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MASTERARBEIT | MASTER'S THESIS

Titel | Title

Relationship between mood, alcohol consumption, and the menstrual cycle
A momentary assessment study

verfasst von | submitted by

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angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2024

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Psychologie
Betreut von | Supervisor:	Univ.-Prof. Dr. Urs Markus Nater
Mitbetreut von | Co-Supervisor:	Nida Ali BSc (Hons) MSc PhD

Acknowledgement

First, I want to express my gratitude to Nida for the supervision of my master thesis. Working in the AAR project has been enriching for me on many levels. Thank you for your guidance and the work together. I am equally thankful for the supervision of Professor Nater, who also offered me a job at the SOLE platform. I am truly thankful for the opportunity to work at the faculty and gaining more insights into academia and stress research.

Special thanks go to my dear friends Yusuf, Marc and Rebekka for the proof reading of my thesis. I am so grateful for your help, and for the general support I receive in our friendships. Additionally, I want to thank Hannah and Jenny for supporting me not only with some practical questions, but also by always listening to me during the last years.

This is also the right moment to express my deepest appreciation to my parents, who have continuously supported me (not only during my years at the university). Thank you so much for always being there for me and for making these years of study possible.

And finally, I want to thank Julian, who encourages me and supports me every day.

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Abstract

Prior research suggests that alcohol consumption in women might fluctuate across the female menstrual cycle. This study aimed to replicate findings of fluctuations of alcohol consumption over the menstrual cycle. It was expected that worsened mood would predict increasing alcohol consumption during the perimenstrual phase. During the periovulatory phase, increased positive mood should predict increasing alcohol consumption. Further, the present study investigated whether trait anxiety functions as a moderator of these cyclical variations.

The ecological momentary assessment study was conducted on 30 healthy women, who completed daily questionnaires over a period of one menstrual cycle. Participants reported their daily mood, alcohol consumption and stress. PMS symptoms and trait anxiety were assessed during an additional appointment at the laboratory. Multilevel modelling techniques were used to investigate the hypotheses.

The analyses indicated that frequency of alcohol consumption did not vary across different cycle phases. However, a significant interaction of perimenstrual phase and negative mood emerged. While negative mood generally inhibited alcohol consumption, it predicted increased consumption during the perimenstrual phase. Additionally, a significant interaction of the periovulatory phase and negative mood suggested that less negative mood during the periovulatory phase predicted increased alcohol consumption. Trait anxiety was not correlated with alcohol consumption and did not moderate cycle-dependent fluctuations.

In conclusion, the findings suggest that the relationship between negative mood and alcohol consumption differs across menstrual cycle phases. Since the present study did not yield sufficient power to detect any cyclicity in alcohol consumption, future research is needed to investigate the topic.

Relationship between mood, alcohol consumption, and the menstrual cycle: A momentary assessment study

Historically, there has been a gender gap in the prevalence and average amount of alcohol consumption (White, 2020). Men typically drink more alcohol than women over the course of their life (Britton et al., 2015). However, research indicates that this gender gap has been decreasing (Grucza et al., 2008; Keyes et al., 2008; Slade et al., 2016). A meta-analysis by Slate et al. (2016) found for example, that the male to female ratio in problematic drinking patterns lineally decreased over time: Men born in the early 1900s had a 3-fold higher risk than women for problematic alcohol consumption. In contrast, men born in the late 1900s only had a 1.2-fold higher risk for problematic consumption patterns (Slate et al., 2016).

One reason explaining the systematic exclusion of women[1] in psychological and medical research, is the lack of knowledge about the effects of the menstrual cycle (Li et al., 2021). The menstrual cycle is associated with a range of variables in women's lives. Most importantly, it impacts physical variables such as temperature (Baker et al., 2020), psychological variables like feelings (Andréen et al., 2009) or the likelihood of performing a certain behavior (Nelson, 2009).

The present article aims to address the gap in research about alcohol consumption of women. Specifically, the relationship between alcohol consumption and the menstrual cycle will be investigated. It has been hypothesized in prior research that alcohol consumption fluctuates over the menstrual cycle. A narrative review by Carroll et al. (2015) reported that seven out of 13 studies found peaking alcohol consumption before or during menses. Investigating these potential fluctuations is highly relevant, because knowledge about cyclicity could be used for accurately timed preventions in vulnerable populations. If cycle-dependent regularity of alcohol consumption exists, therapists could implement just-in-time measures to counteract increasing alcohol consumption.

In this work, the cyclicity of alcohol consumption will be investigated in healthy women. Recent studies about the potential cyclicity of alcohol consumption will be reviewed in detail. Based on findings about the association of mood and alcohol consumption, it is expected that interactions of mood and the menstrual cycle phases predict alcohol consumption. After giving an overview of the menstrual cycle phases, mood deterioration

[1] The present work investigated the relationship between the menstrual cycle and participant's behavior. However, it is recognized that not all women have a menstrual cycle. Additionally, having a menstrual cycle does not allow the automatic conclusion, that the person is a woman.

before and during menses (the perimenstrual phase) will be discussed in the next section. It is hypothesized, that mood deteriorates in the perimenstrual phase. Because of this deterioration of mood, and findings indicating increased coping motivation during the perimenstrual phase (Joyce et al., 2018), it is expected that negative mood during the perimenstrual phase predicts increased alcohol consumption. In addition, inter-individual differences of the tendency to show cycle-dependent alcohol consumption will be discussed.

The Menstrual Cycle

The menstrual cycle is defined by the concentrations of the two steroid hormones estrogen and progesterone. Starting with menses onset, which marks day one of every menstrual cycle, a healthy cycle lasts approximately 28 days. It ends one day before the next menses begins (Schmalenberger et al., 2021). Progesterone remains on a relatively stable and low level at the beginning of the cycle. Estrogen rises slowly at first, and then rapidly during the second week of a standard 28-days menstrual cycle. It peaks right before ovulation, subsequently decreasing again. In the following two weeks, progesterone concentration increases. It peaks during the second half of the menstrual cycle, which occurs in parallel with a secondary peak of estrogen. During the premenstrual days, both hormone levels decline, resting on a low level during the first week of the next menstrual cycle.

Usually, these fluctuations of the steroid hormones are classified into two major phases: The follicular phase, which lasts from the onset of menses until ovulation, and the luteal phase thereafter. Dividing the menstrual cycle in these two phases has been criticized because of the marked heterogeneity of hormonal concentrations during these phases (Schmalenberger er al., 2021). Instead, Schmalenberger et al. (2021) proposed a more differentiated taxonomy with four different phases, which exhibit distinct hormonal conditions: First, the perimenstrual phase includes the days before and during menses, which are characterized by decreasing estrogen and progesterone. The mid-follicular phase, which ranges approximately from day 4 to day 8 of a standard menstrual cycle, includes a state of relatively low and steady estrogen and progesterone. Days 12 to 17 are classified as the periovulatory phase and include the first peak of estrogen. Finally, the mid-luteal phase (approximately day 20 to 24) comprises the double peak of estrogen and progesterone.

Perimenstrual Symptoms

During the perimenstrual phase, which begins three days before the onset of menses and lasts until the second day of menstruation (Schmalenberger et al., 2021), many women experience aversive symptoms. These are linked to the so-called premenstrual syndrome (PMS). A wide range of somatic and psychological symptoms are associated with PMS. The symptoms manifest during the perimenstrual phase, subsequently disappearing by the mid-

follicular phase (Dickerson et al., 2003; Meaden et al., 2005). While the most severe form of perimenstrual symptoms, the Premenstrual dysphoric disorder (PMDD) is an established diagnosis (Goswami et al., 2023) characterized by strong impairment (Halbreich et al., 2003), PMS is not. Instead, the symptoms related to PMS are diverse and heterogenous. Around 200 different symptoms have been associated with PMS (Dickerson et al., 2003). This heterogeneity is problematic as it impedes a uniform definition of the concept (Freeman et al. 2011). Thus, a prospective study by Freeman et al. (2011) tried to identify the symptoms, that distinctively belong to PMS. According to the authors the following symptoms were most frequently reported by women: Cramps, aches, abnormal appetite and eating behavior, mood swings, anxiety, and decreased interest in activities (Freeman et al., 2011). Generally, the symptoms of PMS can be classified as either “physical”, “emotional” and “behavioral”. It must be noted that while a lot of women experience at least one perimenstrual symptom, only a subset of women meets the full criteria for PMS (Direkvand-Moghadam et al., 2014).

