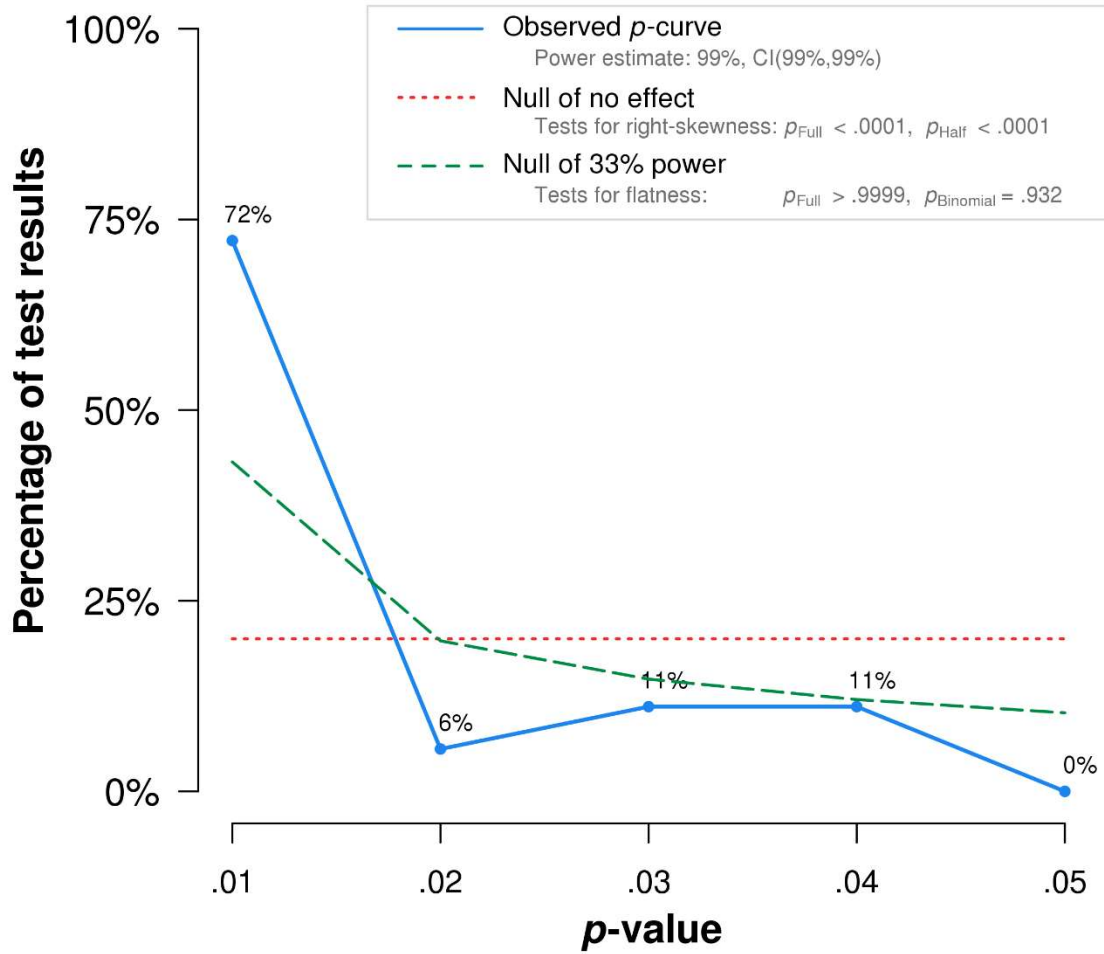
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Note: The observed p -curve includes 10 statistically significant ($p < .05$) results, of which 9 are $p < .025$. There were 6 additional results entered but excluded from p -curve because they were $p > .05$.

