Examining the Relation between Oral Contraceptive Use and Attention-Related Traits and States

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Statement of Contributions

Alyssa Smith was the primary author and was responsible for conceptualization, study design, data collection, and data analysis and interpretation (all chapters).

Jeremy Marty-Dugas contributed to the study design and data analysis (Chapters 2, 3, and 5).

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Brandon Ralph contributed to the coding of the cognitive task (Chapter 5).

Daniel Smilek guided the research process, including conceptualization, study design, data analysis and interpretation, and writing and editing of chapters (all chapters).

A version of Chapter 1 is part of the Introduction for the results presented in Chapter 3. A version of Chapter 2 is available in Smith, A. C., Marty-Dugas, J., & Smilek, D. (2023). Examining the relation between oral contraceptive use and attentional engagement in everyday life. *Frontiers in Human Neuroscience*, 17. https://doi.org/10.3389/fnhum.2023.1147515. A version of Chapter 3 is currently under review. We are currently attempting to replicate the findings in Chapter 4 prior to publication, following this, a version of this chapter will be submitted for publication. A version of Chapter 5 is currently under review. A version of Chapter 6 is available in Smith, A. C., & Smilek, D. (2024). On the relation between oral contraceptive use and self-control. *Frontiers in Endocrinology*, 15, 1335384. https://doi.org/10.3389/fendo.2024.1335384. Chapter 7 largely consists of original writing for the dissertation. Parts of it appear in the published version of Chapter 2.

Abstract

There is a rapidly growing body of work examining the association between the use of oral contraceptives (OCs) and cognition. This dissertation describes a series of studies examining the links between OC use and attention-related traits and states in large diverse samples (all OC Ns > 80). In Chapter 1, the literature on OC use and cognition—and in particular attention—are reviewed, highlighting the limitations of the extant work. Chapter 2 describes studies showing that OC users do not differ from non-OC users in terms of their self-reported traits tendencies to experience inattention (including spontaneous and deliberate mind wandering, attention related errors, and attention lapses). Chapter 3 discusses additional questionnaire-based studies showing that OC users tended to report less boredom proneness than non-users, but roughly equivalent levels of internal or external flow. In Chapter 4, the aforementioned attention-related (with the exception of boredom) were again examined as a function of OC use and OC formulation (in OC users), with results replicating outcomes of the prior studies and additionally showing that OC formulation is not associated with individual differences in attention-related traits. In Chapter 5 OC users and non-users completed a sustained attention task and reported their levels of mind wandering and media multitasking during the task; there were again no consistent differences between OC users and non-users on task performance, thought probe responses, or reports of media multitasking. Chapter 7 includes studies showing that OC users and non-users did not consistently differ on the self-overriding aspect of self-control or self-regulatory assessment, but that OC users consistently reported greater locomotion than non-users. Finally, in Chapter 7 includes a summary of the findings and discusses possible reasons for the inconsistent findings,

the challenges of studying OC use and cognition, limitations of the present studies, and future directions.

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Dedication

To my loved ones, my parents, my sister, and Jeremy – thank you for your support and your unwavering belief in me and what I'm capable of.

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List of Abbreviations

OCs	Oral contraceptives
SIPI	Shortened imaginal process inventory
BF	Bayes Factor
ARCES	Attention related and cognitive errors scale
MAASLO	Mindful attention awareness scale – lapses only scale
MW-S	Mind wandering spontaneous scale
MW-D	Mind wandering deliberate scale
DASS-Dep	Depression, anxiety, and stress scale – depression subscale
DASS-Anx	Depression, anxiety, and stress scale – anxiety subscale
DASS-Stress	Depression, anxiety, and stress scale – stress subscale
SBPS	Short boredom proneness scale
DEC	Deep effortless concentration
DECI	Deep effortless concentration internal scale
DECE	Deep effortless concentration external scale
EE	Ethinyl-estradiol
P	Progestin
SART	Sustained attention to response task
ms	Milliseconds
RMS	Regulatory Mode Scale
BSCS	Brief self-control scale
PGWBI	Psychological general well-being index

Chapter 1: General Introduction

Oral Contraceptives and Cognition

Hormonal contraceptives come in many forms (e.g., patch, injection), but the most common are oral contraceptives, which are used by more than 150 million women worldwide (United Nations, 2019). Oral contraceptives (OCs) are composed of exogenous (or artificial) estrogen and/or progesterone. They work by suppressing endogenous (or naturally occurring) levels of estrogen and/or progesterone, which prevents pregnancy by primarily hindering ovulation, but also by increasing the mucus around the cervix (Frye 2006; Rivera et al., 1999). However, endogenous estrogen and progesterone do not only act locally, nor are they solely synthesized by the gonads. The extant evidence suggests that peripheral estrogen and progesterone can pass through the blood-brain barrier (Banks, 2012) and that estrogen can even regulate the permeability of the blood-brain barrier (Sohrabji, 2006). Estrogen and progesterone also function as neurosteroids that are synthesized and act on receptors in the brain (Fester & Rune, 2021; Mellon & Griffin, 2002). The brain's synthesis of these hormones suggests estrogen and progesterone levels could modulate neuronal excitability and the neural circuits related to many cognitive functions (see McEwen, 2002; Galea et al., 2017 for reviews). Since OCs chronically suppress estrogen and/or progesterone, studies have examined whether there are OC-related changes in neural activity by examining resting-state connectivity in OC users and non-users. These studies have revealed differences between OC users and non-users in the functional connectivity of several brain networks (e.g., salience, executive, reward, default mode networks; Petersen et al., 2014; Pletzer et al., 2016; Sharma et al., 2020).

In light of the physiological effects of sex hormones on many aspects of brain function, it is perhaps not surprising that OC use has been associated with changes in performance in some domains of cognition (see Gurvich et al., 2023 for a review). One aspect of cognition that appears to be different between OC users and non-users is the ability to perform mental arithmetic (Becker et al., 1982; Bradshaw et al. 2020; Pletzer et al., 2014). For example, Bradshaw and colleagues (2020) had hormonal contraceptive users (the majority of which were OC users) and non-users solve GRE math problems. They found that compared to non-users, those using hormonal contraceptives solved fewer problems correctly (Bradshaw et al., 2020). Analyses of completion time data suggested that hormonal contraceptive users were performing worse than non-users because they spent less time on each problem.

There are cognitive processes that consistently appear to be unrelated to OC use (see Gurvich et al., 2023). For instance, most studies examining OC use and various working memory tasks—such as digit span (Gravelsins et al., 2021; Islam et al., 2008; Kuhlmann and Wolf, 2005), and n-back tasks (Gurvich et al., 2020; Herrera et al., 2020)—have not found significant relations between OC use and performance. The one exception is a study reported by Gravelsins et al., (2021), which revealed performance differences between OC users and non-users on the AX-CPT task, a task designed to tax both working memory and cognitive control mechanisms by varying stimulus-response contingencies based on contextual cues. However, the same study showed no influence of OC use on three other working memory tasks, including the n-back, digit span, and digit ordering tasks. Thus, while OCs may influence performance on very specific tasks that

involve working memory, the majority of the extant literature suggests that OC use is not related to differences in performance on most of the commonly used working memory tasks.

In other cognitive domains, the relations between OC use and cognitive performance are less consistent and clear. One example concerns performance on visuo-spatial tasks such as mental rotation and difference detection (see Gurvich et al., 2023 for a review). While some studies in this domain show no relations between OC use and performance (e.g., Gogos, 2013; Gurvich et al., 2020; Patel et al., 2022; Wharton et al., 2008), others—typically those with larger samples—find that performance does differ between OC users and non-users (Beltz et al., 2015; Bradshaw et al., 2020; but also see Beltz et al., 2022). However, these differences in performance are not consistent across studies. Beltz et al. (2015) found that OC users performed better than non-users, while findings from Bradshaw et al. (2020) indicated that hormonal contraceptive users (including OC users) performed worse than non-users.

Oral Contraceptive Use and Attention-related Traits and States

This dissertation is primarily focused on examining the relation between oral contraceptive use and attention-related traits and states, and related factors such as self-control. While there have been a few studies examining these links, at present it is difficult to draw any strong conclusions from the extant studies. One report assessed the relation between OC use and the trait-level tendency to mind wander using the Shortened Imaginal Process Inventory report (SIPI; Raymond et al., 2019). The SIPI is scored on three subscales: attentional control, guilt and fear of failure, and positive mind wandering. Their findings indicated that compared to non-users (N = 14), OC users (N = 28) reported significantly greater mind wandering on the attentional control subscale,

while there were no significant differences between groups on the other two subscales. Unfortunately, the small sample size of the study and the lack of a consistent pattern across the subscales of the SIPI preclude any strong conclusions about the relation between OC use and the trait-level tendency to experience inattention. Furthermore, studies examining OC use in the context of reaction time tasks, which have been used to index attention (Silber et al., 1987; Grikšienė & Rukšėnas, 2009), have yielded mixed results. Silber et al. (1987), found no significant differences in reaction time performance within participants using OCs and not using OCs. In contrast, the findings reported by Grikšienė and Rukšėnas (2009) indicated that OC users had significantly faster reaction times compared to non-users. However, since both studies did not report performance accuracy, only tested small samples of OC users ($Ns \leq 20$), and relied on tasks that might not be optimal indices of attention, it is difficult to draw strong conclusions from these studies as well.

Although the main focus here is the relation between OC use and factors related to attention, given the well-established link between inattention and affective dysfunction (Carriere et al., 2008; Seli, Beaty, Marty-Dugas, & Smilek, 2019; Smallwood & O'Connor, 2011; Poerio, Totterdell, & Miles, 2013), it is important to further consider the link between OC use and affect. On this issue, there has been much debate in the literature, with some studies reporting that OC use does not increase negative affect (Duke et al., 2007; Cheslack-Postava et al., 2015), others reporting that OC use is associated with increased positive mood (Hamstra et al., 2017; Keyes et al., 2013; Toffol et al., 2012), and still other studies report that OCs have a detrimental effect on affect (Anderl et al., 2020, 2022; Skovlund et al., 2016). In addition, there is speculation that the

link between OC use and depression symptoms might be mediated by various individual characteristics; for instance, individuals with a history of depressive symptoms may be particularly at risk of developing mental health problems as a result of OC use (Lewis et al., 2019). It is also worth noting that studies on OC use may be confounded by a "survivor effect". That is, individuals who experience adverse mood effects (or perhaps any adverse effect) as a result of using OCs tend to discontinue the medication and so are excluded from the OC use group, which artificially increases mean levels of mood for the remaining (i.e., "surviving") OC users. Given the associations between OC use and negative mood, as well as inattention and negative mood, it seems prudent to control for depression symptoms when examining the links between OC use and attention-related factors.

As is suggested by the foregoing, when examining the relations between OC use and attention-related traits and states, studies should focus on making several improvements. First, studies should aim to recruit larger (Ns $\geq$ 80), diverse samples of females using OCs and those not using any form of hormonal contraceptives, which will provide statistical power to detect at least medium sized effects (Faul et al., 2007). Second, research should consider and design studies to specifically measure the attentional domain of interest. The broader domain of 'attention' can be divided into multiple subdomains, classically including but not limited to 'mental concentration', 'vigilance' or 'sustained attention', 'selective attention', 'search', 'activation', 'mental set' and 'task switching' (see Moray, 1969, p. 6; Pashler, 1998; Parasuraman & Davies, 1984). It is certainly conceivable that OC use may influence some of these subdomains without meaningfully impacting others. As such, when selecting experimental tasks, we must be aware of these various

subdomains and choose valid measures of the attention domain of interest. Third, given that there will be variation between samples, it would be beneficial to directly self-replicate findings using independent samples where possible. This will lead to a better indication of the stability of the effects observed. Lastly, given the associations between inattention and negative mood (Carriere et al., 2008; Seli, Beaty, Marty-Dugas, & Smilek, 2019; Smallwood & O'Connor, 2011; Poerio, Totterdell, & Miles, 2013), and OC use and affective dysfunction (Duke et al., 2007; Cheslack-Postava et al., 2015; Hamstra et al., 2017; Keyes et al., 2013; Toffol et al., 2012; Anderl et al., 2020, 2022; Skovlund et al., 2016), it also seems sensible to control for this important third variable in analyses of OC use and attentional engagement ability.