Mood and the Menstrual Cycle

Only a minority of women meet the full criteria for a PMS diagnosis, but some authors suggest that up to 85% experience at least one symptom (Dickerson et al., 2003). Considering the psychological symptoms of PMS like anxiety (Freeman et al., 2011), it can be expected that even if not all PMS criteria are met, mood might still fluctuate across the menstrual cycle. However, studies about the relationship between mood and the menstrual cycle find mixed results. In a systematic review, only 65% of the included studies found fluctuations of mood across the menstrual cycle (Romans, Clarkson, et al., 2012). One prospective study by Natale and Albertazzi (2006) for example failed to find significant fluctuations of mood in most of the applied measures. In their prospective study, only the items measuring depressive mood showed cycle-dependent fluctuations. On the other hand, evidence for fluctuations of mood was found by one study (Pierson et al., 2021) with data from 499.000 women from over 100 countries. The study suggested, that among different cyclical predictors, the menstrual cycle influenced women’s mood the most (Pierson et al., 2021). A study by Ross et al. (2003) found a prominent premenstrual change in the incidence of (affective) PMS symptoms, paired with a peak of somatic symptoms on day one of menstruation. Meaden et al. (2005) investigated the timing and intensity of different PMDD and PMS symptoms with a sample of 900 women, including items focusing on affective symptoms like “feeling anxious “, “mood swings”, or “depressed mood”. The authors were able to show, that all symptoms (albeit to varying degrees) fluctuated along the menstrual cycle, peaking on the first day of menstruation (Meaden et al., 2005). Finally, another study providing evidence for fluctuations of mood, showed that well-being fluctuated across the menstrual cycle in 63 healthy women (Gonda et al., 2008). Psychological strain was

significantly increased during the late luteal phase, as measured by scales such as state anxiety, depression and somatization (Gonda et al., 2008).

Psychoneuroendocrinological research on the GABA-system provides an explanation for the deterioration of mood during the perimenstrual phase. The GABA-system is the major inhibitory system of the human central nervous system (Andréen et al., 2009). Modulators of the $GABA_A$-system are substances that bind onto the $GABA_A$ receptors to either increase or decrease the effects of GABA. These modulators are for example alcohol, barbiturates or benzodiazepines (Andréen et al., 2009). The metabolites of progesterone, allopregnanolone and pregnanolone, are modulators of the $GABA_A$ receptors too. These metabolites fluctuate along the menstrual cycle just like progesterone does (Wang, 2011). Andréen et al. (2009) assumed that progesterone influences the GABA-system through these metabolites. The authors presented evidence, that the steroid hormone progesterone is associated with PMDD symptoms and psychological side effects of hormonal contraceptives. Furthermore, the review by Andréen et al. (2009) summarizes literature about the impact of the $GABA_A$ modulators on mood. The modulators of $GABA_A$ have been associated with sedative, anxiolytic or anticonvulsant effects in humans and animals. On the other hand, negative effects like increased irritability, aggression or anxiety have been reported as well (Andréen et al., 2009). The biphasic effects model provides an explanation for these contradictions by proposing that low concentrations of $GABA_A$ modulators can lead to negative effects like aggression or anxiety, while high concentrations on the other hand can lead to positive effects like decreased anxiety. The mechanisms and reasons for these associations are not known yet (Bäckström et al., 2011), but the role of chronic stress was discussed in a systematic review (Bäckström et al., 2011). It is important to note that these biphasic effects only occur in a subgroup of individuals (Andréen et al., 2009).

All in all, these findings related to the GABA-system might explain fluctuations of mood. An abnormality of the $GABA_A$-system is thought to be a potential explanation for the development of PMS or PMDD (Bäckström et al., 2011). Based on the evidence mentioned above, the present study aims to replicate the finding that mood deteriorates during the perimenstrual phase. Meanwhile, the sensitivity to hormonal changes will be controlled for in the analysis to address interindividual differences.

Mood and Alcohol Consumption

Mood has not only been linked to the menstrual cycle in previous research, but also to alcohol consumption. Some studies indicate that mood influences alcohol consumption. For example, an experimental study showed that priming of negative affect words predicted increased alcohol consumption (Zack et al., 2006). Meanwhile, priming of positive or neutral

affect words did not exert any influence on alcohol consumption (Zack et al., 2006). In an ecological momentary assessment study conducted by Monk et al. (2020), mood of male college students was measured before and during every drinking occasion. In the study, negative mood predicted increased alcohol consumption. Furthermore, the participants' mood improved following alcohol consumption, indicating a mood-enhancing effect of alcohol consumption. Another prospective study by Swendsen et al. (2000) demonstrated that nervousness predicted increased alcohol consumption. This effect was more pronounced in men compared to women (Swendsen et al., 2000). In contrast to these two studies, another ecological momentary assessment study found that positive mood predicted increased alcohol consumption (Peacock et al., 2015). Negative mood predicted alcohol consumption, but to a lesser degree than positive mood. While these studies collectively suggest that mood generally influences alcohol consumption, the question of whether positive or negative mood is a stronger predictor remains unresolved.

Drinking Motives of Alcohol Consumption

Since the findings about the relationship between mood and alcohol consumption are ambiguous, the next section will introduce another important predictor variable. According to Kuntsche et al. (2014), the best proximal predictors of alcohol consumption are the drinking motives by Cooper (1994). M. Lynne Cooper assumed that people drink alcohol out of four motives: First, there are social motives, such as drinking at social gatherings like parties. Another reason for drinking alcohol is the conformity motive, which is associated with a perception of external pressure to drink (Kuntsche et al., 2014). One item of the Drinking Motives Questionnaire (Cooper, 1994) indicating a conformity motive is for example "How often do you drink alcohol to fit in with a group you like?" (Cooper, 1994) If people drink alcohol, because they internally enjoy the consumption, they drink out of enhancement motives (e.g. "How often do you drink alcohol because it gives you a pleasant feeling"; Cooper, 1994). In contrast, the coping motive comprises the motivation to drink alcohol to alleviate distress ("How often do you drink alcohol, to forget about your problems"; Cooper, 1994). The four motives can be classified along two independent dimensions. The first dimension is valence, which can be positive or negative. The second dimension is the source, which can be internal or external. Accordingly, social and enhancement motives have a positive valence, while conformity and coping motives have a negative valence. Enhancement and coping motives stem from an internal motivation to drink, while social and conformity reasons are instead motivated by an external setting.

Regarding the relationship between the menstrual cycle and drinking motives, a study by Joyce et al. (2018) suggested, that drinking motives of 90 low-risk drinkers systematically

fluctuated across menstrual cycle phases. While social motives showed a small increase during the menstrual cycle, coping motives were reported most frequently in the perimenstrual phase (Joyce et al., 2018). The increased frequency of coping motives was additionally associated with increased consumption of alcohol during the perimenstrual phase. This finding aligns with prior research, which indicated that coping motives would be associated with increased alcohol consumption (Bresin & Mekawi, 2021; Cooper et al., 1994; Kuntsche et al., 2008). It can be concluded, that coping motives are correlated with dysfunctional drinking patterns (Bresin & Mekawi, 2021; Cooper et al., 1994; Kuntsche et al., 2008).

The study by Joyce et al. (2018) provided evidence for the assumption, that women drink more alcohol during the perimenstrual phase to cope with distress. As outlined in the previous sections, it can be assumed that the well-being of women is lowered during the perimenstrual phase. An ecological momentary assessment study linking mood and drinking motives, revealed that negative mood on a between-person-level predicted increased coping motives (Stevenson et al., 2019). On a within-person-level, anxious and depressed mood states predicted coping motives on a daily base. Positive mood, on the other hand, was predictive of enhancement motives (Stevenson et al., 2019). Thus, it can be assumed that mood not only predicts alcohol consumption (as stated above), but also differentially influences drinking motives. This could potentially explain the findings by Joyce et al. (2018), indicating increased coping motives during the perimenstrual phase. All in all, if mood is worsened during the perimenstrual phase, and participants are more strongly motivated to drink alcohol to cope with the experienced distress, they might drink more alcohol during the perimenstrual phase. A central hypothesis of this study is that women might drink more alcohol during the perimenstrual phase, if they experience worsened mood.

Evidence for Cyclicity in Alcohol Consumption

In the following section, the existing studies about fluctuations of alcohol consumption over the course of the menstrual cycle will be reviewed. According to Schmalenberger et al. (2021), ecological momentary assessment or repeated measures designs are recommended to study the menstrual cycle. The validity of the studies using retrospective self-reports to investigate menstrual cycle related fluctuations consequently is only limited. Studies employing retrospective self-reports (like Allen, 1996; McLeod et al., 1994), will not be discussed here.

Generally, the studies on cyclicity of alcohol consumption can be divided into studies conducted on healthy women and studies conducted on clinical samples. Traditionally, these studies hypothesize increased alcohol consumption during the perimenstrual phase. Partial

evidence for this assumption is provided by a study with 59 alcohol-dependent women (Hayaki et al., 2020). During three months of treatment for alcohol use disorder, most alcohol was consumed during menses. Alcohol consumption was also increased in the premenstrual phase, but the differences between the premenstrual phase and other phases of the menstrual cycle were not significant. While this study only provided evidence for increased consumption during menses, another study found increased alcohol consumption during the premenstrual phase (Epstein et al., 2006). The authors used data from a randomized controlled trial that investigated women with an alcohol use disorder. From the original sample, only women with a regular menstrual cycle who were premenopausal and who were not taking oral contraceptives were included. This resulted in a sample of 12 women, who kept daily logs of daily alcohol consumption and craving intensity for a period of six months. Meanwhile, the participants received treatment for their alcohol use disorder. Analyses revealed that in the first three months of treatment, women drank most alcohol in their premenstrual phases, compared to their menses and the rest of their menstrual cycles (Epstein et al., 2006). However, the sample size of 12 women is not sufficient to make any valid deductions. Furthermore, the classification of the cycle phases was not done according to the recommendations by Schmalenberger et al. (2021). Instead of investigating the perimenstrual phase, both mentioned studies made a distinction between menstrual phase and the premenstrual phase (Epstein et al., 2006; Hayaki et al., 2020). This distinction is not valid, because hormone concentrations and PMS symptoms correspond between the days before menses and during menses (Meaden et al., 2005; Schmalenberger et al., 2021).