B3. P-curve for Sexual Activity studies, Ovulatory vs. Follicular

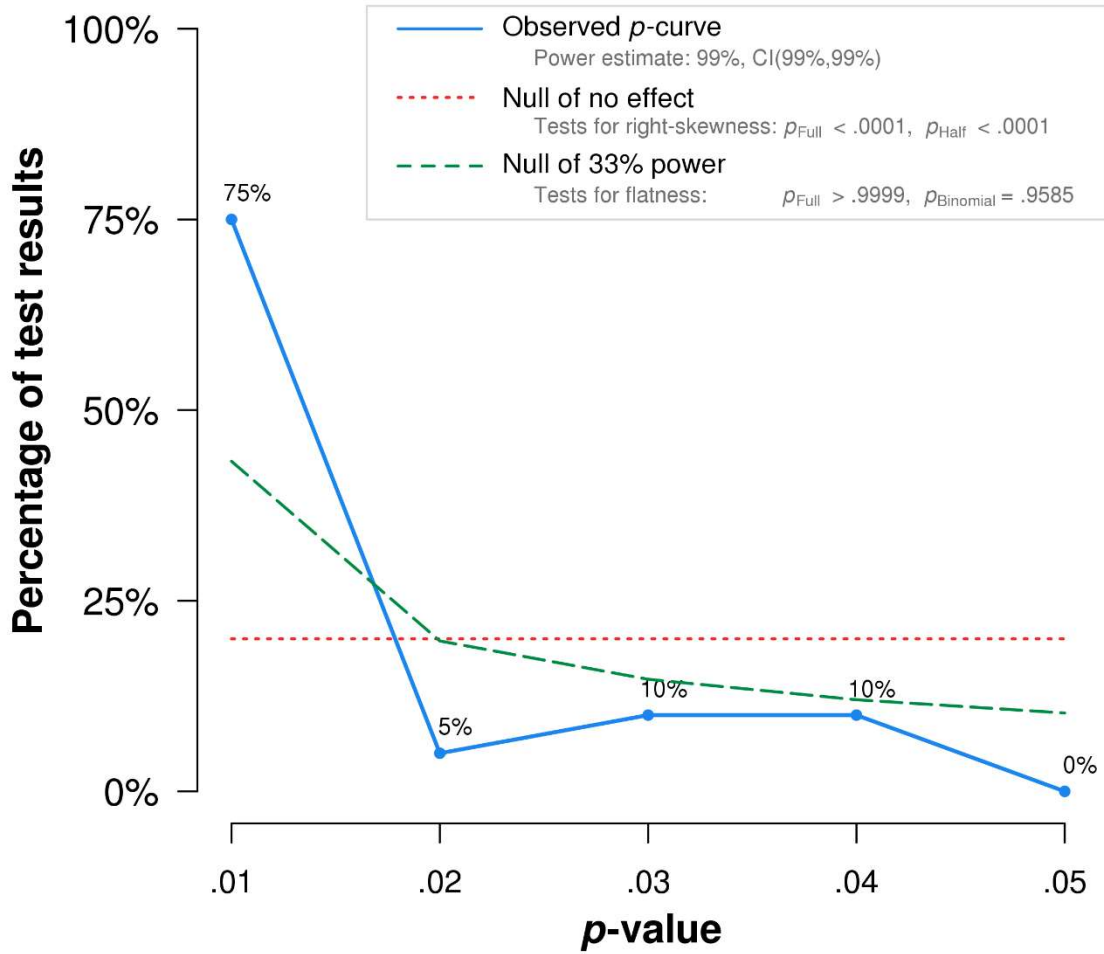
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Note: The observed p -curve includes 18 statistically significant ($p < .05$) results, of which 15 are $p < .025$. There were no non-significant results entered.