The Present Investigations

The work reported in this dissertation includes a series of studies with the broad goal of better understanding the relation between OC use and factors related to attention at both the trait and state-level. In this chapter (Chapter 1), the current state of the literature examining OC use and cognition (more broadly) is examined, as well as the limited extant work that has investigated OC use and attention. Given the ethical precarity of manipulating OC use and non-use between groups, both prior work and the work presented in this dissertation focuses on examining the correlation between OC use and attention-related traits and states. This is an issue of interest given that OCs are commonly used and little is known about whether this medication has unintentional and unknown side effects on cognitive experiences. While this work is correlational and thus will not be able to definitively address issues of causality, it provides a first step in determining whether

an association exists. Critically, if there is a causal effect of OC use on attention-related traits and states, this should manifest as an association between these variables.

Chapter 2 contains a report on our studies examining the relation between OC use and self-reported everyday attention. We collected trait-level measures of mind wandering, attention-related errors, and attention lapses in undergraduate women using OCs (Study 1: OC group N = 467, Study 2: OC group N = 243) and naturally cycling women not using any form of hormonal contraceptives (Study 1: Non-OC group N = 1302, Study 2: Non-OC group N = 915). The results of Study 1 showed that women using OCs reported significantly less spontaneous and deliberate mind wandering than naturally cycling women. There were no differences between groups on attention related errors and attention lapses. In Study 2, these effects did not replicate with our findings indicating that there were no significant differences between groups on any of the attention measures. Regression analyses controlling for depression symptoms and semester of data collection found that OC use did predict unique additional variance on some attention measures, but these effects were small and unreliable across the two studies. Taken together, this data suggests there is no solid evidence that OC use is related to differences in attentional engagement in everyday life.

Chapter 3 describes an investigation of the relation between oral contraceptive (OC) use and a state related to inattention, namely boredom, and also peak attentional engagement, colloquially known as “flow”. We examined OC use and self-reports of boredom and flow proneness in undergraduate females using OCs (Sample 1: OC group N = 343, Sample 2: OC group N = 162) and females not using any form of hormonal contraceptives (Sample 1: Non-OC

group N = 1191, Sample 2: Non-OC group N = 852). We measured boredom proneness and the tendency to experience 'flow', defined as the experience of deep and effortless concentration. In Sample 1, there were no significant differences between the OC and non-OC groups with regard to boredom proneness or flow. However, there was a numerical difference in boredom proneness, such that OC users reported nominally lower boredom proneness than non-users. In Sample 2, there was a significant difference in boredom proneness between groups, with OC users reporting significantly lower boredom proneness than non-users. There were again found no significant differences between groups on the propensity to experience deep and effortless concentration. When the samples were combined, analyses revealed that OC users reported significantly less boredom proneness than non-users and that there were no differences between groups on flow proneness. However, after accounting for the semester of data collection and depression symptoms, group differences in boredom proneness disappeared. Thus, while OC users and non-users differ in boredom proneness, this could be driven by differences in the time of data collection and depression symptoms.

Chapter 4 investigated the possibility that OC formulation might differentially relate to attention-related traits. A limitation of the studies included in Chapters 2 and 3 was the lack of detail on OC formulation (e.g., dose, dosing schedule, and estrogenic, progestenic, androgenic activity). It is possible that by collapsing across OC formulations in these chapters that relations between OC use and attentional engagement were obscured because they were specific to particular formulations. To address this issue, we collected trait-level reports of the tendency to experience attention related errors, attention lapses, spontaneous and deliberate mind-wandering,

boredom, and internal and external flow in undergraduate females using OCs (N = 201). The brand of OC was also collected to derive the formulation. OC formulations differed in ethinyl-estradiol dose, progestin dose, dosing schedule, hormonal activity (or potency), and the type (or 'generation') of progestin used. There was no evidence that different OC formulations were related to differences in attention-related traits which suggests that OC users can be treated as a homogenous group when examining trait-level attention. Comparisons of OC users (collapsing across formulation) to non-users (N = 1192) again revealed no significant differences in trait-level attention.

Across two studies in Chapter 5 the relation between OC use and sustained attention during a cognitive task was examined. We recruited large and diverse samples of women currently using OCs (Study 1: OC N = 80, Study 2: OC N = 79), not currently using any form of hormonal contraceptives and had never used hormonal contraceptives (including OCs; Study 1: N = 189, Study 2: N = 236), and who had previously used but were not currently using OCs (Study 1: N = 39, Study 2: N = 33). All groups completed the Sustained Attention to Response Task (SART) online. During the SART participants were intermittently presented with thought probes asking them to indicate whether they were on task or mind wandering immediately before the probe. Because the study was conducted online, at the end of the task, participants were asked about their media-multitasking behavior during the task. SART performance (indexed by commission errors, omission errors, and go-trial reaction time) was analyzed over time and was used as a behavioural metric of attentional engagement and responses to thought probes and the post-task question about media multitasking were used as a convergent measure. Across both studies, there were no

significant differences between OC groups on SART performance, on-task probe reports, intentional mind wandering probe reports, and confessions of media multitasking during the task. While, in Study 1, current OC users and prior users reported significantly greater unintentional mind wandering than those who had never used OCs, this was not replicated in an independent sample of women in Study 2. This suggests that OC use may be related to differences in self-reports of attention during a cognitive task but these effects are unstable.

Finally, since attentional engagement is influenced by self-control, Chapter 6 examines the relation between oral contraceptive (OC) use and self-reported levels of self-control in undergraduate women using OCs (Study 1: OC group N = 399, Study 2: OC group N = 288) and naturally cycling women not using any form of hormonal contraceptives (Study 1: Non-OC group N = 964, Study 2: Non-OC group N = 997). We assessed the self-overriding aspect of self-control using the Brief Self-Control Scale (BSCS) and strategies for self-regulation using the Regulatory Mode Scale (RMS), which separately measures the tendency to assess one's progress towards a goal (assessment), and the tendency to engage in activities that move one towards an end goal (locomotion). In Study 1, there were no significant differences between OC and non-OC groups in their levels of self-overriding or self-regulatory assessment. However, those in the OC group reported significantly greater levels of self-regulatory locomotion compared to those in the non-OC group, even after controlling for depression symptoms and the semester of data collection. The findings from Study 2 replicated the findings from Study 1 in a different sample of participants, with the exception that OC use was also related to higher levels of assessment in Study 2. These

results indicate that OC use is related to increases in self-regulatory actions in service of goal pursuit and perhaps the tendency to evaluate progress towards goals.

The final chapter includes a conclusion with a general summary of our findings and a discussion of some possibilities behind the inconsistent findings in the literature examining OC use and cognition more broadly (including the current replication crisis in psychology; Maxwell et al., 2015; Open Science Collaboration, 2015; Pashler & Harris, 2014). There is also a discussion on the challenges of studying OC use and cognition, the limitations of the present studies, as well as viable future directions.

Chapter 2: Oral contraceptive use and attentional engagement in everyday life

2.1 Introduction

Previous research has suggested that use of OCs may be linked to increased inattention in everyday life (Raymond et al., 2019). Specifically, Raymond et al. (2019) assessed levels of mind wandering in women using OCs (N=28), naturally cycling women in the luteal phase (N=14), and men (N=29). Naturally cycling women in the luteal phase were chosen because these women were most hormonally dissimilar to women using OCs. That is, women in the luteal phase tend to have higher levels of endogenous estrogen and progesterone, while women using OCs have low levels of endogenous estrogen and progesterone and high levels of exogenous estrogen and progesterone. Mind wandering was indexed using the Short Imaginal Process Inventory (SIPI; Huba & Tanaka, 1983), which is a subjective report questionnaire that assesses three aspects of day dreaming / mind wandering, namely, 1) positive-constructive daydreaming, 2) guilt and fear-of-failure daydreaming and 3) poor attention control. They found no significant differences between women using OCs, naturally cycling women, and men on the guilt and fear-of-failure subscale or the positive-constructive daydreaming subscale of the SIPI. However, they found significant differences between groups on the attentional control subscale, such that women using OCs reported significantly poorer attention control than naturally cycling women and men. To rule out the possibility that these differences were due to differences in depression across groups—since inattention and depression are related (Carriere et al., 2008; Seli, Beaty, Marty-Dugas, & Smilek, 2019; Smallwood et al., 2007)—the authors showed that there were no significant differences among groups with regard to scores on the Beck Depression Inventory (BDI; Beck et al., 1988). It is worth noting, however, that scores on the BDI were associated with lower scores on the

attentional control subscale of the SIPI. Unfortunately, the small sample size of the study precludes any strong conclusions about the relation between OC use and inattention.

Here we present two studies that extend prior work on the relation between attentional engagement in everyday life and OC use. Study 1 had several primary aims. First, we aimed to examine the relation between OC use and attention by recruiting a larger sample of women than has been used in prior related studies. This is important given that prior studies examining this issue have relied on rather small samples (e.g., 28 women using OCs, 14 naturally cycling women in Raymond et al., 2019). Second, while prior work has focused on daydreaming, we aimed to more specifically assess a wide range of everyday attention abilities by using well-validated self-report questionnaires that index spontaneous and deliberate mind wandering (Carriere et al., 2013), attention lapses (Carriere et al., 2008), and attention related errors (Carriere et al., 2008; Cheyne et al., 2006). Third, because of the established relation between OC use and mood, we also included a measure of depressive symptoms and considered this measure when assessing the relation between OC use and trait attention. In Study 2, we sought to replicate our findings from Study 1 using an independent sample of undergraduate women.

2.2 Study 1

2.2.1 Method

This study was reviewed and received ethics clearance through a University of Waterloo's Research Ethics Committee (ORE# 41701). The study was conducted in accordance with relevant guidelines and regulations. All participants provided informed consent. Data was collected online

at the University of Waterloo at the beginning of three semesters during the 2020 calendar year: Winter 2020 (January-February), Spring 2020 (May-June), and Fall 2020 (September-October).

2.2.1.1 Participants

Participants in our study were undergraduate students who indicated their sex as female. Mass Testing was completed in exchange for partial course credit. Exclusions from each semester were made using the criteria outlined in the Data Cleaning section below. The Winter 2020 cohort initially consisted of 1075 females, of which 539 participants were excluded. Thus 536 participants were retained in Winter 2020 with 165 individuals using OCs and 371 naturally cycling and not using any form of hormonal contraceptives. The Spring 2020 sample consisted of data from 861 females. Of these, 518 participants were excluded leaving 343 participants in the analysis (97 using OCs and 246 naturally cycling). The Fall 2020 cohort initially included 1724 females, of which 834 were excluded leaving 890 participants (205 OC users and 685 naturally cycling women). Altogether, in Study 1 we included 1769 participants in total, with 467 using OCs and 1302 naturally cycling participants who were not using any form of hormonal contraceptives.

Participants in this final sample had an average age of 20.38 years.

2.2.1.2 Mass Testing Procedure

Data collection utilized the Mass Testing procedure at the University of Waterloo. Mass Testing is a large battery of psychological questionnaires administered to participants at the beginning of each semester (usually during the first 8 weeks). Participants are eligible to complete Mass Testing if they are enrolled in at least one psychology course that semester. The surveys included in Mass Testing are requested by researchers (i.e., faculty, post-doctoral fellows, graduate

and undergraduate researchers) in the Department of Psychology and can vary between semesters. Surveys are presented to participants in a random order unless a particular ordinal position is requested by a researcher. Each page of the Mass Testing procedure collects timing and click data which allows researchers to determine how long participants took to complete a particular questionnaire and/or Mass Testing as a whole. It is structured to take approximately one hour to complete.