One study that used the recommended cycle phases (Schmalenberger et al., 2021) provides additional evidence for increased alcohol consumption during the perimenstrual phase (Barone et al., 2023). The study was conducted on over 90 participants with various psychological diseases (except psychosis, bipolar disorder and substance use disorders). Participants answered daily questionnaires over the period of three menstrual cycles (Barone et al., 2023). The study revealed that coping motives were more frequently reported in the perimenstrual phase. Participants were more likely to drink heavily on weekends during the perimenstrual phase, as well as the periovulatory phase.

The double peak of alcohol consumption during the perimenstrual and the periovulatory phase was replicated by two additional studies by Holzhauer er al. (2020) and Martel et al. (2017). The first study by Holzhauer et al. (2020) looked at the association between daily mood, alcohol consumption and the menstrual cycle in 41 female college students. Mood was conceptualized as a within-variance-factor, and as a between-variance factor. Mood as a between-variance factor distinguished between women with a more overall positive mood and women with a more overall negative mood. Alcohol consumption

increased during the perimenstrual phase and the periovulatory phase, depending on the mood of participants: Periovulatory increases of consumption were associated with elevated mood, while perimenstrual increases of consumption were associated with negative mood. Additionally, women who generally had a worse mood than other participants, tended to drink more alcohol during menses. The hypothesis, that mood interacts with the menstrual cycle in predicting fluctuations of alcohol consumption, is not supported by the study by Martel et al. (2017). The study with 22 healthy women failed to find any associations between the menstrual cycle, mood and alcohol consumption. Salivary estrogen and progesterone were measured daily over the period of 35 days. The authors found increased alcohol consumption before ovulation and during the premenstrual days (Martel et al., 2017). The authors argued that increased periovulatory consumption could be caused by the inhibiting effect that estrogen exerts onto the GABA-system. Because of lowered GABA concentrations, higher dopamine and increased reward sensitivity could emerge (Martel et al., 2017). However, these proposed mechanisms behind the cyclicity of alcohol consumption remain to be directly studied.

A recent study by Hoffmann et al. (2024) found increased alcohol consumption during the periovulatory phase of the menstrual cycle, too. The authors collected data from 74 women and 278 men with alcohol use disorder over a period of a whole year (Hoffmann et al., 2024). Every second day, participants reported their alcohol consumption of the last two days. Blood samples were collected four times at the baseline and four, eight and twelve months later) to determine progesterone and estrogen levels. While there were no significant findings related to the general probability of alcohol consumption on a given day, the binge drinking probability was lowest during the premenstrual days. The binge drinking probability peaked during the periovulatory phase (Hoffmann et al., 2024). Hence, the study by Hoffmann et al. (2024) does not support the hypothesis of increased alcohol consumption during the perimenstrual phase.

Overall, it can be concluded that the studies reviewed above provide evidence for cyclicity in alcohol consumption. However, the peaks of consumption that were found, vary: Some studies observed peak alcohol consumption during the perimenstrual phase (Barone et al., 2023; Holzhauer et al., 2020), while others reported peaks only during menses (Hayaki et al., 2020) or the premenstrual days (Epstein et al., 2006; Martel et al., 2017). Another peak of consumption has been found to be periovulatory (Barone et al., 2023; Hoffmann et al., 2024; Holzhauer et al., 2020) or before ovulation (Martel et al., 2017). It can be concluded that the results are ambiguous. Of the above-mentioned studies, a majority were conducted on clinical populations. Evidence for healthy women is still sparse.

Anxiety and Alcohol Consumption

One reason for the mixed results regarding cyclicity might be the existence of interindividual differences. One study suggests, that cyclicity of alcohol consumption is present in women with a family history of alcoholism: Women with a family history of alcoholism consumed significantly more alcohol in the premenstrual phase, compared to the follicular phase of the menstrual cycle (Svikis et al., 2006). In contrast, women without a family history of alcoholism showed no differences of alcohol consumption during these two phases (Svikis et al., 2006). These findings highlight the importance of considering inter-individual differences when studying cycle-dependent fluctuations of alcohol consumption.

This study hypothesizes that trait anxiety could be a moderator variable of cyclicity of alcohol consumption. Research about associations between anxiety and alcohol consumption include different concepts of anxiety: One the one hand, trait anxiety represents a stable disposition of experiencing anxiety in response to challenging situations (Spielberger et al., 1970). On the other hand, state anxiety refers to the situational experience of anxiety. According to Spielberger et al. (1970), high trait anxiety in a person predicts higher prevalences of state anxiety in their lives (Spielberger et al., 1970). In the following section, findings about the relationship between state anxiety or trait anxiety and alcohol consumption will be discussed.

Previous studies suggested that heightened state anxiety appears during alcohol hangovers (Mc Kinney & Coyle, 2006) and withdrawals (McKeon et al., 2008). These results could be linked to alcohol's function as a modulator of the $GABA_A$ receptors. As stated above, alcohol could potentially generate either anxiogen or anxiolytic effects depending on its concentration (Andréen et al., 2009). In a systematic review by Gilpin et al. (2015) the authors concluded that the central amygdala plays a substantial role in both alcohol use disorders and anxiety disorders. The central amygdala is responsible for the processing of fearful and aversive stimuli and is closely linked to the GABAergic system. The conclusion by Gilpin et al. (2015) might explain that alcohol use disorders oftentimes co-occur with anxiety disorders (Lai et al., 2015). Specifically, persons exhibiting a heightened tendency of self-medicating[2] behavior are more likely to develop an alcohol use disorder on top of their pre-existing mood or anxiety disorder (Turner et al., 2018). Anxiety disorders often precede alcohol use disorders, which could be explained by self-medication. A study providing evidence for this assumption indicated that social anxiety disorders usually precede alcohol

[2] The term "self-medication" originated from the well-known "self-medication hypothesis" by Khantzian (1997). This theory posits that substance use disorders develop because of dysfunctional coping attempts with a primary stressor. In order to cope with this primary stressor, individuals cope with consuming the substance and "self-medicate".

use disorders and are a risk factor for an alcohol use disorder (Morris et al., 2005). Moreover, there are gender-specific findings indicating, that women typically develop a mood- or anxiety disorder prior to an alcohol use disorder. On the other hand, the sequence typically is reversed in men (Nolen-Hoeksema, 2004). The evidence indicates that women are more likely to develop a dependency through self-medication, while men do so due to characteristics like sensation seeking (Fonseca et al., 2021).

The concept of trait anxiety has also been linked to alcohol consumption in different studies. For example, two longitudinal studies found that high trait anxiety during alcohol withdrawal predicted relapse six months (Driessen et al., 2001) and a year later (Willinger et al., 2002). Additionally, in a study with more than 500 teenagers, trait anxiety specifically predicted a tendency towards expressing increased coping motives in alcohol consumption, while other personality facets consequently predicted other drinking motives (Comeau et al., 2001).

All in all, these findings emphasize the complex relationship between alcohol consumption and anxiety, suggesting that anxiety might be closely linked to self-medication behavior and alcohol consumption. Therefore, it can be expected, that individuals with high trait anxiety might show an increased intention to self-medicate and cope with alcohol (Comeau et al., 2001). If coping motives are assumed to be more prevalent during the perimenstrual phase of the menstrual cycle, it can be expected that especially women who are high in trait anxiety might try to cope during the perimenstrual phase by drinking alcohol. Thus, the present study aims to research whether high trait anxiety in individuals might intensify cyclicity in alcohol consumption. The following hypotheses are posed:

Hypothesis 1: Mood fluctuates over the course of the menstrual cycle. While controlling for hormone sensitivity, it is expected, that negative mood increases during the perimenstrual phase.

Hypothesis 2: Alcohol consumption fluctuates along the menstrual cycle in healthy women. Positive mood predicts increased alcohol consumption during the periovulatory phase of the menstrual cycle. Negative mood predicts increased alcohol consumption during the perimenstrual phase of the menstrual cycle.

Hypothesis 3: Trait anxiety influences cyclicity of alcohol consumption. Perimenstrual increases in alcohol consumption paired with negative mood will be more pronounced in women who are high in trait anxiety.

To account for potential hormone-sensitivity in women, the variable “PMS distress” will be included as a covariate in all analyses.

Methods

This study was conducted in the framework of a larger study about the alpha-amylase awakening response (AAR). The aim of the AAR study is to investigate the influences of daily life on salivary alpha amylase, which is a marker for the sympathetic nervous system (Nater et al., 2007). To gain insights into the influences of daily life onto the diurnal changes of alpha amylase, the study was designed as an ecological momentary assessment study with 90 healthy participants (50% female). Consequently, the design of the AAR study functions as basis for the present study. This framework places external constraints on the possible methods and procedures. Independently of this work, seven other master's students have been involved in the project: Anne Baumgartner, Anton von Hinüber, Rebekka Sattelberger, Marie Charlotte Preußer, Janina Marleen Gresser, Alexander Lifu Winkler und Leonie Hofinger.