B4. P-curve for Sexual Activity studies, Ovulatory vs. Luteal

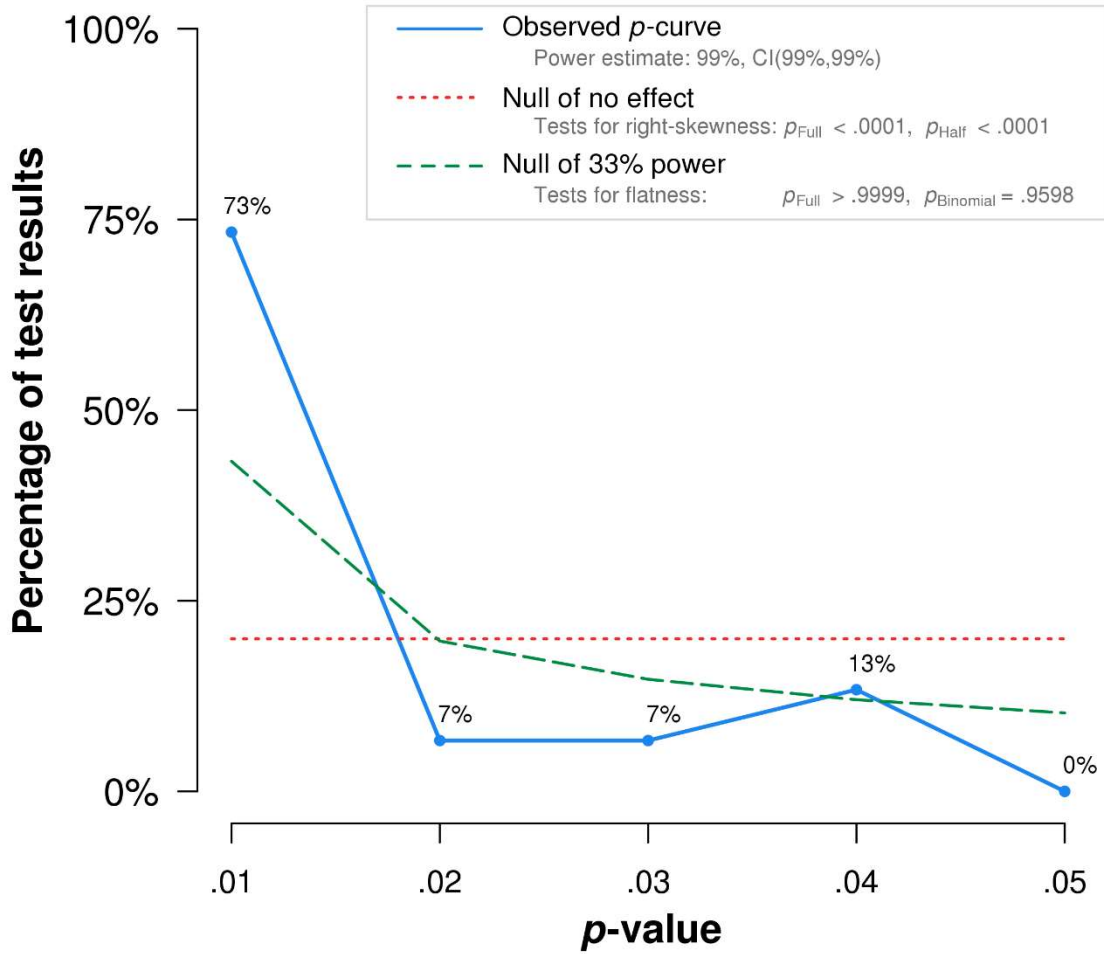
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Note: The observed p -curve includes 20 statistically significant ($p < .05$) results, of which 17 are $p < .025$. There were no non-significant results entered.