2.2.1.3 Prescreen data

The data collected for this study were a part of a larger test battery (Mass Testing). Mass Testing is administered online during the first 8 weeks of each semester using Qualtrics survey software. Students enrolled in undergraduate psychology courses at the University of Waterloo were eligible to complete this survey. This enabled us to survey a large number of females currently using or not using oral contraceptives. Participants also complete a separate prescreen survey (the Mass Testing and Pre-screen surveys are typically completed in close succession at the beginning of each semester) in which they were asked to provide their biological sex and to answer the following question about hormonal birth control use: "Are you currently using one of the following methods of birth control?" Participants responded by selecting from a list that included: oral contraception (i.e., birth control or "the pill"), birth control patch, vaginal ring, birth control injection, IUD, hormonal implant, none of the above (in Winter 2020 this option was 'does not apply to me'), and prefer not to answer. Participants were also asked to specify whether they were currently being treated for depression or anxiety, whether they were currently using medications for psychosis, and the date of their last menstruation.

2.2.1.4 Data Cleaning

In this section, we describe the basic data cleaning that was performed on all samples prior to computing descriptive and inferential statistics. For all semesters, the cleaning process was virtually identical. The exclusion criteria and data cleaning procedure were determined a priori. To maintain independent samples, participants who were included in multiple semesters of data were only included in the analyses for the first semester in which they met the inclusion criteria (i.e., participants who were in subsequent semesters were excluded from those samples). Winter 2020 was the first semester of data cleaned, so all participants were included for this criterion. In Spring 2020, we excluded 64 participants who were included in the Winter 2020 sample and in Fall 2020, 288 participants who were included in Winter 2020 and/or Spring 2020 were removed. Since we were interested in OC use in particular, participants were also excluded if they did not respond to the item inquiring about hormonal contraceptive use (N = 261; Winter 2020: N = 77, Spring 2020: N = 64, Fall 2020: N = 120), reported using a hormonal contraceptive other than OC (N = 45; Winter 2020: N = 11, Spring 2020: N = 11, Fall 2020: N = 23), or reported use of an IUD (N = 167; Winter 2020: N = 36, Spring 2020: N = 39, Fall 2020: N = 92). The Mass Testing survey is administered by the department (rather than by individual researchers), and as a result, sometimes there are changes/additions to the survey that are outside of researchers' control. For example, there were minor variations in the wording of the responses to the question inquiring about hormonal contraceptive use. In Winter 2020, "does not apply to me" was included, while in Spring 2020 and Fall 2020 this option was amended to "none of the above". These options were treated as the same response.

To avoid possible mental health confounds[1], participants who reported they were currently receiving treatment for depression (N = 277; Winter 2020: N = 70, Spring 2020: N = 56, Fall 2020: N = 151), treatment for anxiety (N = 111; Winter 2020: N = 29, Spring 2020: N = 25, Fall 2020: N = 57), and/or use of anti-psychotic medications (N = 3; Winter 2020: N = 0, Spring 2020: N = 0, Fall 2020: N = 3) were removed (similar to Raymond et al., 2019; Bradshaw et al., 2020). Participants who did not respond to these mental health items were also excluded (N = 60; Winter 2020: N = 12, Spring 2020: N = 7, Fall 2020: N = 41).

Next, we employed additional data cleaning procedures to ensure high quality data in participant responses. This is because the Mass Testing survey is a lengthy questionnaire, and many participants may not remain fully attentive over the course of the survey. Participants were excluded from the analyses based on 3 criteria: 1) if the number of clicks they made was fewer than the number of required responses per page of a survey (N = 1; Winter 2020: N = 0, Spring 2020: N = 0, Fall 2020: N = 1), 2) if their responses were faster than 1-second per scale item (we reasoned that participants needed at least 1-second to read and respond appropriately to each item) (N = 105; Winter 2020: N = 33, Spring 2020: N = 24, Fall 2020: N = 48), and 3) if participants responded to fewer than 50% of survey items (N = 1; Winter 2020: N = 1, Spring 2020: N = 0, Fall 2020: N = 0). We chose this cut-off for survey items because we scored each scale by averaging across the all scale items. Data were analyzed before and after removing participants based on age (to ensure our sample consisted of females of reproductive age; 18-45 years age).

[1] Since it may be argued that excluded participants currently undergoing treatment for mental health concerns may obscure differences in attention, we also conducted the analyses with these participants included. The inclusion of these participants did not meaningfully change the results.

The removal of participants based on age did not impact the results in a meaningful way. Below we report the analyses of data after removing participants who did not report their birth year (N = 24) or were older than 45 years of age (N = 11).

Participants who were removed during this cleaning process for one semester were still eligible to be included in subsequent semesters should they subsequently meet the inclusion criteria. For example, if a participant was removed for responding too quickly in Winter 2020, her data could still be included in Fall 2020 if her responses were slower. That is, responding to questions too quickly in an earlier semester did not preclude that participant from inclusion in a later semester.

2.2.1.5 Materials

Spontaneous (MWS) and Deliberate (MWD) Mind Wandering Scales. The MWS is a measure of spontaneous or unintentional mind wandering, whereas the MWD is a measure of deliberate or intentional mind wandering (Carriere et al., 2013). These self-report questionnaires consist of 4 statements each; representative examples include, "I allow my thoughts to wander on purpose" (MWD), and "I find my thoughts wandering spontaneously" (MWS). Each participant responds on a 7-point scale that ranges from 1 (*rarely)* to 7 (*a lot*). Higher scores indicate a greater tendency to engage in mind wandering (deliberate or spontaneous) in everyday life.

Mindful Attention Awareness Scale-Lapses Only **(MAASLO)**. The MAASLO (Carriere et al., 2008) is a revised version of the MAAS (Brown and Ryan, 2003) which includes 12 items related to mindlessness or attention lapses in everyday life. Participants respond to items such as "I rush through activities without being really attentive to them" on a scale from 1 (*almost never)*

to 6 (*almost always)*. Higher frequencies of attention lapses are reflected as higher scores on the scale.

Attention-Related Cognitive Errors Scales **(ARCES)**. The ARCES measures the tendency to experience performance errors caused by attention lapses (Carriere et al., 2008; Cheyne et al., 2006). Participants rate items such as "I have to go back to check whether I have done something or not (e.g., turning out lights, locking doors)" on a scale from 1 (*never)* to 5 (*very often)*. Higher scores indicate a greater frequency of cognitive errors.

Depression Anxiety Stress Scale-21 **(DASS-21).** The DASS is a 21-item measure assessing symptoms of depression, anxiety, and stress over the previous week (Antony et al., 1998). Participants rate items such as "I felt that I had nothing to look forward to" (depression), "I was worried about situations in which I might panic and make a fool of myself" (anxiety), and "I found it hard to wind down" (stress) on a scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). The scale contains seven items related to each of depression, anxiety, and stress and higher scores on the scale items indicate higher levels of these experiences.

2.2.2 Results and Discussion

All analyses were performed in R (R Core Team 2019). We used the psych and basic R packages to perform the Null Hypothesis Significance Tests as well as the Bayes Factor package to calculate Bayes Factors (BFs). The Bayes Factor package calculates the BFs as the ratio of the alternative to null hypothesis, such that smaller BFs indicate evidence for the null hypothesis, while larger BFs are evidence for the alternative hypothesis. We utilized the default prior scale in the Bayes Factor package and interpret BFs based on Andraszewicz et al. (2014).

2.2.2.1 Descriptive Statistics

Descriptive statistics for both groups are provided in Table 2.1. All scales showed high reliabilities, with Cronbach alphas of 0.75 or greater. Cronbach alpha values (left panel) and Pearson correlations (right panel) between the measures within each group are provided in Table 2.2. Boxplots depicting each of the attention measures as a function of OC use condition (averaged across semesters) are shown in Figure 2.1.

Table 2.1. Descriptive statistics of measures by semester and group (Study 1; N = 1769)

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Winter 2020	Non-OC group	ARCES	371	2.95	0.64	0.14	0.38
		MAASLO	371	3.24	0.75	−0.15	0.08
		MWS	371	4.33	1.27	−0.11	−0.09
		MWD	371	4.33	1.41	−0.35	−0.34
		DASS-Dep	371	0.82	0.73	0.86	-0.15
		DASS-Anx	371	0.73	0.64	0.89	-0.01
		DASS-Stress	371	0.94	0.67	0.50	-0.48
	OC group	ARCES	165	2.89	0.62	0.63	0.73
		MAASLO	165	3.19	0.71	0.01	−0.04
		MWS	165	4.07	1.27	−0.09	−0.06
		MWD	165	4.07	1.47	−0.21	−0.68
		DASS-Dep	165	0.70	0.65	1.25	1.08
		DASS-Anx	165	0.64	0.58	1.10	1.09
		DASS-Stress	165	0.96	0.67	0.87	0.36
Spring 2020	Non-OC group	ARCES	246	2.84	0.62	0.13	0.43
		MAASLO	246	3.04	0.81	−0.08	−0.16
		MWS	246	4.04	1.39	−0.13	−0.53
		MWD	246	4.13	1.45	−0.07	−0.64
		DASS-Dep	246	0.79	0.65	0.89	-0.01
		DASS-Anx	246	0.61	0.51	1.01	0.66
		DASS-Stress	246	0.86	0.58	0.64	0.06
	OC group	ARCES	97	2.78	0.65	0.47	0.48
		MAASLO	97	3.05	0.78	−0.03	0.29
		MWS	97	3.96	1.37	−0.05	−0.35
		MWD	97	3.99	1.51	−0.19	−0.57
		DASS-Dep	97	0.72	0.67	1.30	1.31
		DASS-Anx	97	0.58	0.50	0.92	0.56
		DASS-Stress	97	0.88	0.59	1.16	1.77

Fall 2020	Non-OC group	ARCES	685	3.03	0.66	0.41	0.23
		MAASLO	685	3.26	0.78	−0.07	0.20
		MWS	685	4.38	1.38	−0.30	−0.24
		MWD	685	4.63	1.54	−0.40	−0.49
		DASS-Dep	685	0.89	0.75	0.92	0.10
		DASS-Anx	685	0.75	0.64	1.05	0.75
		DASS-Stress	685	1.02	0.68	0.43	-0.42
	OC group	ARCES	205	2.96	0.73	0.33	0.06
		MAASLO	205	3.23	0.77	−0.31	0.16
		MWS	205	4.15	1.46	−0.15	−0.46
		MWD	205	4.32	1.59	−0.30	−0.81
		DASS-Dep	205	0.81	0.73	1.01	0.26
		DASS-Anx	205	0.75	0.66	0.95	0.27
		DASS-Stress	205	1.04	0.69	0.60	-0.18

Note. MW-S = Spontaneous Mind Wandering, MW-D = Deliberate Mind Wandering, MAAS-LO = Mindful Attention Awareness Scale; ARCES = Attention-Related Cognitive Errors Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 2.2. Cronbach alphas (left panel) and pearson correlations (right panel) of the OC group (above the diagonal; N=467) and non-OC group (below the diagonal; N = 1302)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. MW-S	.89	.87	--	.50 **	.49 **	.55 **	.34 **	.31 **	.35 **
2. MW-D	.91	.90	.39 **	--	.25 **	.30 **	.17 **	.14 *	.11 *
3. MAAS-LO	.87	.87	.52 **	.26 **	--	.52 **	.45 **	.40 **	.46 **
4. ARCES	.91	.89	.52 **	.22 **	.59 **	--	.31 **	.39 **	.41 **
5.DASS-Depression	.90	.90	.38 **	.13 **	.42 **	.32 **	--	.59 **	.70 **
6. DASS-Anxiety	.75	.79	.29 **	.09 *	.39 **	.33 **	.63 **	--	.71 **
7. DASS-Stress	.84	.84	.36 **	.10 **	.43 **	.36 **	.70 **	.74 **	--

Note. MW-S = Spontaneous Mind Wandering, MW-D = Deliberate Mind Wandering, MAAS-LO = Mindful Attention Awareness Scale; ARCES = Attention-Related Cognitive Errors Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.
* p = .05, ** p < .001

2.2.2.2 Analysis Plan

To determine whether there were differences between OC users and non-users we first conducted a series of planned comparisons using t-tests comparing those using OCs and those not using OCs (a similar structure to the analyses of Raymond et al. (2019)) on each of our attention measures. While it was not one of the primary aims of the present study, we also compared depression, anxiety, and stress symptoms across OC and non-OC groups (for details on these analyses please see Appendix A: Supplementary Data).