Procedure

Participants for the AAR study were recruited via the platform Vienna Cognitive Science Hub. This is a platform for students who are interested in participating in psychological studies. In addition, flyers about the study were distributed in local supermarkets, at the university and in fitness centers. The sample consisted of healthy, low-risk drinkers. Eligibility of the participants was examined in standardized screening phone calls. Female participants were eligible for the study, if they were healthy (no chronic or acute somatic or psychological disorder), had a regular menstrual cycle (between 25 and 35 days), were not pregnant or breastfeeding and did not use any hormonal contraception. Participants had to be between 18 and 35 years old, needed a working knowledge of German, and a BMI between 18 and 25. Only persons who did not drink more than five small glasses of alcohol per week were included. People who smoked more than 5 cigarettes per week or who smoked cannabis in the last 14 days were excluded. Persons who consumed any hard drugs in the past were excluded.

After the screening phone calls, participants were invited to the laboratory for their first appointment. During that appointment, the study was explained, and participants gave their informed consent. Men started the study on a chosen day, women began the study on day two of their next menstrual cycle. Every morning, participants collected three saliva samples immediately after awakening and 15 and 30 minutes later. Subsequently, participants filled out a morning questionnaire on the phone via the app "movisensXS" (version 1.5.23). The questionnaire included items about sleep duration for example. In the evenings, participants were prompted to fill out a second questionnaire on movisens right before bedtime. Among other things, participants were asked about their perceived stress

and their mood. Women completed participation on day three of their next menstrual cycle, while men finished after a full month. In the last step, participants came to the laboratory for a second appointment, during which the materials were given back to the study employees and the participants were thanked for their participation. During the laboratory appointments at the beginning and the end of the study, questionnaires were completed by the participants. As compensation, participants received 100 euros for their study participation.

Sample

Between the 30th of September 2022 and the 30th of April 2024, 120 people were screened for eligibility. Participants were excluded for multiple reasons like various health conditions. 36 healthy women were included in the study. Of these, four women had to be excluded from analyses because they drank no alcohol. Two persons were excluded from analyses because of technical problems with the app movisens and a lack of compliance. The final sample consisted of 30 women that were on average 23.43 years old (SD=2.4). In total, 23 complete cycles were captured.

Coding of the menstrual cycle

The menstrual cycle was coded according to the recommendations by Schmalenberger et al. (2021). The dates of the onset of menstruation were obtained from participant's self-reports and were coded as day one. All available study days were coded both with the forward- and backward-counting method. Day +4 to +7 of forward-counting were assigned to the mid-follicular phase. Based on the backward-counting method, day -15 to -12 were assigned to the periovulatory phase. Days -9 to -5 were coded as mid-luteal. Finally, the perimenstrual phase was determined by a combination of backward and forward counting (day -3 until day +2).

Measures

Alcohol consumption

Every morning, participants indicated the amount of alcohol consumed during the previous day. The following item was used to assess the amount of alcohol consumption: "Haben Sie gestern Abend oder Nacht alkoholische Getränke zu sich genommen?"[3] Participants could choose between the options "Nein", "Ja, ein bis zwei kleine Getränke (≙0,33l Bier oder 1/8 Wein)", "Ja, 3 bis 5 kleine Getränke" or "Weiß nicht". A dummy variable

[3] English translation: "Did you drink any alcoholic beverages last evening or last night?" Options for responding: "No", "Yes, 1-2 small drinks (≙0,33l beer or 1/8 wine)", "Yes, 3-5 small drinks" or "Don't know"

for alcohol consumption was created. The dummy variable differentiated whether there was any alcohol consumption (=value 1) on a given day or not (=value 0).

Mood

During the ecological momentary assessment period, participants responded to the Positive and Negative Affect Scale every evening. They rated their mood on a 5-point-Likert-scale ranging from “1 = not at all” to “5=extremely”. 10 Items had to be rated, five items indicating positive mood (e.g. “inspired”), and five items indicating negative mood (e.g. “nervous”). The five items indicating positive mood were combined into a continuous variable representing positive mood. The five items indicating negative mood were combined into an independent continuous variable negative mood. The Positive and Negative Affect Scale is a widely used questionnaire in psychological research with good internal consistency and validity (MacKinnon et al., 1999). In the present study, the scale positive mood had an acceptable internal consistency of $\alpha = .78$. The scale negative mood had a good internal consistency of $\alpha = .81$.

Trait Anxiety

Trait anxiety was measured once at the beginning of the study with the widely used trait anxiety scale of the Trait-State-Anxiety Inventory in its German version (Laux et al., 1981). It consists of 20 items reflecting general tendencies like “Ich glaube, dass meine Schwierigkeiten mir über den Kopf wachsen.“[4] All items were rated on a 4-point-Likert-scale ranging from “1=almost never” to “4=almost always”. Higher scores referred to higher trait anxiety. The questionnaire has demonstrated good psychometric properties (Spielberger et al., 1971) and showed an excellent internal consistency in the present study with $\alpha = .93$.

PMS

Perimenstrual symptoms were examined with a German PMS questionnaire that measures symptoms based on the premenstrual dysphoric disorder of the DSM-IV-TR (Ditzen et al., 2011). The questionnaire has 27 items with 13 scales measuring depressive symptoms, anxiety, labile mood, anger, decreased interest in activities, problems with concentration, fatigue, abnormal eating behavior, perception of lack of control, sleep behavior, sensitivity of breasts, pain, and the perception of weight. Three additional items measure the extent of impairment that are caused by those symptoms at work, in social activities and in relationships. Those three items were combined into an overall score of “PMS distress” that was used as an approximation of whether women were sensitive to

[4] English translation: “I believe that my difficulties are getting out of hand.”

hormonal changes. All items were rated on a 4-point-Likert scale ranging from “1=does not apply” to “4=strongly applies”. An overall score for PMS symptoms was calculated by averaging the single items, with higher values reflecting a higher symptom load. The questionnaire has demonstrated generally good psychometric properties (Ditzen et al., 2011), which was also reflected by excellent internal consistency in the present study $\alpha = 0.93$.

Stress

Daily stress was included in the analysis as a covariate to control for its potential influence onto mood (Romans, Kreindler, et al., 2012). Previous research has shown that the usage of a shortened version of the Perceived Stress Scale (PSS) for daily assessment in ecological momentary assessment studies is reliable and valid (Murray et al., 2023). Hence, four items were taken from the Perceived Stress Scale (PSS-10) for daily assessment. Whereas the original version of the PSS refers to stress experienced in the last month, the items were rephrased to refer to stress on the same day. One item stated for example: “Wie oft hatten Sie heute das Gefühl, wichtige Dinge in Ihrem Leben nicht beeinflussen zu können?”[5] Two of the four items were positively worded and consequently reverse-coded to create an overall daily stress score. Items were rated on a five-point-Likert scale ranging from “1=never” to “5=very often”. The PSS-10 was validated in its German version (Klein et al., 2016) and showed good psychometric properties. In the current study, the scale reached an acceptable internal consistency with $\alpha = 0.76$.

Statistical Plan

Analyses were conducted in the program R (version 4.4.0). At first, the data was preprocessed. If evening questionnaires were completed during the following morning, they were excluded from analysis. The trait variables PMS symptoms, PMS distress, and trait anxiety were grand-mean-centered. The daily measures positive mood, negative mood, and perceived stress were person-mean-centered. In total, there were two missing values in the STAI-questionnaire across the entire sample. To create a trait anxiety value for these two persons, the missing values were imputed with the individual mean scores of the other trait anxiety items. Due to the nested structure of the data, multilevel modelling methods were used to test the hypotheses. Different days of study participation were entered on level one of the models, participants on level two. A series of different models was calculated. The first hypothesis stated that negative mood would increase in the perimenstrual phase. The outcome variable negative mood was continuous. So, linear mixed effect models were calculated with the restricted maximum likelihood method for parameter estimation. Four

[5] English Translation: “How often have you felt that you were unable to control the important things in your life today?”

dummy variables for each cycle phase were created. The dummy variable “perimenstrual phase” had the value “1”, if a study day fell into the perimenstrual phase of the menstrual cycle, and the value “0” for all other days. Thus, it was possible to test if negative mood changed significantly during the perimenstrual phase in comparison to all the other cycle phases. However, only days that fell into any cycle phase were included in the analysis, excluding the transition days. A series of nested models were calculated, and model fit indices compared. After calculating an intercept-only model to estimate the intraclass correlation coefficient (ICC), the perimenstrual phase was inserted as a main predictor variable into the first model. Then, the covariates PMS distress and perceived stress were included. Model three comprised an interaction term for mood and PMS distress. Finally, random slopes were examined. To compare the model fit, the Akaike information criterion (AIC) and Bayesian information criterion (BIC) were compared.

In the second hypothesis, alcohol consumption was the main outcome. The hypothesis stated that alcohol consumption would vary as a function of mood across different cycle phases. Specifically, it was expected that negative mood and the perimenstrual cycle phase, and positive mood and the periovulatory phase would predict increased alcohol consumption. Alcohol consumption was coded as a dummy variable indicating whether the participant consumed alcohol on a given day (=value 1) or not (=value 0). Thus, logistic multilevel models with a binomial distribution and logit-link function were used to assess the hypothesis. The dummy variables “perimenstrual phase” and “periovulatory phase” were the main predictors. Two series of models were calculated for each cycle phase. After inserting perimenstrual phase into the first model, negative mood was entered as the second predictor. In a third step, the interaction between the cycle phase and mood was added to the model, as well as the covariate PMS distress in the fourth model. The final model contained an additional random slope for cycle phase. A similar sequence of models was conducted to test whether there was increased alcohol consumption during the periovulatory phase. Here, the dummy variable for the periovulatory phase was used as main predictor variable, and positive mood as the second predictor variable.