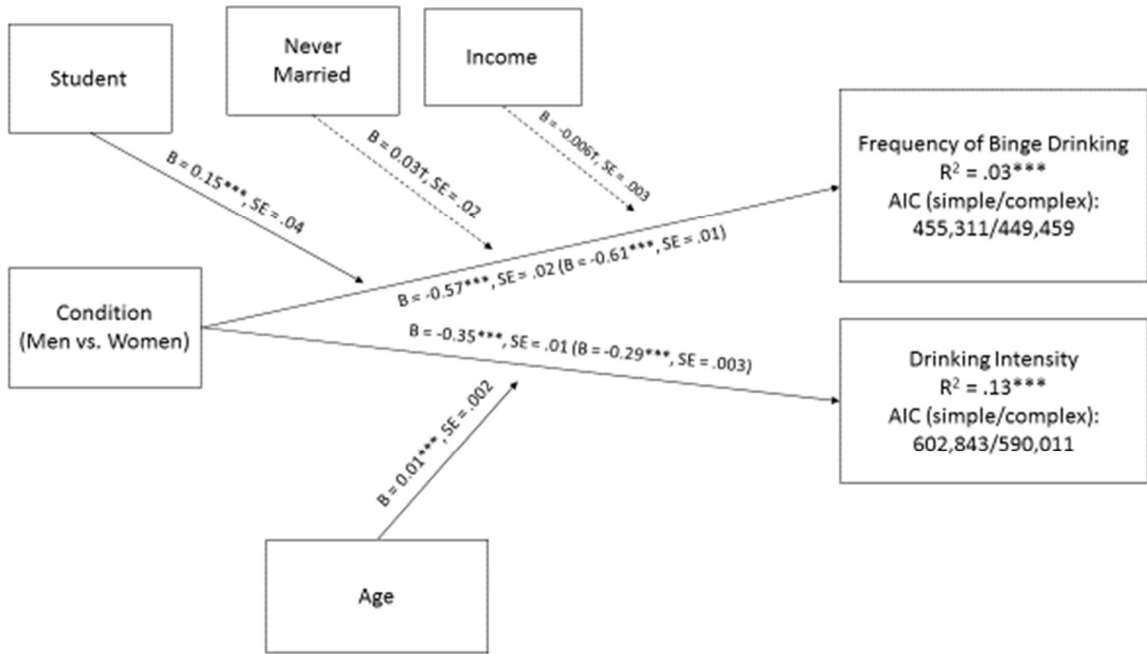
B5. P-curve for Sexual Activity studies, Ovulatory vs. Menstrual

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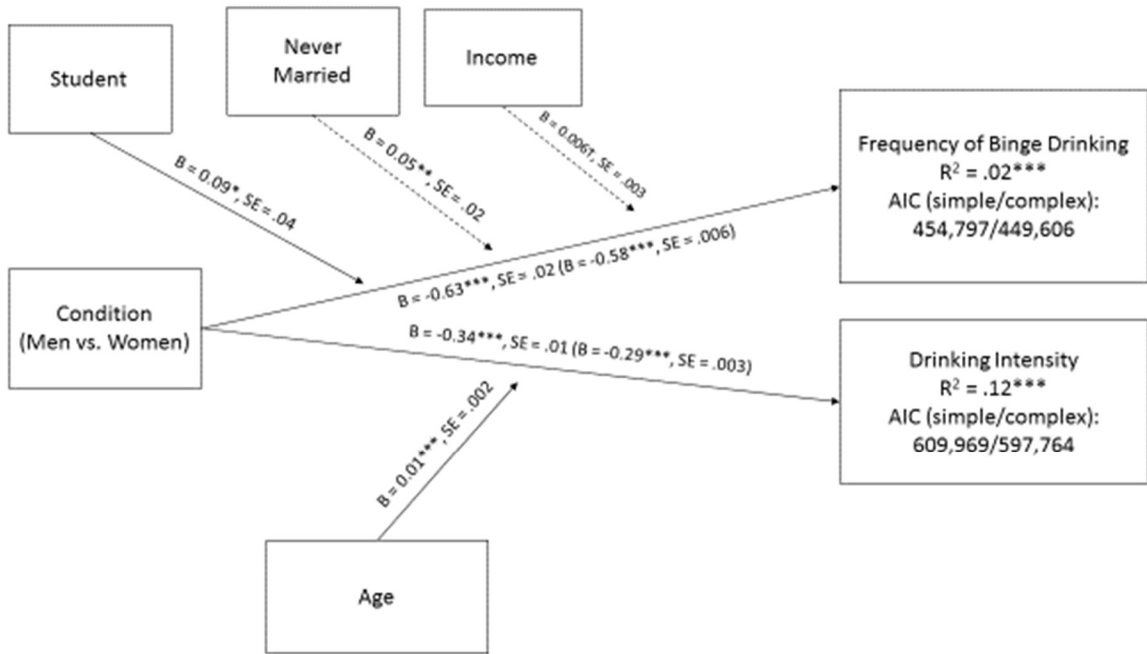


Note: The observed p-curve includes 15 statistically significant ($p < .05$) results, of which 13 are $p < .025$. There were no non-significant results entered.