Further, given the relation between OC use and symptoms of depression (e.g., Keyes et al., 2013; Skovlund et al., 2016), we also sought to determine whether OC use could predict our attention measures over and above symptoms of depression. We also wanted to control for the semester of data collection since we were collecting data during the COVID-19 pandemic. To examine OC use while accounting for depression symptoms and the semester of data collection, we conducted a series of hierarchical regressions.

Planned comparisons. To examine whether there are differences in attention between OC users and non-users, we collapsed across semesters and conducted a series of independent sample t-tests (Figure 2.1). To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .013 (.05 / 4). These tests revealed that individuals using oral contraceptives reported significantly less spontaneous mind wandering (as measured by the MWS), $t(812.3) = 3.00$, $p = .003$, $d = .16$, $BF_{10} = 5.49$ (moderate evidence for the alternative hypothesis), and less deliberate mind wandering (as measured by MWD), $t(803.9) = 3.50$, $p < .001$, $d = .19$, $BF_{10} = 29.68$ (strong evidence for the alternative hypothesis). There were no significant differences in

attention-related errors (which we measured using the ARCES), $t(793.3) = 1.96$, $p = .050$, $d = .11$, $BF_{10} = 0.44$ (anecdotal evidence for the null hypothesis). There was also no significant effect of contraceptive use on reports of attention lapses (as measured by the MAASLO), $t(849.7) = 0.86$, $p = .388$, $d = .05$, $BF_{10} = 0.09$ (anecdotal evidence for the null hypothesis).

Again, while it was not a primary goal of the present studies, we also investigated whether there were differences between OC users and non-users in their reports of symptoms of depression, anxiety, and stress. We again collapsed across semesters and conducted independent sample t-tests. Our findings indicated there was a significant difference in symptoms of depression, such that OC users reported significantly fewer depression symptoms compared to non-users. However, we found no significant differences between groups on anxiety or stress (for details see Appendix A: Supplementary Data).

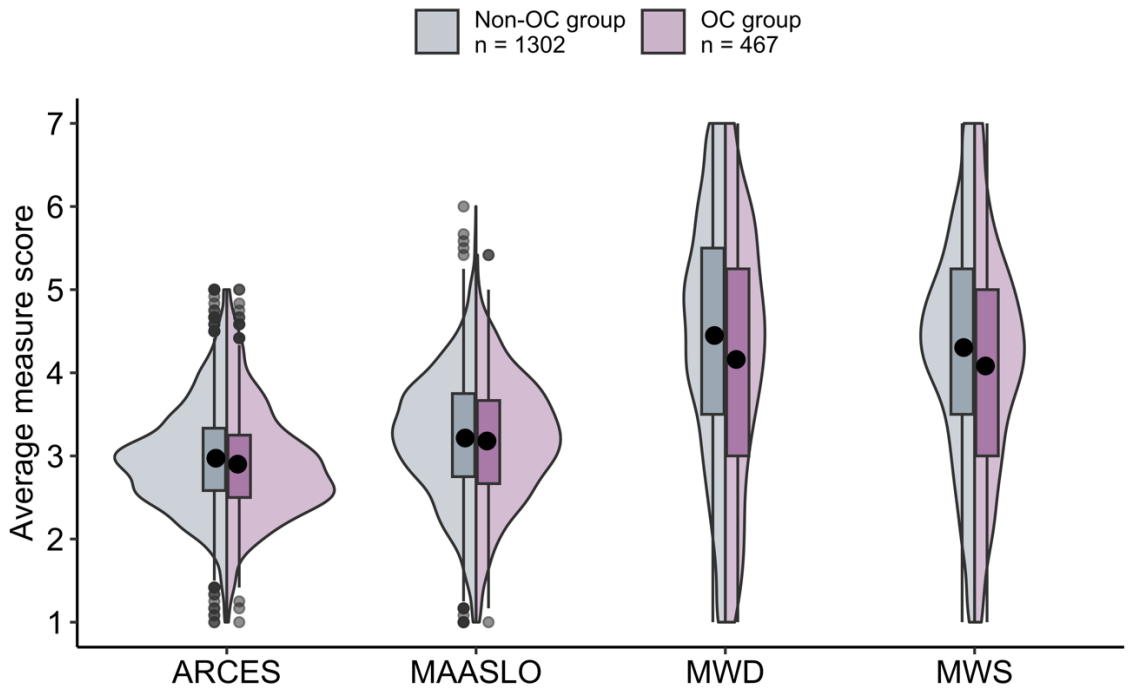


Figure 2.1. Split violin plots with box and whisker plots (boxplots) for each of the attention measures (MWS, MWD, MAASLO, and ARCES) as a function of group in Study 1.

Regressions. Given the relation between oral contraceptive use and symptoms of depression (e.g., Keyes et al., 2013; Skovlund et al., 2016), we also sought to determine whether oral contraceptive use could predict the attention measures over and above symptoms of depression and the semester of data collection, since data collection occurred during the COVID-19 pandemic. To this end, we conducted a series of hierarchical regressions entering semester and DASS-depression as predictors in the first step and adding oral contraceptive use in the second step (Table 2.3). As can be seen in Table 2.3, entering semester and depression symptoms in Step 1 accounted for a significant amount of variance in each measure of inattention. Critically, OC use explained significant additional variance over and above semester and depression in spontaneous and

deliberate mind wandering, such that OC use uniquely predicted less spontaneous and deliberate mind wandering (MWS: $\beta = -0.15$, $p = .031$; MWD: $\beta = -0.23$, $p = .004$). However, we note that the amount of additional variance explained by OC use is quite small (e.g. less than 1%). OC use did not explain additional variance in attention related errors or attention lapses (see ΔR^2 in Table 2.3).

Table 2.3. Regression model statistics for Study 1

		Beta	*SE*	*p*
DV: MWS		**R^2 = .141, F = 96.56, SE = 1.27, Model *p* < .001**		
Step 1	Intercept	4.28	0.05	< .001
	Spring 2020	-0.22	0.09	.011
	Fall 2020	0.02	0.07	.783
	DASS-Dep	0.50	0.03	< .001
Step 2		**R^2 = .143, F = 73.73, SE = 1.26, Model *p* < .001**		
		ΔR^2 = .002, *p for* ΔR^2 = .031		
	Intercept	4.32	0.06	< .001
	Spring 2020	-0.23	0.09	.010
	Fall 2020	0.01	0.07	.907
	DASS-Dep	0.50	0.03	< .001
	OC status	-0.15	0.07	.031
DV: MWD		**R^2 = .036, F = 21.72, SE = 1.49, Model *p* < .001**		
Step 1	Intercept	4.26	0.06	< .001
	Spring 2020	-0.15	0.10	.145
	Fall 2020	0.28	0.08	< .001
	DASS-Dep	0.21	0.04	< .001
Step 2		**R^2 = .040, F = 18.46, SE = 1.49, Model *p* < .001**		
		ΔR^2 = .005, *p for* ΔR^2 = .004		
	Intercept	4.32	0.07	< .001
	Spring 2020	-0.16	0.10	.129
	Fall 2020	0.27	0.08	.001
	DASS-Dep	0.21	0.04	< .001
	OC status	-0.23	0.08	.004
DV: ARCES		**R^2 = .011, F = 73.80, SE = 0.62, Model *p* < .001**		
Step 1	Intercept	2.94	0.03	< .001
	Spring 2020	-0.10	0.04	.012
	Fall 2020	0.06	0.03	.102
	DASS-Dep	0.21	0.01	< .001
Step 2		**R^2 = .011, F = 55.63, SE = 0.62, Model *p* < .001**		
		ΔR^2 = .00, *p for* ΔR^2 = .292		
	Intercept	2.96	0.03	< .001
	Spring 2020	-0.11	0.04	.012
	Fall 2020	0.05	0.03	.120
	DASS-Dep	0.21	0.01	< .001
	OC status	-0.04	0.03	.292
DV: MAASLO		**R^2 = .188, F = 136.50, SE = 0.70, Model *p* < .001**		
Step 1	Intercept	3.24	0.03	< .001
	Spring 2020	-0.17	0.05	< .001
	Fall 2020	-0.01	0.04	.851
	DASS-Dep	0.33	0.02	< .001
Step 2		**R^2 = .188, F = 102.40, SE = 0.70, Model *p* < .001**		
		ΔR^2 = .00, *p for* ΔR^2 = .736		
	Intercept	3.24	0.03	< .001
	Spring 2020	-0.17	0.05	< .001
	Fall 2020	-0.01	0.04	.871
	DASS-Dep	0.33	0.02	< .001
	OC status	0.01	0.04	.736

Note 1: DV = Dependent variable; MWS = Spontaneous Mind Wandering, MWD = Deliberate Mind Wandering, MAASLO = Mindful Attention Awareness Scale; ARCES = Attention-Related Cognitive Errors Scale
Note 2: Semester of data collection and depression symptoms are entered in Step 1. In Step 2, OC use is added to the model.
Note 3: ΔR^2 values may not exactly represent Step 2 R^2 – Step 1 R^2 due to rounding.

2.3 Study 2

Contrary to prior work, our results from Study 1 indicated that there was no relation between OC use and reports of poorer attention in everyday life. In fact, our findings from this study indicated that OC use may provide a modest attentional benefit. Given this interesting result, we sought to determine whether this effect would replicate. To do this, we utilized the same method as Study 1 in an independent sample of undergraduate women.

2.3.1 Method

This study was also reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 41701). The study was conducted in accordance with relevant guidelines and regulations. All participants provided informed consent. Similar to Study 1, data was collected online at the University of Waterloo at the beginning of three semesters during the 2021 calendar year: Winter 2021 (January-February), Spring 2021 (May-June), and Fall 2021 (September-October).

2.3.1.1 Participants

As in Study 1, all participants were female undergraduates, completed Mass Testing in exchange for partial course credit, and exclusions were made using the criteria outlined in the Data Cleaning section above. In Winter 2021, data was collected from 1573 female participants and 1052 were excluded (as a reminder, the number of exclusions is higher because a large number of

participants were included in previous semesters; see data cleaning procedure below for details). This resulted in 521 participants in Winter 2021, with 124 using OCs and 397 naturally cycling. Spring 2021 initially consisted of 490 participants but 357 were excluded leaving 133 participants with 22 OC users and 111 non-users. Fall 2021 began with data from 1309 participants, of which 805 were excluded. After exclusions, Fall 2021 was composed of 504 participants, 97 using OCs and 407 naturally cycling. Thus, altogether, Study 2 included a total of 1158 participants with 243 OC users and 915 non-users.

Participants in Study 2 had an average age of 20.56 years old.

2.3.1.2 Prescreen

The prescreen procedure was identical to Study 1.

2.3.1.3 Data Cleaning

The data cleaning procedure and exclusion criteria were identical to Study 1. To ensure Study 1 and Study 2 were independent samples, we excluded participants from Winter 2021 who had already been included in Study 1 (in Winter, Spring, or Fall 2020; N = 567). We also removed 207 participants were removed from Spring 2021 who had already been included in Study 1 or Winter 2021 and excluded 444 participants from Fall 2021 who has been in Study 1, Winter 2021, or Spring 2021 samples. Thirty-five participants (Winter 2021: N = 20, Spring 2021: N = 3, Fall 2021: N = 12) were excluded because they reported using a hormonal contraceptive other than OC, 200 participants were removed because did not report whether or not they used a hormonal contraceptive (Winter 2021: N = 110, Spring 2021: N = 32, Fall 2021: N = 58), and 176 were

excluded because they reported use of an IUD (Winter 2021: N = 85, Spring 2021: N = 29, Fall 2021: N = 62).