For hypothesis three, a last series of models was calculated. The aim was to investigate the potential moderating influence of trait anxiety onto cyclicity of alcohol consumption. Again, the outcome was the binary variable alcohol consumption. Logistic multilevel models were used just like described above. First, the three variables perimenstrual phase, negative mood and trait anxiety were entered into the equation. Model fit was compared with the intercept-only model. In a second model, a three-way-interaction between these variables was included.

Results

Overall, 175 occasions of alcohol usage were captured. Of these,15.43% occurred in the mid-follicular phase, 12% in the periovulatory phase, 18.86% in the mid-luteal phase and 14.29% in the perimenstrual phase. The frequency of alcohol consumption per person ranged from 1-13 times after excluding the participants who did not drink at all. On average, every participant drank 5.83 times. The means of positive mood, negative mood, and perceived stress per cycle phase can be seen in Table 1. Descriptives of the trait variables can be seen in table 2.

Table 1

Average Positive Mood, Negative Mood and Stress by Cycle Phase

	Negative Mood	Positive Mood	Perceived Stress
Mid-follicular	1.43 (.47)	3.19 (.69)	2.12 (.59)
Periovulatory	1.45 (.64)	3.21 (.7)	2.22 (.8)
Mid-luteal	1.34 (.53)	3.26 (.77)	2.16 (.85)
Perimenstrual	1.47 (.58)	3.11 (.81)	2.24 (.81)
Overall[a]	1.47 (.59)	3.21 (.74)	2.26 (.78)

Note. Means of negative mood, positive mood, and perceived stress across the cycle phases (mid-follicular phase, periovulatory phase, mid-luteal phase and perimenstrual phase). Standard deviations are shown in the brackets.

[a] The overall averages were calculated including all study days. Some of these study days did not belong to any cycle phase but were transitional. This is why the overall average does not equal the average of the cycle phases.

Table 2

Descriptive Statistics of Trait Variables

Questionnaire	Mean (SD)	Minimum	Maximum	Scale
PMS Symptoms	2.26 (0.6)	1.07	3.22	1-4
PMS Distress	2.36 (0.87)	1	3.67	1-4
STAI	1.97 (0.53)	1.1	3.05	1-4

Note. Means, Standard Deviations in brackets, Minima, Maxima and original scales of PMS Symptoms, PMS Distress and Trait Anxiety, as measured in the State Trait Anxiety Inventory (STAI).

Correlations

A mean value of negative mood, positive mood, and perceived stress across all study days was created for each participant. Correlations between these values, the overall frequency of alcohol consumption, and the trait variables PMS symptoms, PMS distress and trait anxiety were computed. The Shapiro-Wilk test was used to examine if the variables in question followed a normal distribution. Because alcohol consumption, negative mood and perimenstrual distress were not normally distributed, bivariate Spearman correlations were calculated for all variables (see table 3). In addition, scatter plots were generated to determine if the association between the variables were linear. Upon examining the scatter plots, the frequency of alcohol consumption and trait anxiety showed a rather u-shaped relationship (see Figure 1).

Table 3

Spearman Correlations of Alcohol Consumption, Mood and Trait Variables

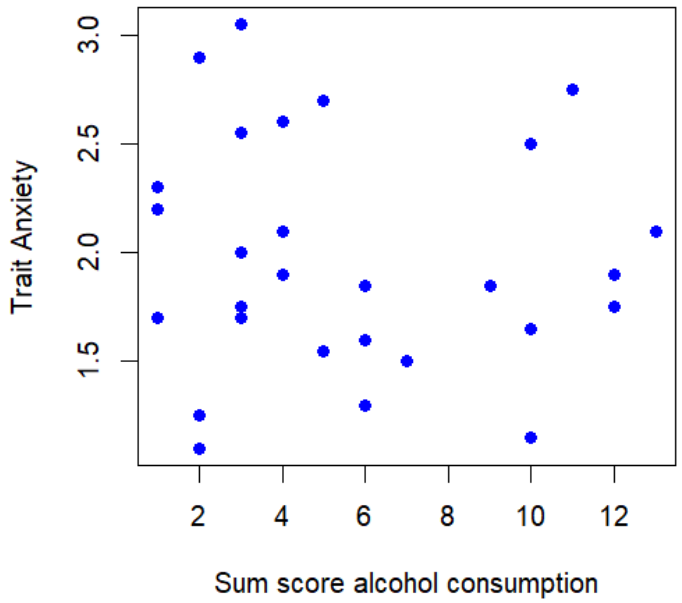
	Alcohol	STAI	Pos. mood	Neg. mood	PMS	PMS Distress	PSS
Alcohol	1	-.08	.12	.49**	.23	.15	-.11
STAI		1	-.67***	.48**	.35	.39*	.65***
Pos. mood			1	-.29	-.28	-.23	-.63***
Neg. mood				1	.51*	.62**	.6**
PMS					1	.7***	.43*
PMS Distress						1	.43*
PSS							1

Note. Alcohol refers to the total amount of times participants consumed alcohol during their study participation. STAI refers to trait anxiety, as measured with the State Trait Anxiety Inventory. Pos. mood refers to the average positive mood across all study days per person. Neg. mood refers to the average negative mood across all study days per person. PMS refers to the mean of reported perimenstrual symptoms in the PMS questionnaire, while PMS Distress refers to the degree of impairment associated with those symptoms. PSS refers to the average perceived stress across all study days per person. All these values refer to between-person differences.

*p<.05. **p<.01. ***p<.001.

Figure 1

Relationship between Alcohol Consumption and Trait Anxiety



Note. Scatterplot of Trait Anxiety Values and Alcohol Consumption. The sum score of alcohol consumption refers to the number of times that participants drank alcohol during the study participation.

Hypothesis 1: Fluctuations of Mood over the Menstrual Cycle

It was hypothesized, that negative mood increases during the perimenstrual phase. To examine this hypothesis, linear-mixed effect models were calculated with the continuous variable negative mood as outcome. The model fit indices AIC and BIC were compared with the Chi-square test of deviance. At first, an intercept-only model was computed. Accordingly, the intercept only-model yielded an intraclass correlation (ICC) of ρ=(0.09/0.22+0.09)=0.29. Therefore, about one third of the variance in negative mood is explained by between-person differences. The second model, which included the two covariates perceived stress and PMS distress, was deemed best fitting according to the model fit indices and Chi-square test of deviance. Contrary to what was expected, the fixed effect of the perimenstrual cycle phase was not significant b=0 (SE=.05, 95 CI [-.09, .08]), t(423.79)=-.01, p=.99. Meanwhile, the two covariates predicted negative mood significantly: The fixed effect of perceived stress was b=.42 (SE=.04, 95 CI [.35, .5]), t(427.70)=11.1, p=.00. The fixed effect of PMS distress was b=.22 (SE=.06, 95CI [.09, .35]), t(25.11)=3.63, p=.00. After including the covariates in the

second model, the amount of explained variance increased markedly from zero to $R^2 = .26$. On the other hand, the first model which included only the non-significant predictor "perimenstrual phase" (see table 4), did not explain any of the variance. These results suggest that inclusion of the cycle phase did not significantly improve model fit compared to the intercept-only model. Perceived stress and perimenstrual distress on the other hand significantly improved the prediction of negative mood. Table 5 contains further information on the model fit indices of the models.

To explore whether there were any fluctuations mood over the menstrual cycle, the other cycle phases were included as predictor variables, and positive mood as outcome variable. No significant fluctuations of mood emerged.

Table 4

Regression Coefficients Predicting Negative Mood in a Series of Multilevel Models

	Model 0	Model 1	Model 2	Model 3	Model 4
Intercept	1.43 (.06)**	1.43 (.06)**	1.46(.05)**	1.46 (.05)**	1.46 (.05)**
PMP		.03 (0.05)	-.00(.05)	-.00 (.05)	.01 (.05)
PSS			0.42(.04)**	0.42 (.04)**	.42 (.04)**
PMS Distress			.22(.06)**	.23 (.06) **	.23 (.06)**
Interaction				-.04 (.05)	-.04 (.06)

Note This table shows the regression coefficients of the variables perimenstrual phase (PMP), perceived stress (PSS), PMS Distress and the interaction term for Perimenstrual Phase and PMS Distress predicting negative mood.

*p<.05. **p<.01. ***p<.001.

Table 5

Model Characteristics in a Series of Multilevel Models Predicting Negative Mood

	Modell 0	Model 1	Model 2	Model 3	Model 4
Nr. of observations	454	454	454	454	454
AIC	665.45	667.07	551.84	553.17	553.05
BIC	677.81	683.54	576.55	581.99	590.11
R^2	0	0	.26	.26	.25
χ^2		.38	119.22***	.68	4.12

Note Number of observations (in negative mood, perimenstrual phase and covariates), model fit indices AIC and BIC, amount of explained variance (R^2) and values of the Chi-Square test (χ^2) in a series of models predicting negative mood
*p<.05. **p<.01. ***p<.001.