ANNEX CHAPTER 6

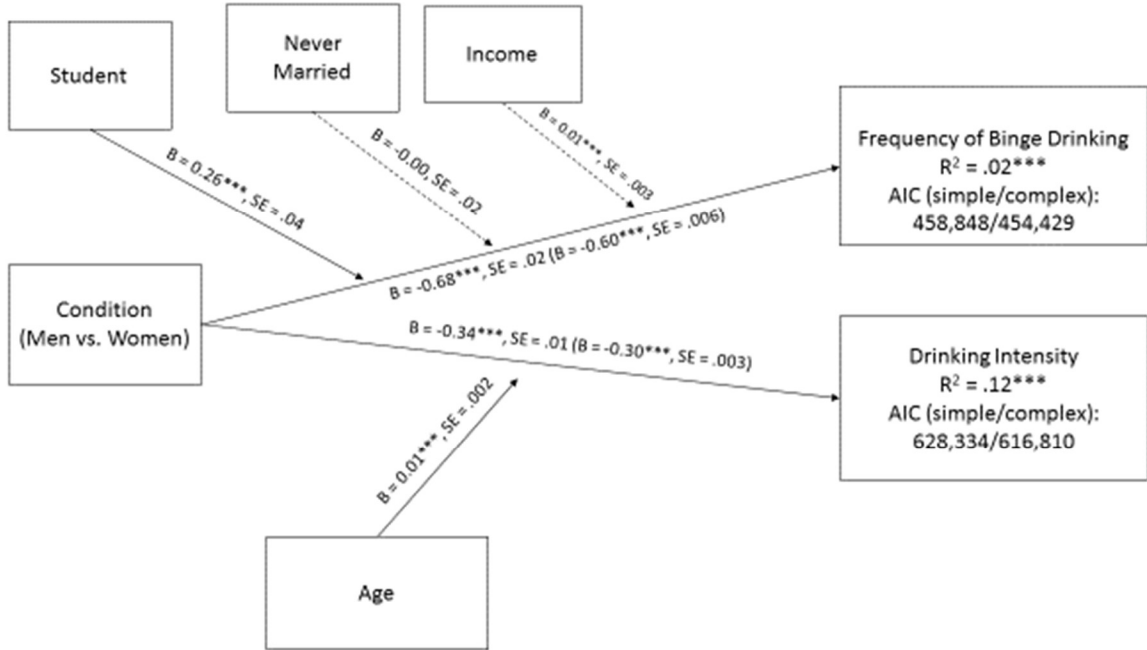


Full Model for the 2008 dataset.