We again addressed the possibility of mental health confound[2] by removing participants if they indicated they were currently receiving treatment for depression (N = 328; Winter 2021: N = 149, Spring 2021: N = 47, Fall 2021: N = 133) or anxiety (N = 79; Winter 2021: N = 20, Spring 2021: N = 17, Fall 2021: N = 42), or if they did not report whether or not they were currently undergoing treatment for depression (N = 34; Winter 2021: N = 18, Spring 2021: N = 4, Fall 2021: N = 12) or anxiety (N = 10; Winter 2021: N = 5, Spring 2021: N = 1, Fall 2021: N = 4). Additionally, participants who reported use of anti-psychotic medication (N = 3; Winter 2021: N = 1, Spring 2021: N = 0, Fall 2021: N = 1) or did not respond to the item inquiring about anti-psychotic medication (N = 2; Winter 2021: N = 1, Spring 2021: N = 0, Fall 2021: N = 0) were excluded.

Finally, we screened participants' behaviour during the questionnaire to ensure high data quality by excluding participants based on 3 criteria: 1) if the number of clicks they made was fewer than the number of required responses per page of a survey (N = 0; Winter 2021: N = 0, Spring 2021: N = 0, Fall 2021: N = 0), 2) if their responses were faster than 1-second per scale item (we reasoned that participants needed at least 1-second to read and respond appropriately to each item) (N = 73; Winter 2021: N = 35, Spring 2021: N = 12, Fall 2021: N = 26), and 3) if participants responded to fewer than 50% of survey items (N = 3; Winter 2021: N = 2, Spring

[2] We again also conducted the analyses including participants undergoing treatment for depression, anxiety, and/or psychosis. This did not meaningfully change the results.

2021: N = 1, Fall 2021: N = 0). Data were analyzed before and after removing participants based on age (to ensure our sample consisted of females of reproductive age; 18-45 years age). The removal of participants based on age did not impact the results in a meaningful way. Below we report the analyses of data after removing participants who were older than 45 (N = 11) as well as participants who did not report their birth year (N = 23).

2.3.1.4 Materials

The materials were identical to those used in Study 1.

2.3.2 Results and Discussion

Analyses were again performed in R (R Core Team 2019) using the same packages as Study 1.

2.3.2.1 Descriptive Statistics

Descriptive statistics for both groups are provided in Table 2.4. Scales again showed high reliabilities, with Cronbach alphas of 0.81 or greater (Table 2.5; left panel). We also include Pearson correlations between the measures within each group in Table 2.5 (right panel). Boxplots depicting each of the attention measures as a function of OC use condition (averaged across semesters) are shown in Figure 2.2.

Table 2.4. Descriptive statistics of measures by semester and group (Study 2; N = 1158)

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Winter 2021	Non-OC group	ARCES	397	2.98	0.66	0.12	0.10
		MAASLO	397	3.24	0.82	−0.11	−0.06
		MWS	397	4.32	1.34	−0.15	−0.40
		MWD	397	4.45	1.56	−0.29	−0.71
		DASS-Dep	397	0.93	0.75	0.64	-0.49
		DASS-Anx	397	0.74	0.64	0.85	-0.07
		DASS-Stress	397	0.98	0.65	0.31	-0.75
	OC group	ARCES	124	3.07	0.67	0.51	0.23
		MAASLO	124	3.30	0.74	−0.60	0.41
		MWS	124	4.48	1.33	−0.09	−0.67
		MWD	124	4.49	1.52	−0.22	−0.69
		DASS-Dep	124	0.81	0.75	1.16	0.95
		DASS-Anx	124	0.71	0.69	1.01	0.16
		DASS-Stress	124	1.00	0.69	0.61	-0.32
Spring 2021	Non-OC group	ARCES	111	2.92	0.71	0.57	0.26
		MAASLO	111	3.34	0.80	0.09	0.31
		MWS	111	4.47	1.39	−0.03	−0.54
		MWD	111	4.45	1.47	−0.15	−0.44
		DASS-Dep	111	0.93	0.76	0.92	0.17
		DASS-Anx	111	0.71	0.66	1.12	0.83
		DASS-Stress	111	1.02	0.69	0.40	-0.51
	OC group	ARCES	22	3.17	0.66	-0.09	−0.76
		MAASLO	22	3.62	0.82	−0.18	−1.09
		MWS	22	4.57	1.27	−0.93	1.89
		MWD	22	4.23	1.12	0.72	0.47
		DASS-Dep	22	0.86	0.66	1.35	2.01
		DASS-Anx	22	0.86	0.62	0.89	0.84
		DASS-Stress	22	1.13	0.54	1.10	1.16
Fall 2021	Non-OC group	ARCES	407	3.03	0.71	0.16	0.23
		MAASLO	407	3.28	0.78	−0.40	0.23
		MWS	407	4.45	1.45	−0.24	−0.36
		MWD	407	4.67	1.47	−0.37	−0.53
		DASS-Dep	407	0.89	0.72	0.72	-0.31
		DASS-Anx	407	0.83	0.66	0.86	0.20
		DASS-Stress	407	1.06	0.64	0.34	-0.63
	OC group	ARCES	97	3.14	0.78	0.46	−0.14
		MAASLO	97	3.41	0.85	0.49	0.46
		MWS	97	4.52	1.42	−0.33	−0.13
		MWD	97	4.51	1.62	−0.30	−0.91

DASS-Dep	97	0.81	0.70	0.91	0.19
DASS-Anx	97	0.82	0.65	0.66	-0.56
DASS-Stress	97	1.09	0.63	0.44	-0.12

Note. MW-S = Spontaneous Mind Wandering, MW-D = Deliberate Mind Wandering, MAAS-LO = Mindful Attention Awareness Scale; ARCES = Attention-Related Cognitive Errors Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 2.5. Cronbach alphas (left panel) and pearson correlations (right panel) of the OC group (above the diagonal; N=243) and non-OC group (below the diagonal; N = 915)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. MW-S	.87	.89	--	.44 **	.46 **	.50 **	.28 **	.31 **	.37 **
2. MW-D	.91	.90	.44 **	--	.17 *	.21 *	.17 *	.18 *	.17 *
3. MAAS-LO	.88	.87	.49 **	.26 **	--	.60 **	.42 **	.49 **	.52 **
4. ARCES	.92	.90	.51 **	.20 **	.55 **	--	.40 **	.44 **	.41 **
5.DASS-Depression	.90	.90	.37 **	.19 **	.47 **	.38 **	--	.66 **	.76 **
6. DASS-Anxiety	.82	.81	.34 **	.14 **	.41 **	.39 **	.61 **	--	.79 **
7. DASS-Stress	.82	.83	.38 **	.18 **	.49 **	.38 **	.69 **	.73 **	--

Note. MW-S = Spontaneous Mind Wandering, MW-D = Deliberate Mind Wandering, MAAS-LO = Mindful Attention Awareness Scale; ARCES = Attention-Related Cognitive Errors Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.
* p = .05, ** p < .001

2.3.2.2 Analysis Plan

The Analysis Plan for Study 2 was identical to Study 1. We conducted planned comparisons of OC users to non-users and hierarchical regressions to determine whether OC use could predict our attention measures over and above the semester of data collection and symptoms of depression.

Planned comparisons. To investigate whether there were differences in our self-reported attention measures between those using OCs and those not using OCs, we again collapsed across

semesters and conducted a series of independent samples t-tests (Figure 2.2). To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .013 (.05 / 4). We did not find significant differences in spontaneous mind wandering (which we measured using the MWS), $t(389.6) = 1.06$, $p = .292$, $d = .07$, $BF_{10} = 0.14$ (moderate evidence for the null hypothesis), or deliberate mind wandering (as measured by the MWD), $t(377.1) = 0.65$, $p = .514$, $d = .05$, $BF_{10} = 0.10$ (moderate to strong evidence for the null hypothesis). Our findings also indicated there were no significant differences in attention related errors (as measured by the ARCES), $t(372.7) = 2.05$, $p = .041$, $d = .15$, and the Bayes Factor indicated anecdotal evidence for the null hypothesis, $BF_{10} = 0.68$. There were also no significant differences in attention lapses (indexed using the MAASLO), $t(382.0) = 1.77$, $p = .078$, $d = .13$, $BF_{10} = 0.37$ (anecdotal evidence for the null hypothesis).

While it was not a goal of the present study, we also examined whether symptoms of depression, anxiety, and stress differed between OC users and non-users by collapsing across semesters and conducting an independent samples t-tests. We found no significant differences between groups on symptoms of depression, anxiety, or stress. However, OC users reported numerically fewer symptoms of depression compared to non-users ($p = .059$, $d = .13$), which is consistent with our findings from Study 1 (for details please see Appendix A: Supplementary Data).

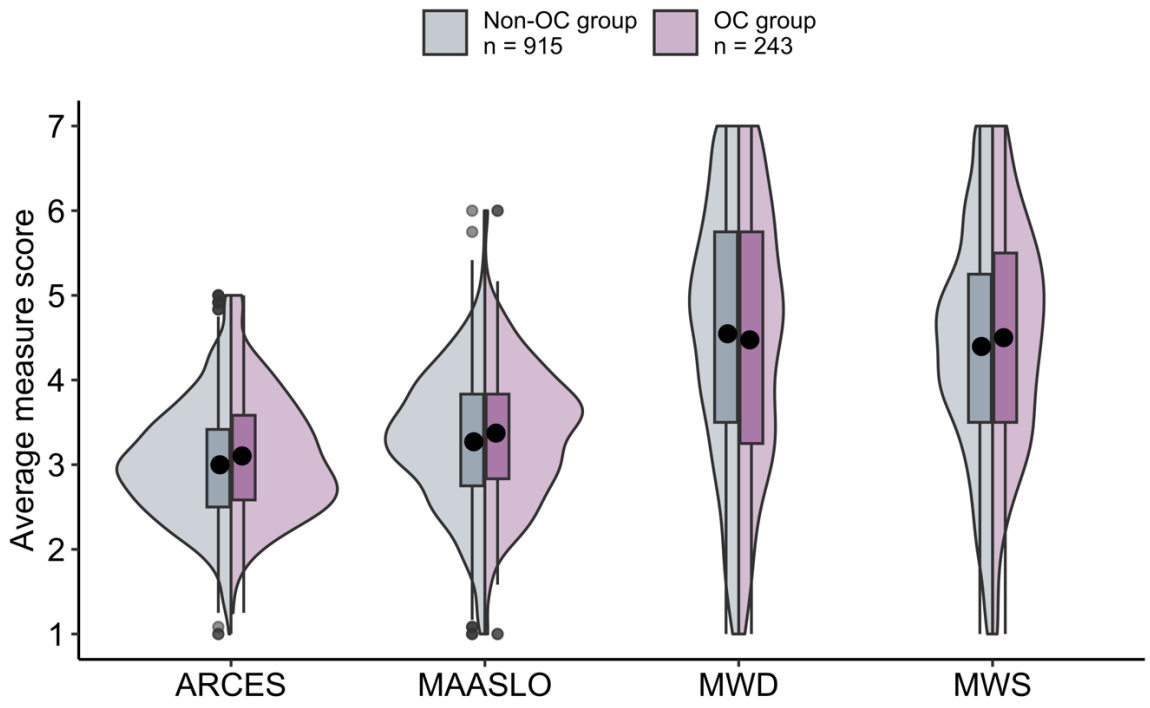


Figure 2.2. Split violin plot with box and whisker plots (boxplots) for each of the attention measures (MWS, MWD, MAASLO, and ARCES) as a function of OC group (Non-OC vs. OC) in Study 2.

Regressions. As in Study 1, we sought to examine whether OC use uniquely predicted our attention measures over and above symptoms of depression. As before, we conducted a series of hierarchical regressions. In the first step of these regressions we entered semester and DASS-depression as predictors. In the second step we added contraceptive use (Table 2.6). Semester and depression symptoms together accounted for a significant amount of variance in each measure of inattention. However, the present findings differed from those in Study 1. OC use did not explain additional variance in spontaneous or deliberate mind wandering, however OC use did explain significant additional variance over and above semester and depression in attention related errors and attention lapses (ARCES: $\beta = 0.14$, $p = .002$; MAASLO: $\beta = 0.16$, $p = .002$), such that OC use

uniquely predicted more attention related errors and more attention lapses (see ΔR^2 in Table 2.6). However, once again, we note that the amount of additional variance explained by OC use is quite small (e.g. less than 1%).