Hypothesis 2: Cyclicity of Alcohol Consumption

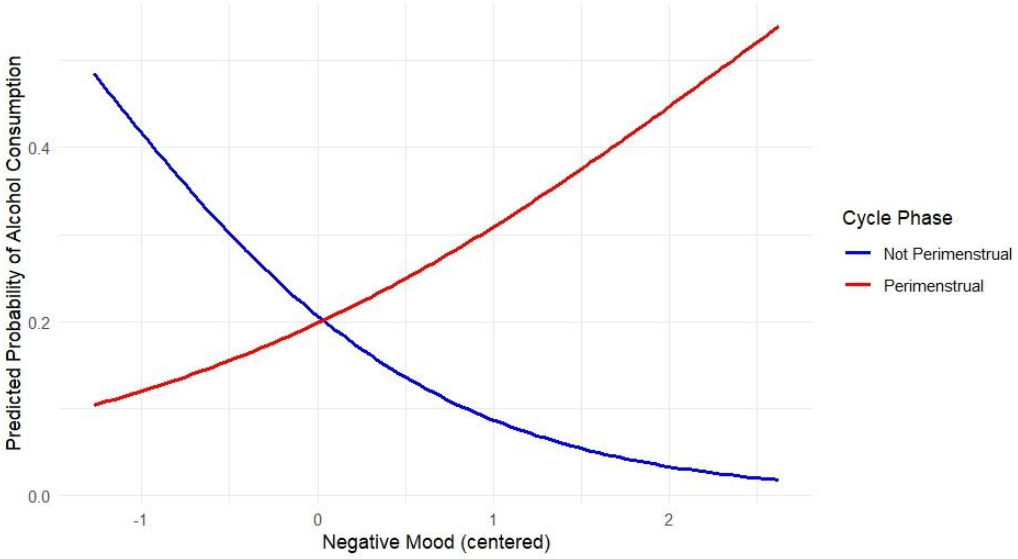
The second hypothesis stated that alcohol consumption would vary as a function of mood over the menstrual cycle. It was expected that positive mood during the periovulatory phase, and negative mood during the perimenstrual phase would predict increased alcohol consumption. The ICC for the binary outcome “alcohol consumption” was calculated following the recommendations by Sommet and Morselli (2017). The intercept only model yielded an ICC of .13, meaning that 13% of the drinking probability are explained by the differences between the individuals. Meanwhile, 87% of the probability of drinking alcohol on a given day is explained by the within-changes in persons. To determine if the ICC was big enough to justify multilevel logistic modelling, the design effect was calculated with deff=1+[(average cluster size)-1]*ICC, which resulted in deff=1+[(31.73)-1]*0.13=4.99. As values above two are deemed high enough to justify multilevel modelling (Sommet & Morselli, 2017), multilevel logistic modelling was considered appropriate for the data.

A series of six models was calculated to address the hypothesis. After entering the perimenstrual phase and negative mood as predictor variables in model one and two, an interaction term was included in the third model. Model four comprised the covariate PMS distress, and model five an additional random slope for the cycle phase. According to the

model fit indices AIC, BIC, and the Chi-square test of deviance, the third model showed the best fit to the data. The calculation of the third model yielded an insignificant fixed effect for the perimenstrual phase b=-.05 (SE=.31 95CI [-.74, .52]) z=-.17, p=.86. The fixed effect for negative mood on the other hand was significant b=-1.01 (SE=.38 95 CI [-1.92, -.28]), z=-2.62, p=0.01. The coefficient was converted into an odds ratio (following the recommendations by Sommet & Morselli, 2017), resulting in an odds ratio of 1/2.75. That means, that the probability of not drinking alcohol is 2.75 times as high as the probability of drinking alcohol when experiencing a change in negative mood by one unit. The fixed effect for the interaction of negative mood and perimenstrual phase was significant b=1.6(SE=.65 95CI [.23, 3.02]) z=2.47 p=0.01. A visualization of the interaction effect can be seen in figure two. The results suggest that the perimenstrual phase alone did not change the probability of consuming alcohol. Negative mood on the other hand significantly decreased the probability of alcohol consumption. However, negative mood during the perimenstrual phase increased the probability of alcohol consumption. Detailed information about the regression coefficients and model fit indices of the other models can be found in table six and seven.

Figure 2

Interaction of Perimenstrual Phase and Negative Mood on Alcohol Consumption



Note. Interaction effect of the perimenstrual phase and negative mood (which was person-centered) on the probability of alcohol consumption. One standard deviation increase of negative mood outside the perimenstrual phase is associated with lowered probability of drinking alcohol. During the perimenstrual phase, increases of negative mood are associated with increased drinking probabilities.

Table 6

Regression Coefficients in a Series of Logistic Multilevel Models Predicting Alcohol Consumption

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	-1.29 (.18)**	-1.26 (.19)**	-1.29 (.19)**	-1.34 (.19)**	-1.33 (.18)**	-1.34 (.19)**
PMP		-.1 (.3)	-.1 (.3)	-.05 (.31)	-0.07 (.31)	-.05 (0.34)
Negative mood			-.5 (.29)	-1.01(.38)**	-0.96 (.37)*	-.97 (.38)*
Interaction				1.6 (.65)*	1.55 (.64)*	1.57 (.64)*
PMS Distress					.34 (.2)	.35 (.21)

Note Logistic regression coefficients of perimenstrual phase (PMP), negative mood, interaction term between perimenstrual phase and negative mood and PMS distress predicting alcohol consumption.
*p<.05. **p<.01. ***p<.001.

Table 7

Model Characteristics in a Series of Multilevel Models Predicting Alcohol Consumption

	Modell 0	Model 1	Model 2	Model 3	Model 4	Model 5
Nr. of observations	388	388	388	388	388	388
AIC	498.3	413.9	412.8	408.7	407.7	411.7
BIC	506.6	425.8	428.7	428.5	431.5	443.4
R^2	0	0	.04	0.11	0.17	0.16
χ^2		.18	3.09	6.19*	2.93	.02

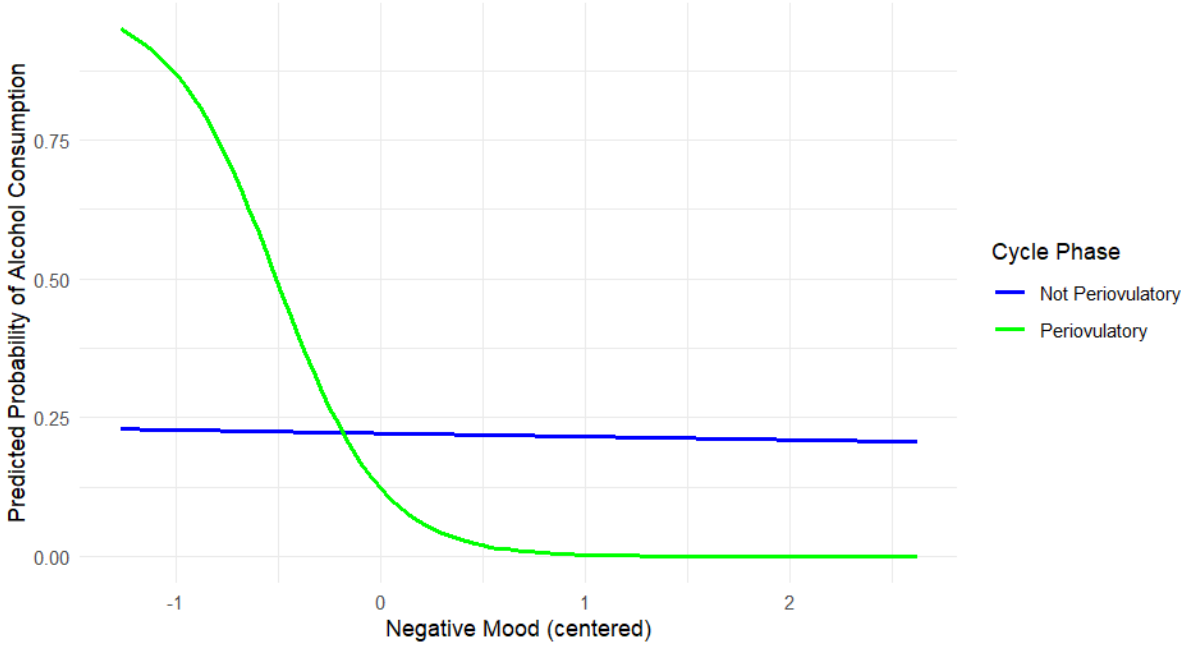
Note Number of observations (in alcohol consumption, negative mood, perimenstrual phase and covariates), model fit indices AIC and BIC, amount of explained variance (R^2) and

values of the Chi-Square test (χ^2) in a series of models predicting negative mood
*p<.05. **p<.01. ***p<.001.

Regarding the hypothesized interaction of periovulatory phase and positive mood, no significant effects emerged. Neither the periovulatory phase, nor positive mood yielded any significant influence onto alcohol consumption. According to the Chi-square test of deviance, no model had a significantly better model fit than the intercept-only model. Nonetheless, an exploratory analysis of the interaction of the periovulatory phase and negative mood resulted in findings that support the hypothesis. While the fixed effects for periovulatory phase and negative mood were both insignificant, a significant interaction of the periovulatory phase and negative mood existed b=-3.86 (SE=1.26, 95CI [-7.49, -1.84]) z=-3.04, p=.00. The interaction effect can be seen in Figure 3.