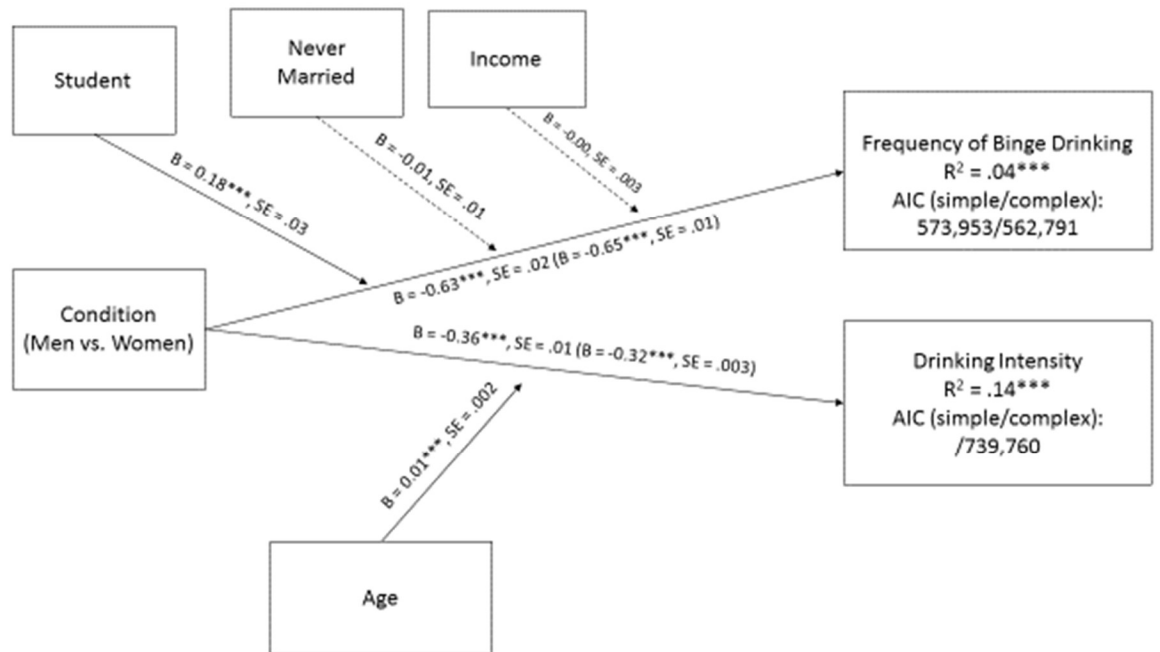


Full Model for the 2009 dataset.

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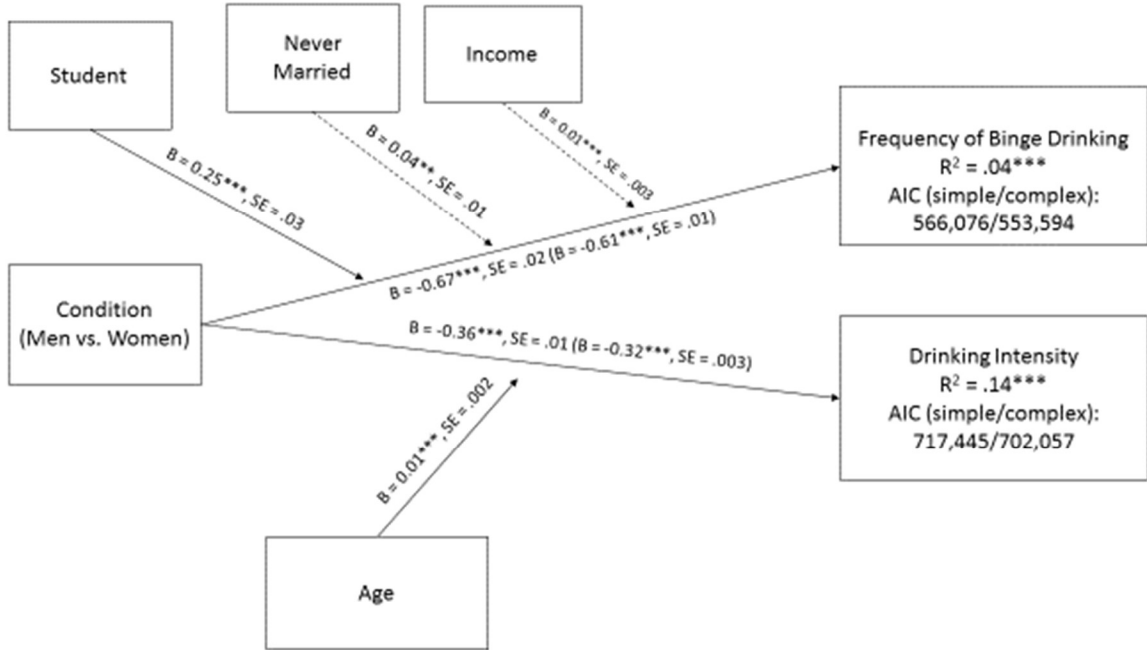


Full Model for the 2010 dataset.