Table 2.6. Regression model statistics for Study 2

		Beta	*SE*	*p*
DV: MWS		**R^2 = .124, F = 54.58, SE = 1.30, Model *p* < .001**		
Step 1	Intercept	4.35	0.06	< .001
	Spring 2021	0.12	0.13	.348
	Fall 2021	0.13	0.08	.122
	DASS-Dep	0.49	0.04	< .001
Step 2		**R^2 = .127, F = 41.95, SE = 1.30, Model *p* < .001**		
		ΔR^2 = .003, *p for* ΔR^2 = .057		
	Intercept	4.31	0.06	< .001
	Spring 2021	0.13	0.13	.298
	Fall 2021	0.13	0.08	.099
	DASS-Dep	0.49	0.04	< .001
	OC status	0.18	0.09	.057
DV: MWD		**R^2 = .039, F = 15.49, SE = 1.49, Model *p* < .001**		
Step 1	Intercept	4.45	0.07	< .001
	Spring 2021	-0.05	0.14	.732
	Fall 2021	0.19	0.09	.042
	DASS-Dep	0.28	0.04	< .001
Step 2		**R^2 = .039, F = 11.62, SE = 1.49, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .802		
	Intercept	4.46	0.07	< .001
	Spring 2021	-0.05	0.14	.722
	Fall 2021	0.19	0.09	.044
	DASS-Dep	0.28	0.04	< .001
	OC status	-0.03	0.11	.802
DV: ARCES		**R^2 = .148, F = 66.83, SE = 0.64, Model *p* < .001**		
Step 1	Intercept	3.00	0.03	< .001
	Spring 2021	-0.04	0.06	.481
	Fall 2021	0.06	0.04	.134
	DASS-Dep	0.27	0.02	< .001
Step 2		**R^2 = .155, F = 52.85, SE = 0.64, Model *p* < .001**		
		ΔR^2 = .007, *p for* ΔR^2 = .002		
	Intercept	2.97	0.03	< .001
	Spring 2021	-0.03	0.06	.589
	Fall 2021	0.07	0.04	.096
	DASS-Dep	0.27	0.02	< .001
	OC status	0.14	0.05	.002
DV: MAASLO		**R^2 = .208, F = 101.20, SE = 0.71, Model *p* < .001**		
Step 1	Intercept	3.25	0.03	< .001
	Spring 2021	0.12	0.07	.073
	Fall 2021	0.06	0.04	.183
	DASS-Dep	0.36	0.02	< .001
Step 2		**R^2 = .215, F = 78.86, SE = 0.71, Model *p* < .001**		
		ΔR^2 = .006, *p for* ΔR^2 = .002		
	Intercept	3.21	0.03	< .001
	Spring 2021	0.14	0.07	.050
	Fall 2021	0.07	0.04	.134
	DASS-Dep	0.37	0.02	< .001
	OC status	0.16	0.05	.002

Note 1: DV = Dependent variable; MWS = Spontaneous Mind Wandering, MWD = Deliberate Mind Wandering, MAASLO = Mindful Attention Awareness Scale; ARCES = Attention-Related Cognitive Errors Scale
Note 2: Semester of data collection and depression symptoms are entered in Step 1. In Step 2, OC use is added to the model.
Note 3: ΔR^2 values may not exactly represent Step 2 R^2 – Step 1 R^2 due to rounding.

2.4 General Discussion

In two large samples, we did not find reliable and robust evidence to support the notion that OC use is detrimental to women's attentional engagement in everyday life. In Study 1, our findings indicated a very modest opposite effect such that individuals using OCs reported slightly better attention (as indexed by reports of significantly *less* spontaneous and deliberate mind wandering) than those in the non-OC group. Bayes Factors supported this conclusion indicating support for the alternative hypotheses when comparing spontaneous and deliberate mind wandering between OC users and non-users. Regression analyses in Study 1 revealed that OC use predicted less spontaneous and deliberate mind wandering even when semester of data collection and depression were controlled for; though this was not the case attention-related errors and attention lapses. While the method of Study 2 was identical to Study 1, the results of Study 1 were not replicated in Study 2. Specifically, in Study 2, we did not find significant differences between groups on the tendency to spontaneously and deliberately mind wander (with Bayes Factors finding evidence for the null hypotheses). While we consistently found no significant differences in attention related errors and attention lapses in both Study 1 and 2. The Bayes Factors were also consistent across studies in this regard, with the Bayes Factors indicating support for the null hypothesis when comparing reports of attention related errors between groups in Study 1 and Study 2. Our findings also indicated that when controlling for semester of data collection and depression in Study 2, OC use did not explain additional variance in spontaneous and deliberate mind

wandering. Moreover, after controlling for semester and depression in Study 2, OC users showed *more* attention-related errors and attention lapses than non-OC users. However, we draw particular attention to the small size of the effects revealed by the regression models, which appear to be unreliable and are unlikely to represent meaningful differences between groups in attentional engagement in everyday life. Our data also suggest there is considerable variability between cohorts and underscores the importance of collecting large samples when examining the relation between OC use and cognitive variables.

Our findings in Study 2 could be interpreted as being partially consistent with those reported by Raymond et al. (2019), who found that women using OCs reported *more* mind wandering on one subscale of the SIPI than naturally cycling women. While we found that OC users showed *less* mind wandering than non-OC users (Study 1) or no difference from non-OC users (Study 2), our regression analyses in Study 2 showed that OC use was associated with more attention-related errors and lapses, which are constructs that are positively related to mind wandering. However, we hasten to highlight the inconsistency across studies even in the present analyses and the concerningly small effect sizes, which are likely related to the variability of outcomes across studies. Given the inconsistency between these two large samples, drawing strong conclusions about the relation between OC use and attention using smaller samples is likely problematic regardless of the measures used.

That being said, we should also note several ways in which our studies differed from those reported by Raymond et al. (2019). First, we used a different measure of mind wandering: We opted to measure mind wandering using the MWS and MWD, which measure participants' general

tendencies to spontaneously and deliberate mind wander without reference to specific situations. In contrast, Raymond et al. used the SIPI, which measures mind wandering in very specific contexts (e.g., while working).[3] Given the different measurements employed, there is the possibility that each study captured different aspects of mind wandering. Second, with 28 women using OCs and 14 naturally cycling women, Raymond et al.'s study might not have been adequately powered to yield stable results. Because small sample sizes have been implicated as a significant limitation (Warren et al., 2014) of many studies examining the relation between OC use and cognition, in the present study we aimed to recruit considerably larger samples than those used in previous work.

Finally, our work suggests several directions for future investigations. First, we collected self-reports of (or *perceptions* of) everyday attentional engagement. Prior has shown that these self-reports are better predictors of real-world outcomes than behavioural tasks (Eisenberg et al., 2019). However, some may argue that self-reports are meta-cognitive judgments, and self-monitoring and memory can affect the accuracy of these reports (Koriat & Shitzer-Reichert, 2002). Future work could examine attention behaviourally on an attentional task to determine if performance differs between OC users and non-users (see Chapter 5). Second, our analyses utilized secondary data and as such, we lacked details on participants current and historical OC use (e.g., the specific brand/generation of OCs used, length of use, whether non-users had used OCs in the past). Since different brands/generations of OCs have slightly different combinations of exogenous

[3] The SIPI includes items such as "I find it difficult to concentrate with the TV on", "my mind seldom wanders from my work", and "I find that I easily lose interest in things that I have to do". This measure excludes mind wandering outside of the specific contexts listed (e.g., it would fail to capture difficulty concentrating in a noisy coffee shop, the tendency to daydream outside of work, and the loss of interest in leisure activities).

estrogen and progesterone (by dose and composition), some have noted that by collapsing across brand/generations it becomes impossible to learn whether there are effects specific to particular brands/generations (e.g., Beltz et al., 2015; Wharton et al., 2008). However, it is worth considering that splitting the OC group by brand/generation can result in small sample sizes in the resulting groups, which will lower statistical power. Indeed, while power analyses have demonstrated that a between subjects design requires 128 participants (64 participants per group) to detect a medium sized effect (Faul et al., 2007), few studies examining OC use and cognition reach this threshold to begin with – let alone after splitting the OC group with this specificity (see Gurvich et al., 2023; Warren et al., 2014). Nonetheless, we describe our attempt at such analyses in Chapter 4. Lastly, given that we collected data during the COVID-19 pandemic, it is possible that these circumstances and associated restrictions affected participants' reports of attentional engagement. One possibility is that individuals were more inattentive or distractible during the pandemic (Hicks et al., 2021) and this suppressed differences in attention between OC users and non-users. Future work could attempt to replicate our findings after most pandemic-related restrictions have been lifted (see Chapter 4).

In summary, we found little evidence that OC users have poorer everyday attentional abilities than do non-OC users. Our findings indicate that any differences between OC users and non-users are small and unlikely to translate into meaningful differences in attentional engagement between groups. Future research should assess the influence of OC use on other attention-related factors with well powered studies.

Chapter 3: On the Relation Between Oral Contraceptive Use, Boredom, and Flow

3.1 Introduction

Although considerable progress has been made in documenting the relations between OC use and various cognitive functions (see Gurvich et al., 2023 for a review), the associations between OC use and some cognitive functions remain unresolved. In some cognitive domains the existing results remain conflicting. This is particularly the case in the broad domain of human attention, in which, for example, the relation between OC use and mind wandering has been inconsistent across studies (Raymond et al., 2019; Chapter 2). In other cognitive domains the required studies examining OC use in the context of these domains have yet to be conducted. Such is the case with relations between OC use and other attention-related experiences, such as boredom and deep states of concentration (i.e., flow), which have yet to be explored. Here we take some steps to fill gaps in this literature by examining the link between OC use and two aspects of attentional engagement, namely, boredom and 'flow' (i.e., states of deep and effortless concentration; Marty-Dugas & Smilek, 2019).

Boredom and Flow

Boredom is a negative experience that tends to arise when the current situation is lacking meaning, interest, and/or challenge, and has been described as wanting to engage with a satisfying activity but being unable to do so (Eastwood et al., 2012). This aversive experience is thought to provide motivation to change one's behaviour or situation. The extant evidence suggests that there are individual differences in the propensity to experience boredom (Farmer & Sundberg, 1986; Struk et al., 2017; Malkovsky et al., 2012; Hunter & Eastwood, 2018; Tam et al., 2021). This

tendency has been most commonly measured using the Boredom Proneness Scale (BPS; Farmer & Sundberg, 1986) or the more recently refined Short Boredom Proneness Scale (SBPS; Struk et al., 2017). This individual trait appears to be related to other personality variables. For example, those higher in boredom proneness tend to also have poorer self-control and be lower in self-regulatory locomotion (the tendency to initiate and maintain goal-related actions) and higher in self-regulatory assessment (the tendency to evaluate and compare goal-related actions; Struk et al., 2016). Boredom proneness is also associated with poorer sustained attention in the form of more attention lapses, attention related cognitive errors, and mind wandering (Carriere, Cheyne, & Smilek, 2008; Cheyne, Carriere, & Smilek, 2006; Malkovsky et al., 2012; Damrad-Frye & Laird, 1989).

Boredom can be contrasted with the state of "flow," in which an individual is completely immersed in a task, loses track of time, and finds the experience to be intrinsically rewarding (Csikszentmihalyi, 1975/2000). This experience has also been described as being 'in the zone'. While flow has been measured and conceptualized in a variety of ways (Jackson & Marsh, 1996; Nakamura & Csikszentmihalyi, 2002; Swann et al., 2012; Marty-Dugas & Smilek, 2019), in recent work it has been characterized in terms of the experience of deep and effortless concentration (DEC), which is generally viewed as the core aspect of flow (see Nakamura & Csikszentmihalyi, 2002, p. 92; and Marty-Dugas & Smilek, 2019 for a discussion of conceptual issues in flow). Individual differences in the tendency to experience DEC has been measured using the Deep Effortless Concentration Internal (DECI: focusing on thoughts) and External (DECE: focusing on external tasks) scales (Marty-Dugas & Smilek, 2019). The available evidence suggests that the

propensity to experience DEC as indexed by the DECI/E is negatively correlated with the tendency to experience attention-related failures (Marty-Dugas & Smilek, 2019; Carriere, Cheyne, & Smilek, 2008; Cheyne, Carriere, & Smilek, 2006).