Figure 3

Interaction of Periovulatory Phase and Negative Mood on Alcohol Consumption



Note. One standard deviation decreases of negative mood (which was person-centered) during the periovulatory phase is associated with a dramatic increase of the probability of drinking alcohol. Increasing negative mood on the other hand is associated with lowered probability of drinking alcohol during the periovulatory phase. The main effect of negative mood was not significant in this model.

Finally, it was explored whether the frequency of consuming alcohol significantly varied between the cycle phases. From the analyses described above, it was already clear that neither the perimenstrual, nor the periovulatory phase predicted increased alcohol consumption. The other two dummy variables for the mid-luteal and the mid-follicular phase were separately added as predictor variables for alcohol consumption. No significant results emerged. Thus, no overall fluctuations of alcohol consumption across the cycle phases were found.

Hypothesis 3: Trait Anxiety

The inclusion of trait anxiety into the models did not yield any significant effects b=-.05 (SE=.35, 95 CI [-.71, .69]) z=-.13, p=.89. Model fit indices did not significantly decrease after including trait anxiety, or the three-way interaction, indicating that trait anxiety did not influence alcohol consumption.

Discussion

The present study investigated the associations between alcohol consumption, the menstrual cycle, and daily mood in healthy women. It was hypothesized that negative mood and alcohol consumption would fluctuate over the course of the menstrual cycle. Specifically, it was expected that during the perimenstrual phase, negative mood, and during the periovulatory phase, positive mood would predict increased alcohol consumption.

Consistent with expectations, a significant interaction of negative mood and the perimenstrual phase emerged. Negative mood during the perimenstrual phase predicted increasing chances of alcohol consumption. In contrast, the main effect of negative mood on alcohol consumption was inhibitory. Hence, negative mood generally predicted lower chances of alcohol consumption in healthy women. This finding contradicts other prospective studies, which found that negative mood predicted increased alcohol consumption (Monk et al., 2020; Swendsen et al., 2000). However, the study by Monk et al. (2020) was conducted exclusively on male college students. Another study (Swendsen et al., 2000) found a reinforcing effect of negative mood on alcohol consumption, which was more pronounced in men than in women. These results suggest that gender differences exist in the relationship between mood and alcohol consumption. Furthermore, the relationship between mood and alcohol consumption might be influenced by the menstrual cycle phase of women. While

negative mood might have a generally inhibitory effect on alcohol consumption in women, it could reinforce motivations to drink alcohol during the perimenstrual phase. Some of the studies that investigated cyclicity of alcohol consumption failed to find any associations between mood, cycle phase and alcohol consumption (Hoffmann et al., 2024; Martel et al., 2017). In contrast, one study by Holzhauer et al. (2020) found that perimenstrual increases of alcohol consumption were associated with negative mood, and periovulatory increases of alcohol consumption were associated with positive mood. These findings are partially consistent with the results of this work. Regarding the expected periovulatory peak of alcohol consumption paired with positive mood, no significant interaction emerged. However, there was a significant interaction between the periovulatory phase and negative mood, suggesting that increased negative mood during the periovulatory phase predicted decreased alcohol consumption. Thus, the results by Holzhauer et al. (2020) were successfully partially replicated within this paper. While there was a lack of findings concerning positive mood and alcohol consumption, the significant interaction term between negative mood and the periovulatory phase still suggests that alcohol consumption during the periovulatory phase might be more probable if negative mood is less pronounced.

Cyclicity of Alcohol Consumption

One aim of this project was to study the existence of cycle-dependent fluctuations of alcohol consumption. Prior studies suggested that alcohol consumption peaks during the perimenstrual phase and the periovulatory phase (Barone et al., 2023; Epstein et al., 2006; Hayaki et al., 2020; Hoffmann et al., 2024; Holzhauer et al., 2020; Martel et al., 2017). In the present work, no cycle phase was significantly associated with alcohol consumption. Neither the perimenstrual phase, nor the periovulatory phase alone were predictors for alcohol consumption. According to the descriptive statistics, alcohol was most frequently consumed during the mid-luteal phase, followed by the mid-follicular phase and perimenstrual phase. The differences between the number of times participants consumed alcohol during the different phases of the menstrual cycle were small. However, it can be concluded that the results do not demonstrate overall cyclicity of alcohol consumption. That raises the question whether this lack of findings is caused by the study characteristics or by the non-existence of the proposed effect. Several studies have provided evidence for the existence of cyclicity of alcohol consumption in different samples (Barone et al., 2023; Epstein et al., 2006; Hayaki et al., 2020; Hoffmann et al., 2024; Holzhauer et al., 2020; Martel et al., 2017). Because the effect sizes are generally small, the present study probably did not have sufficient power to detect cyclicity. Furthermore, methodological limitations like the lack of LH-tests to determine ovulation (Schmalenberger et al., 2021) were present. The operationalization of alcohol consumption can also be considered a major methodological limitation. As the outcome was

binary, no valid information about the amount of alcohol consumption was available. Meanwhile, a lot of the studies that find cyclicity in alcohol consumption use binge drinking, or the amount of alcohol consumption, as an outcome (Barone et al., 2023; Hayaki et al., 2020; Hoffmann et al., 2024; Martel et al., 2017). In contrast, the study by Holzhauer et al. (2020) measured the frequency of alcohol consumption by also including the intentions to consume alcohol on a given day. That means, the outcome variable had the following categories: Person “Did not drink, would not have drunken”, “did not drink, but would have drunken” and “did drink”. This consideration of intentions is beneficial, because sometimes alcohol might not be consumed due to external restrictions, even if the motivation of drinking is a given. That means, the consideration of contextual variables might be important. Contextual variables like availability of alcohol, social setting, or weekdays might exert a strong influence on alcohol consumption. For example, the probability of alcohol consumption increased in a study, if more than two close friends were present (Monk et al., 2020). Weekdays have also been shown to influence alcohol consumption, with stronger consumption during weekends (Martel et al., 2017). These contextual influences might obscure potential cyclicity in alcohol consumption. In the present work, no contextual variables were included in the analyses. Given the small effect sizes of cyclicity, the lack of control of context may have made it even harder to find any effects. In addition, some authors note that the consideration of interindividual differences is of importance (Svikis et al., 2006).

Trait Anxiety

One personality facet that was assumed to influence cyclicity in alcohol consumption, is trait anxiety. It was hypothesized, that trait anxiety raises the probability of cyclicity in alcohol consumption. The associated hypothesis is not supported by the present data: Trait anxiety was not correlated with alcohol consumption, nor did it predict alcohol consumption in any of the calculated multilevel models. In addition, the three-way interaction between trait anxiety, negative mood and the perimenstrual phase was not significant. This finding was unexpected, considering the various associations between anxiety and alcohol reported in existing literature. The scatterplot depicting alcohol consumption and trait anxiety suggests that there might be a u-shaped relationship between those two variables: High trait anxiety was associated with both low and high alcohol consumption. Low trait anxiety on the other hand seemed to be associated with moderate alcohol consumption. The potential u-shaped relationship between trait anxiety and alcohol consumption could explain the non-significant correlation and lack of findings. Potentially, there are other factors influencing the relationship. It is possible, that high trait anxiety could result in increased concernment for the own physical health, leading to a promotion of health behaviors. A meta-analysis has

suggested that one of the main motives for abstinence from alcohol is health-related (Rosansky & Rosenberg, 2020). In this case, high trait anxiety, paired with concern for physical health, could lead to low alcohol consumption. On the other hand, if paired with dysfunctional coping styles, high trait anxiety could also lead to increased coping motives with alcohol consumption, as suggested by Comeau et al. (2001). More research is needed to disentangle the effects of trait anxiety on alcohol consumption patterns.

Fluctuations of Mood

The final aim of the present study was to replicate the fluctuations of mood over the menstrual cycle. Based on findings about PMS and mood across different menstrual cycle phases, it was expected, that negative mood would increase during the perimenstrual phase. Contrary to expectations, no fluctuations of positive or negative mood were found in this study. Analyses revealed that mood did not alter significantly in the perimenstrual phase, nor did it significantly change in any other phase of the menstrual cycle. Consequently, the phases of the menstrual cycle did not predict mood. On the other hand, perceived stress was a significant predictor for negative mood. This finding is in line with previous research by Romans, Kreindler, et al. (2012), who found in their prospective study that stress, physical health, and social support were more influential on daily mood than the menstrual cycle was. In their study, only two mood items (irritability and sadness) showed significant cycle-dependent changes. In a systematic review on fluctuations of mood, more than 35% of the reviewed studies did not find any associations with mood (Romans, Clarkson, et al., 2012). There are two explanations for the lack of significant results. The first explanation is that there exist no fluctuations of mood across the menstrual cycle phases. Due to the interindividual differences in women's sensitivity to the hormonal changes of the menstrual cycle (Schmalenberger et al., 2021), this might be true for some. The sample investigated in this study could be on average less sensitive to hormonal fluctuations. However, studies with large numbers of participants suggested that fluctuations in mood exist (Meaden et al., 2005; Pierson et al., 2021). The second explanation for the lack of findings is that the applied instruments were not sensitive enough to detect any changes in women, who might be sensitive to hormonal changes. Schmalenberger et al. (2021) recommended identifying these women by prospective observation of perimenstrual symptoms. Alternatively, the authors suggested choosing large sample sizes to be able to detect any effects. The current study was conducted on 30 women. This sample might not have been large enough to detect any effects. It was attempted to control for interindividual sensitivity to hormonal changes with the variable "PMS distress" of the PMS questionnaire (Ditzen et al., 2011). It was found that PMS distress was a significant predictor of negative mood generally, but not specifically during the perimenstrual phase of the menstrual cycle (which was shown by the lack of a significant

interaction term of PMS distress and perimenstrual phase). The results indicate that women with higher perimenstrual stress did not experience worsened mood in the perimenstrual phase. This contradiction could exist due to methodological issues related to the measurement of PMS distress. As a consequence, PMS distress was only measured once at the appointment preceding the ecological momentary assessment phase of the study. However, self-reports of perimenstrual symptoms tend to be affected by recall bias and general perceptions about PMS (Marván & Cortés-Iniestra, 2001). All in all, adding the variable PMS distress as a covariate in the analyses is not a valid alternative to prospective identification of women, who are sensitive to hormonal changes (Schmalenberger et al., 2021).