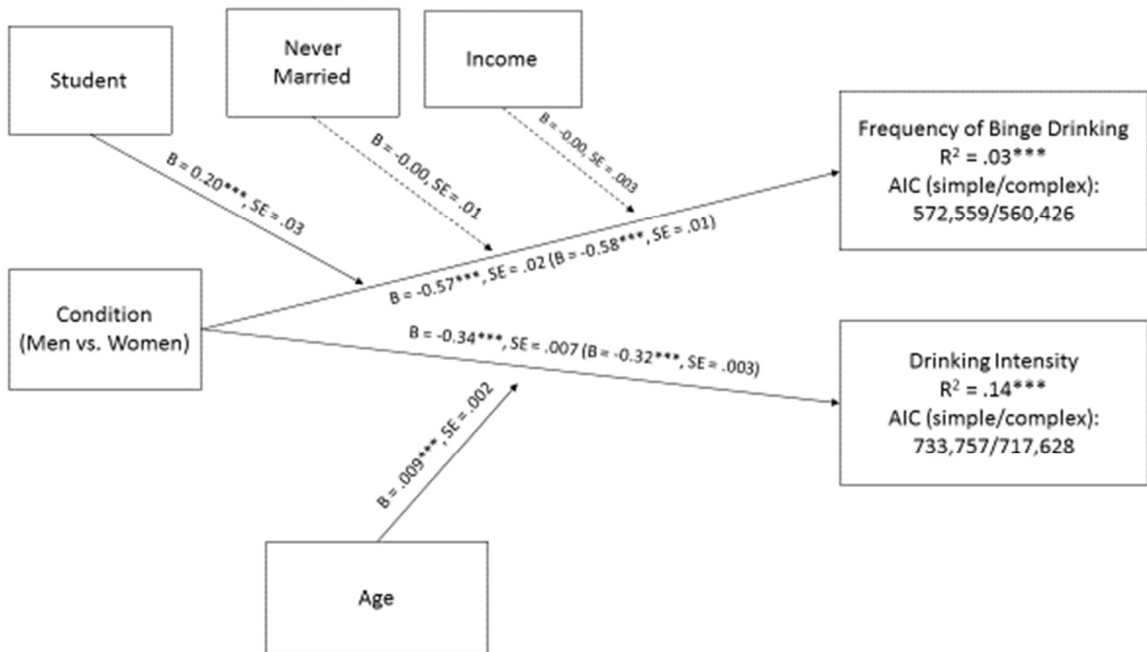


Full Model for the 2011 dataset.