Some evidence suggesting a possible relation between OC use and boredom and flow comes from work showing that each of these—boredom, flow, and OC use—has been associated with activity in the default mode network (DMN; Petersen et al., 2014; Sharma et al., 2020; Pletzer et al., 2016; Ulrich et al., 2014; Danckert & Merrifield, 2018). Specifically, several studies have examined the relation between OC use and resting-state functional connectivity in the DMN (e.g., Petersen et al., 2014; Sharma et al., 2020; Pletzer et al., 2016). For example, Petersen and colleagues examined resting state connectivity in naturally-cycling females and females using an OC. Individuals in the naturally cycling group were further categorized by the phase of the menstrual cycle they were in at the time of scanning (luteal vs. follicular phase). The findings indicated that compared to non-users in the follicular phase, OC users showed decreased connectivity in some components of the DMN (Petersen et al., 2014). Interestingly, connectivity within the DMN tends to decrease during active cognitive tasks and increases during autobiographical remembering, thinking about the self, mind wandering, etc. (Raichle, 2015). Activity in the DMN has also been implicated in boredom and flow. For instance, Ulrich and colleagues (2014) found decreased activation in a part of the DMN (the medial prefrontal cortex; mPFC) during a condition in which people experienced flow compared to a condition in which they experienced boredom. Along similar lines, Danckert and Merrifield's (2018) work on the neural correlates of boredom also implicated the DMN.

The Present Investigation

In the present studies, we investigated whether there was a link between OC use and boredom and flow proneness. We examined these relations using data from beginning of term surveys administered to undergraduates at the University of Waterloo. The surveys consisted of a large battery of psychological questionnaires and included items assessing OC use, as well as measures of the tendency to experience boredom (the Short Boredom Proneness Scale; Struk et al., 2017), and of internal and external flow proneness (the Deep Effortless Concentration Internal and External scales; Marty-Dugas & Smilek, 2019).

The surveys also included a measure of depression (as part of the Depression Anxiety Stress Scale-21; Antony et al., 1998), which provided us with the opportunity to examine the relation between OC use and boredom and flow proneness while controlling for symptoms of depression. Prior work has established links between mood, boredom, and flow. Specifically, this work has shown that negative mood (and depression) is related to higher levels of boredom (Farmer & Sundberg, 1986; van Hooff & van Hooft, 2015; Goldberg et al., 2011; Isacescu et al., 2016; LePera, 2011) and less flow (Ullén et al., 2012). Many studies have shown links between OC use and mood (Skovlund et al., 2016; Hamstra et al., 2017; Keyes et al., 2013; Toffol et al., 2012; Duke et al., 2007; Cheslack-Postava et al., 2015), though the directionality of this relation has been contested. Given these possible associations, and to account for the possible confounding effects of depression, we thought it prudent to control for these symptoms in our analyses.

Lastly, since our measures of interest were included in multiple semesters of data collection, we were able to aggregate the data across these semesters to achieve reasonably large

samples sizes as well as test for replicability. Accordingly, we divided the data into two large samples. Sample 1 included data from Fall 2021 and Winter 2022. We used analyses of Sample 1 as the foundation for a pre-registered replication, which we refer to as Sample 2, and which included data from Fall 2022 and Winter 2023. To address the possible confound of time, we statistically controlled for the semester of data collection when assessing the relations between OC use, boredom, and flow.

3.2 Sample 1

3.2.1 Method

3.2.1.1 Participants

Participants consisted of undergraduate students enrolled the University of Waterloo who indicated their sex as female. Participants received partial course credit in exchange for completing the Pre-screen and Mass Testing surveys (see below). Participants were excluded from each semester based on the criteria outlined in the Data Cleaning section below. The Fall 2021 cohort included 1315 females, of which 450 were excluded. This left 865 participants, with 190 using OCs and 675 non-OC users who were not using any hormonal contraceptives. The Winter 2022 cohort was 1402 females and 733 were excluded, leaving 669 participants, with 153 OC users and 516 non-OC users. We collapsed across these two semesters to create Sample 1, which included a total of 1534 participants, with 343 participants using OCs and 1191 non-OC users.

3.2.1.2 Pre-screen and Mass Testing Surveys

We collected data for this Sample at the University of Waterloo as a part of the Prescreen survey and the Mass Testing survey. These surveys were administered to undergraduates enrolled

in psychology courses and included a series of questions administered at the beginning of each semester in close succession. The Prescreen survey included items asking about sex, gender, age, and hormonal birth control use. The hormonal birth control item was, "Are you currently using one of the following methods of birth control?" Participants responded by selecting from a list that included: oral contraception (i.e., birth control or "the pill"), birth control patch, vaginal ring, birth control injection, copper IUD, hormonal IUD, hormonal implant, none of the above, and prefer not to answer. Other items asked participants whether they were currently being treated for depression and anxiety. The Mass Testing survey included a large battery of questionnaires. Relevant to the present study are 1) the Boredom Proneness Scale – Short Form (Struk et al., 2017), 2) the Deep Effortless Concentration – Internal, and the Deep Effortless Concentration – External scales (Marty-Dugas & Smilek, 2019), and 3) the Depression Anxiety and Stress Scale-21 (Antony et al., 1998).

3.2.1.3 Data Cleaning

We utilized a similar data cleaning procedure as in our prior work (see Chapter 2). Exclusion criteria was determined a priori unless otherwise stated.

In Fall 2021, we excluded participants for a) use of a hormonal contraceptive other than OCs (N = 12), b) use of an IUD (Copper N = 11, Hormonal N = 60), or c) failing to disclose whether or not they used a hormonal contraceptive (N = 94). To avoid mental health as a possible confound[4], we also excluded participants who reported that they were currently being treated for depression (N = 145; OC N = 54, non-OC N = 91), or currently being treated for anxiety (N = 60;

[4] The results do not meaningfully change when the participants undergoing mental health treatment are included.

OC N = 24, non-OC N = 36). We also removed participants who did not respond to these items inquiring about mental health treatment (depression: N = 12; anxiety: N = 4). We also conducted data quality checks and eliminated poor quality data based on participants' patterns of responses. Specifically, participants were excluded from the analyses if 1) the number of clicks they made was fewer than the number of required responses per page of a survey (N = 0), 2) their responses were faster than 1-second per scale item (N = 34; we reasoned that participants needed at least 1-second per item to read and respond to the item in good faith; if they were faster than this we removed them because this may indicate they were responding randomly), and if 3) participants responded to fewer than half of the items on a scale (N = 2; responses on items for a given scale were averaged to arrive at the scale scores). Finally, to ensure our sample consisted of females of reproductive age, the data were analyzed both before and after removal of participants based on this age criterion. The removal of participants based on age did not impact the outcomes in a meaningful way. Below are reported the analyses of data after the removal of participants based on the age criterion. This included the removal of participants for either not reporting their birth year (N = 6) or being older than 45 (N = 7).

In Winter 2022, we applied the same exclusion criteria as in Fall 2021 with one additional criterion: we first excluded participants who were already included in the Fall 2021 cohort to ensure participants were not double counted (N = 306). Sixteen participants were excluded for using a hormonal contraceptive other than OCs and 64 participants were excluded because they used an IUD (Copper N = 13, Hormonal N = 51). We also removed an additional 90 participants because they did not respond to the item on hormonal contraceptive use. One hundred and thirty-

six (OC N = 54, non-OC N = 82) were excluded because they were currently being treated for depression and 59 (OC N = 23, non-OC N = 36) were excluded because they were currently being treated for anxiety. Twenty-one participants were also removed because they did not disclose whether or not they were currently being treated for depression or anxiety. We again checked for an excluded participants with poor data quality using the same three criterion as we applied in Fall 2021. In this process, 30 participants were excluded for speeding through a survey (using the same 1-second per item criterion as in Fall 2021) and an additional 4 participants were also excluded because completed fewer than 50% of the items on the DASS. Like Fall 2021, we analyzed the data with and without exclusions based on age. This did not change the results in a meaningful way. The below analyses exclude participants who did not report their birth year (N = 6) or had an age greater than 45 (N = 1).

3.2.1.4 Materials

***The Short Boredom Proneness Scale* (SBPS).** The Boredom Proneness Scale – Short Form is an 8-item measure used to assess the tendency to experience boredom (Struk et al., 2017). Participants respond to statements such as "I find it hard to entertain myself" and "In most situations, it is hard for me to find something to do or see to keep me interested" and rate them on how typical the statements are of themselves on a 7-point scale that included anchors from 1 – *strongly disagree* to 7 – *strongly agree*. No items are reverse coded. Higher scores indicate a greater tendency to experience boredom.

Deep, Effortless Concentration Internal* (DECI) *Scale and Deep, Effortless Concentration External* (DECE) *Scale. The DECI and DECE are trait-level measures of flow

during internal tasks (such as thinking or remembering) and external tasks (such as sports of hobbies; Marty-Dugas & Smilek, 2019). Each scale consists of eight items. Participants rate the frequency with which they experience internal and external flow. They respond to statements such as "When thinking/performing an external task, I get completely engaged without having to work at it". Items are rated on a 7-point scale which include anchors from 1 – *never* to 7 – *always*. Higher scores indicate a greater frequency of flow experiences during internal or external tasks.

Depression Anxiety Stress Scale-21 **(DASS-21).** The DASS is a 21-item measure assessing symptoms of depression, anxiety, and stress over the previous week (Antony et al., 1998). Participants rate items such as "I felt that I had nothing to look forward to" (depression), "I was worried about situations in which I might panic and make a fool of myself" (anxiety), and "I found it hard to wind down" (stress) on a scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). The scale contains seven items related to each of depression, anxiety, and stress and is scored on these three subscales (DASS-Dep, DASS-Anx, DASS-Stress). Higher scores on the scale items indicate higher levels of these experiences.

3.2.2 Results and Discussion

We used (R Core Team 2019) to perform all analyses. We used the psych, stats, and basic R packages to perform the Null Hypothesis Significance Tests and Bayes Factor package to calculate Bayes Factors (BFs). We first conducted a series of planned comparisons between the OC and non-OC groups to determine whether there were differences between OC users and non-

users on each of our measures[5]. We then conducted a series of hierarchical regressions predicting the measures with OC use while statistically controlling for depression symptoms and the semester the data was collected.

3.2.2.1 Descriptive Statistics

Descriptive statistics for each measure as a function of semester (Fall 2021 vs. Winter 2022) and group (OC vs. Non-OC) are presented in Table 3.1. All scales showed high reliabilities, with Cronbach alphas of .81 or greater (Table 3.2; left panel). Pearson correlations between the measures within each group are provided in Table 3.2 (right panel). Figure 3.1 includes Boxplots depicting each of the measures as a function of OC use condition (averaged across semesters).

[5] We also compared depression, anxiety, and stress symptoms across OC and non-OC groups. However, since this was not a research question of interest in the current paper, these analyses are included in the Appendix A: Supplementary Data.