Limitations

As the design of the present study was initially constructed for researching alpha amylase and not alcohol consumption, there were some methodological limitations that restricted the validity of the present project. First and foremost, participants were not able to report on the real amount of alcohol they consumed on a given day. The item that captured alcohol consumption differentiated only between zero to five small glasses. Therefore, the quantity of alcohol consumption could not be considered in the analysis of the present work.

Another methodological issue was the timing of the questionnaires capturing mood. Participants were instructed to complete the questionnaires in the evenings, with no external restrictions on timing. In consequence, participants completed the evening questionnaires at variable times ranging from the afternoon until 5 am in the morning. Consequently, the effects of mood and alcohol consumption were severely blurred. There was no control if participants reported their mood before, during or after consuming alcohol. The lack of information about the timing of the mood questionnaires leads to a potential alternative explanation of the main finding. As stated above, this study observed that negative mood during the perimenstrual phase would predict increased alcohol consumption. However, an alternate explanation is that alcohol consumption during the perimenstrual phase predicts increased negative mood. The study by Monk et al. (2020) showed that alcohol consumption changed prior affect. Because it is impossible to deduce the order of events from the data, future research is necessary to rule out this possibility.

Finally, the study is limited by the fact that only one menstrual cycle per person was captured. Different menstrual cycles also vary between each other, with some menstrual cycles being more affected by perimenstrual symptoms, and others less (Potter et al., 2009). Studying more than one menstrual cycle per person would be beneficial. Additionally, LH-testing to determine if ovulation took place would be a valuable extension to the utilized study

design. Measurement of hormone concentrations would allow to investigate the relationship between alcohol consumption and the hormones.

Strengths

While these limitations lessen the validity of the results, this study also exhibits some pertinent methodological strengths. First, classification and coding of the menstrual cycle phases were done by following the recommendations by Schmalenberger et al. (2021). Past studies on the cyclicity of alcohol consumption were often using invalid classifications of the menstrual cycle phases (e.g. Tate & Charette, 1991). The existing heterogeneity of the conceptualization of the menstrual cycle led to confusion in the literature and to ambiguous results. In the future, the correct classification of the menstrual cycle is the foundation of studying cyclicity-related questions. Another strength of this project is the prospective ecological momentary assessment design, which has high value in observing daily behavior, which can be biased in retrospective reports. Finally, the application of multilevel modelling techniques to account for the nested structure of the data is another advantage.

Future Research

Future research is necessary to disentangle the different effects that the menstrual cycle has on the frequency and quantity of alcohol consumption. Future studies are recommended to consider interindividual differences (like hormone sensitivity in women), contextual variables (like weekdays), intentions to drink, (Holzhauer et al., 2020) and alcohol drinking motives (Cooper, 1994).

If cyclicity in alcohol consumption exists, the findings in the literature could be linked to preventive measures and treatment approaches in therapeutic settings. This would be especially beneficial for women with alcohol use disorder, who might experience increased cravings during the perimenstrual phase (Hayaki et al., 2020), and women prone to self-medication behavior. Psychoeducation about cyclicity and self-medication behaviors could be included into therapy, encouraging women to observe their cravings and coping motivations in a daily diary. If cyclicity in craving, coping motives and alcohol consumption are present, emphasis could be placed on reinforcing alternative coping strategies.

Conclusion

In conclusion, the present work did not find evidence for cyclicity of alcohol consumption in young, healthy low-risk drinkers. This lack of findings could be due to methodological limitations and lack of power. However, the results suggest the existence of an interaction of the menstrual cycle and negative mood. Negative mood generally inhibited alcohol consumption, especially during the periovulatory phase. On the other hand, negative

mood during the perimenstrual phase predicted increased alcohol consumption. These results indicate that the relationship between mood and alcohol consumption depends on the menstrual cycle phase.

Future research is needed to understand if cyclicity in alcohol consumption exists. If it does, the potential mechanisms behind cyclicity and moderating variables remain to be unveiled. The present study proposes that trait anxiety does not function as a moderator variable on cyclicity in alcohol consumption. As it seems to be associated with alcohol consumption in a non-linear relationship, future research could try to disentangle the complex effects of alcohol consumption, coping motives, and trait anxiety.

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Tables and Figures

Abbreviations

AIC = Akaike information criterion

BIC = Bayesian information criterion

CI = Confidence interval

ICC = Intraclass correlation coefficient

PMP = Perimenstrual phase

PMS = Premenstrual syndrome

PSS = Perceived Stress Scale

R^2 = Amount of explained variance

SE = Standard error

STAI = State Trait Anxiety Inventory

Appendix A:

German Abstract

Bisherige Forschung zu den Schwankungen von Alkoholkonsum über den Menstruationszyklus hinweg lieferte keine eindeutigen Ergebnisse. Einige Studien berichteten von verstärktem Konsum um die Menstruation herum (perimenstruelle Phase), andere von verstärktem Konsum rund um den Eisprung (Ovulationsphase). In der vorliegenden Arbeit wurde davon ausgegangen, dass verstärkter Alkoholkonsum in der perimenstruellen Phase von schlechter Stimmung vorhergesagt wird, und verstärkter Konsum in der Ovulationsphase von guter Stimmung. Zudem wurde vermutet, dass Personen mit einer ängstlichen Persönlichkeitsstruktur (Trait Anxiety) stärker zu diesen zyklischen Verhaltensmustern neigen. Die prospektive Studie wurde an 30 gesunden Frauen durchgeführt, die täglich Stimmung, Alkoholkonsum und Stress berichteten. In einem Labortermin wurden zusätzlich Trait Anxiety und PMS-Symptome erfasst. Multilevelmodelle wurden berechnet, um die Hypothesen zu testen. Dabei ergab sich, dass die Menge an Alkoholkonsum nicht signifikant über den Menstruationszyklus hinweg fluktuierte. Allerdings wurde eine signifikante Interaktion von Stimmung und der perimenstruellen Phase gefunden. Allgemein führte verstärkte schlechte Stimmung zu einer niedrigeren Wahrscheinlichkeit von Alkoholkonsum. In der perimenstruellen Phase ging stärkere schlechte Stimmung jedoch mit einer höheren Wahrscheinlichkeit für Alkoholkonsum einher. Trait Anxiety war kein signifikanter Moderator für die Fluktuationen von Alkoholkonsum und korrelierte nicht mit Alkoholkonsum. Die Befunde unterstreichen, dass der Zusammenhang zwischen schlechter Stimmung und Alkoholkonsum über die Phasen des Menstruationszyklus hinweg fluktuiert.

Appendix B:

Additional Results

Results for hypothesis 2: Drinking behavior during the periovulatory phase

Table B.1

Regression Coefficients Predicting Alcohol Consumption in a Series of Multilevel Models

	Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	-1.29 (.18)**	-1.27 (.19)**	-1.28(.19)**	-1.28(.19)**	-1.27(.18)**	-1.26(.17)**
POP		-.09 (.3)	-.1(.3)	-.09 (.3)	-.09 (.3)	-.2 (.37)
Positive mood			.2(.2)	.21 (.23)	-.21 (.23)	.22 (.23)
Interaction			.12(.1)	-.05 (.5)	-.07(.5)	-.07(.53)
PMS Distress				.	0.37(.2)	0.39(.2)

Note This table shows the regression coefficients of the variables periovulatory phase (POP), positive mood, interaction of periovulatory phase and positive mood, and PMS distress predicting alcohol consumption
*p<.05. **p<.01. ***p<.001.

Table B.2

Model Characteristics in a Series of Multilevel Models Predicting Alcohol Consumption

	Modell 0	Model 1	Model 2	Model 3	Model 4	Model 5
Nr. of observations	388	388	388	388	388	388
AIC	412.1	414.05	415.1	417	415.8	419.3
BIC	420	425.93	430.9	436.9	439.6	451
R^2	0	0	.01	.01	.08	.09
χ^2		.08, n.s.	.99, n.s.	.01, n.s.	3.26, n.s.	.51, n.s.

Note Number of observations, model fit indices AIC and BIC, amount of explained variance (R^2) and values of the Chi-Square test (χ^2) in a series of models predicting negative mood