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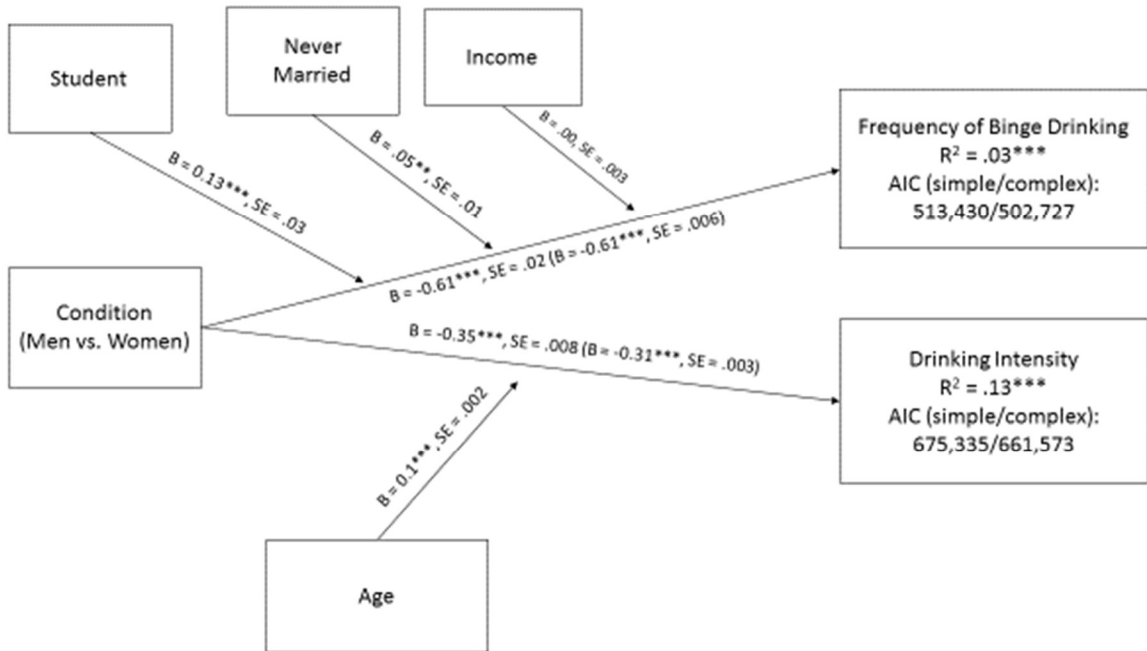


Full Model for the 2012 dataset.

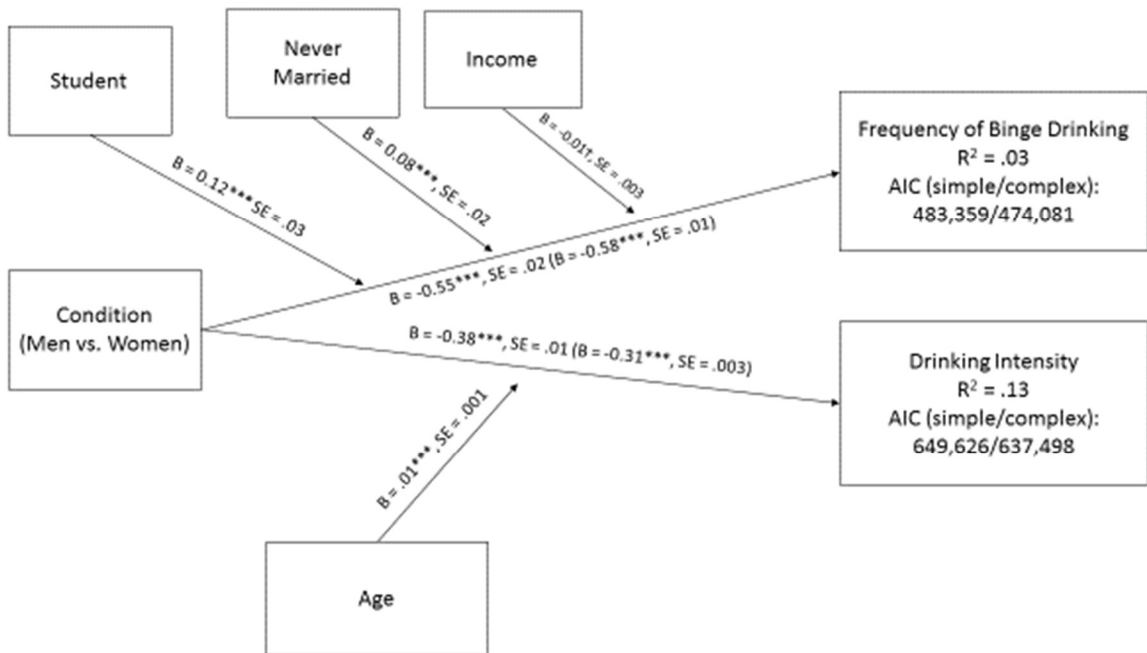


Full Model for the 2013 dataset.

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Full Model for the 2014 dataset.



Full Model for the 2015 dataset.

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