Table 3.1. Descriptive statistics of measures by semester and group for Sample 1

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Fall 2021	Non-OC group	SBPS	675	3.41	1.16	0.25	-0.47
		DECE	675	4.17	1.32	0.05	-0.50
		DECI	675	4.07	1.23	0.09	-0.03
		DASS-Dep	675	0.93	0.74	0.69	-0.40
		DASS-Anx	675	0.84	0.68	0.85	0.04
		DASS-Stress	675	1.08	0.65	0.37	-0.46
	OC group	SSBPS	190	3.19	1.10	0.05	-0.81
		DECE	190	4.16	1.26	-0.07	−0.56
		DECI	190	4.13	1.22	0.10	-0.21
		DASS-Dep	190	0.81	0.73	0.95	0.20
		DASS-Anx	190	0.79	0.69	0.79	-0.34
		DASS-Stress	190	1.05	0.65	0.39	-0.43
Winter 2022	Non-OC group	SBPS	516	3.46	1.12	0.09	-0.68
		DECE	516	4.28	1.28	0.02	-0.27
		DECI	516	4.17	1.16	0.15	-0.19
		DASS-Dep	516	0.92	0.76	0.80	-0.08
		DASS-Anx	516	0.77	0.67	0.89	0.15
		DASS-Stress	516	0.97	0.69	0.63	-0.06
	OC group	SBPS	153	3.45	1.10	0.34	-0.66
		DECE	153	4.37	1.27	0.12	-0.58
		DECI	153	4.08	1.18	0.11	0.18
		DASS-Dep	153	0.81	0.72	1.19	0.81
		DASS-Anx	153	0.79	0.64	0.94	0.43
		DASS-Stress	153	0.99	0.64	0.76	0.24

Note. SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 3.2. Cronbach alphas (left panel) and Pearson correlations (right panel) of the OC group (above the diagonal; N = 343) and non-OC group (below the diagonal; N = 1191)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*
1. SBPS	.88	.88	--	-.37 **	-.30 **	.64 **	.46 **	.47 **
2. DECE	.97	.96	-.35 **	--	.49 **	-.28 **	-.21 **	-.27 **
3. DECI	.96	.95	-.31 **	.48 **	--	-.25 **	-.14 *	-.20 **
4.DASS-Depression	.91	.90	.54 **	-.18 **	-.15 **	--	.73 **	.73 **
5. DASS-Anxiety	.83	.81	.38 **	-.14 **	-.14 **	.67 **	--	.79 **
6. DASS-Stress	.84	.84	.40 **	-.16 **	-.15 **	.72 **	.76 **	--

Note. SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.
* p = .05, ** p < .001

Planned Comparisons. We collapsed across semester to conduct a series of independent samples t-tests comparing OC users and non-users on measures of boredom proneness and flow (Figure 3.1). To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .017 (.05 / 3). We also calculated Bayes Factors to determine the evidence we had for the alternative or null hypotheses. For the measure of boredom proneness (i.e., the SBPS) there was no significant difference between OC users and non-users, $t(569.8) = 1.81$, $p = .071$, $d = .11$, and the Bayes Factor ($BF_{10} = 0.32$), indicated there is moderate evidence for the null hypothesis. There were also no significant differences between OC users and non-users on measures of external flow (i.e., the DECE), $t(567.1) = 0.51$, $p = .610$, $d = .03$, and internal flow (i.e., the DECI), $t(556.4) = 0.12$, $p = .906$, $d = .00$. The Bayes Factors for external ($BF_{10} = 0.08$) and internal ($BF_{10} = 0.07$) flow revealed strong evidence for the null hypothesis in both cases.

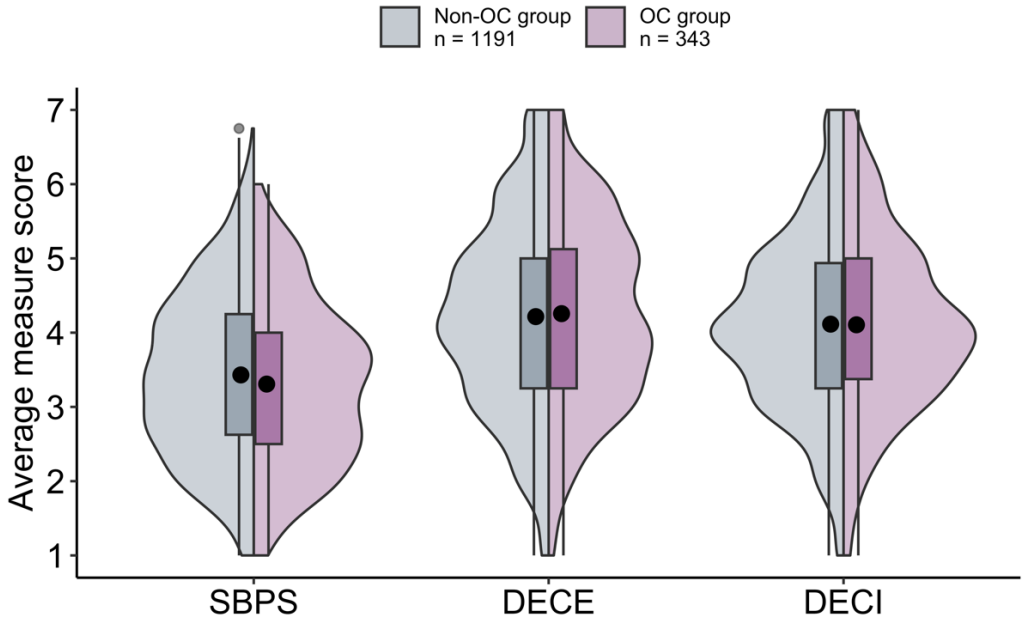


Figure 3.1. Split violin plots with box and whisker plots (boxplots) for each of the measures (SBPS, DECE, and DECI) as a function of OC use in Sample 1.

Regressions. To determine whether oral contraceptive use could predict boredom and flow proneness over and above symptoms of depression and the semester of data collection, we conducted a series of hierarchical regressions. We entered semester and DASS-depression as predictors in the first step and then added oral contraceptive use in the second step (see Table 3.3).

As can be seen in Table 3.3, when semester and depression symptoms were entered in Step 1 they accounted for a significant amount of overall variance in boredom proneness and internal and external flow measures. More specifically, in Step 1 both semester and depression symptoms accounted for a significant amount of unique variance when predicting the SBPS and DECE, but only depression symptoms (and not semester) accounted for significant and unique variance in the DECI. The inclusion of OC use in Step 2 did not explain additional variance in any outcome

variable (see ΔR^2 in Table 3.3). In Step 2, semester and depression symptoms continued to predict significant unique variance in the SBPS and DECE, while depression symptoms alone (not semester) continued to predict significant unique variance in the DECI.

Table 3.3. Regression model statistics for Sample 1

		Beta	*SE*	*p*
DV: SBPS		**R^2 = .321, F = 361.10, SE = 0.94, Model *p* < .001**		
Step 1	Intercept	3.36	0.03	< .001
	Winter 2022	0.10	0.05	.032
	DASS-Dep	0.86	0.03	< .001
Step 2		**R^2 = .321, F = 240.70, SE = 0.94, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .608		
	Intercept	3.36	0.03	< .001
	Winter 2022	0.10	0.05	.031
	DASS-Dep	0.86	0.03	< .001
	OC status	-0.03	0.06	.608
DV: DECE		**R^2 = .042, F = 33.97, SE = 1.27, Model *p* < .001**		
Step 1	Intercept	4.17	0.04	< .001
	Winter 2022	0.14	0.07	.038
	DASS-Dep	-0.35	0.04	< .001
Step 2		**R^2 = .042 , F = 22.63, SE = 1.27, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .997		
	Intercept	4.17	0.05	< .001
	Winter 2022	0.14	0.07	.038
	DASS-Dep	-0.35	0.04	< .001
	OC status	-0.00	0.08	.997
DV: DECI		**R^2 = .030, F = 23.22, SE = 1.19, Model *p* < .001**		
Step 1	Intercept	4.09	0.04	< .001
	Winter 2022	0.06	0.06	.320
	DASS-Dep	-0.28	0.04	< .001
Step 2		**R^2 = .030 , F = 15.57, SE = 1.19, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .583		
	Intercept	4.10	0.04	< .001
	Winter 2022	0.06	0.06	.318
	DASS-Dep	-0.28	0.04	< .001
	OC status	-0.04	0.07	.583

Note 1: DV = Dependent variable; SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale
Note 2: Step 1 included semester of data collection and depression symptoms as predictors. In Step 2, OC use was added to the model.

In summary, the findings from Sample 1 revealed there were no significant differences between OC users and non-users in terms of boredom proneness or flow. These patterns remained even when variance associated with the semester of data collection and depression symptoms was statistically partialled out in regression analyses.

3.3 Sample 2

The purpose for analyzing data from Sample 2 was to determine whether the results of Sample 1 would replicate in an independent sample of undergraduate OC users and non-users.

3.3.1 Method

3.3.1.1 Participants

As in Sample 1, all participants were undergraduates who reported their sex as female and who completed the Mass Testing survey and Prescreen questionnaire in exchange for partial course. Exclusions were made using the same exclusion criteria as Sample 1. These criteria were pre-registered on OSF (https://osf.io/f6xqa/) prior to beginning the analyses for Sample 2. Exclusions (and Ns) are described in the Data Cleaning section below. We collected data from 1348 female participants in Fall 2022. We excluded 767 participants according to the exclusion criteria, resulting in 581 participants in Fall 2022, with 86 OC users and 495 non-OC users. In Winter 2023, we collected data from 1289 female participants of which 856 were excluded (375 participants who were part of Sample 1 and 155 individuals who participated in Fall 2022), leaving 433 participants (76 OC users and 357 non-users). In total, Sample 2 included 1014 participants with 162 OC users and 852 OC non-users who were also not using any other hormonal contraceptives.

3.3.1.2 Pre-screen and Mass Testing Surveys

The Pre-screen and Mass Testing procedure was identical to Sample 1 with the exception that data was collected a year later at the beginning of two different semesters: Fall 2022 (September to October) and Winter 2023 (January to February). The items of the Pre-screen and

Mass Testing vary from semester to semester but the main measures of interest were the same across semesters.

3.3.1.3 Data Cleaning

The data cleaning procedure was identical to Sample 1. In Fall 2022, we began with 1348 female participants. We first excluded 374 participants who were already included in Sample 1. We then excluded 18 participants because they used an IUD or hormonal contraceptive other than an OC. We also excluded 12 participants for copper IUD use, 48 for hormonal IUD use, and 58 participants for declining to respond to the item about hormonal birth control use. To prevent mental health as a possible confound[6], we excluded 148 participants (OC N = 60, non-OC N = 88) who reported currently receiving treatment for depression and 14 participants who did not disclose whether or not they were currently receiving depression treatment. Participants currently receiving treatment for anxiety were also removed (N = 60; OC N = 21, non-OC N = 39) as well as participants who did not report whether or not they were receiving treatment for anxiety (N = 6). Next, we checked for and excluded participants with poor data quality. Twenty-three participants were excluded for moving too quickly through the scales of interest and an additional 3 participants were removed because they responded to fewer than half of the items on the DASS. Data analyses were completed with and without exclusions based on age. This did not change the results in a meaningful way. The below analyses exclude 3 participants who were older than 45 to ensure our sample consisted of pre-menopausal females.

[6] The inclusion of participants undergoing mental health treatment does not meaningfully change the results.

The Winter 2023 sample began with 1289 female participants. To ensure our samples were independent, we excluded 529 participants who were included in either Fall 2022 or the Sample 1 samples. Fifteen participants were removed for use of a hormonal contraceptive other than OC as well as 60 participants for use of an IUD (Copper N = 7; Hormonal N = 53). Fifty participants were excluded because they did not respond to the item inquiring about hormonal contraceptive use. We excluded 108 participants (OC N = 45, non-OC N = 63) currently receiving treatment for depression and 15 participants who did not respond to the item asking about depression treatment. We also excluded 45 participants because they were currently receiving treatment for anxiety as well as 3 participants who did not disclose whether or not they were receiving anxiety treatment. We also removed an additional 27 participants for poor data quality (N = 24 for speeded responses and N = 3 who did not respond to any items on the DASS). Post-hoc we removed 2 participants older than 45 and 2 participants who did not report their birth year to include participants within the reproductive age range. This did not meaningfully change the results.

3.3.1.4 Materials

The materials were identical to those used in Sample 1.

3.3.2 Results and Discussion

We again performed the analyses in R (R Core Team 2019) with the same packages that were used to analyze data from Sample 1. We conducted the same analyses as we implemented in Sample 1 and these analyses were pre-registered on OSF (see link above). Similar to Sample 1, we compared OC users and non-users on the measures of boredom and flow proneness and also

utilized hierarchical regressions to assess whether OC use could predict our measures over and above depression symptoms and the semester of data collection.

3.3.2.1 Descriptive Statistics

Descriptive statistics for both the OC and non-OC groups are presented in Table 3.4. All scales showed high reliabilities, with Cronbach alphas of .82 or greater (Table 3.5; right panel). We also include Pearson correlations between the measures within each group in Table 3.5 (left panel).

Table 3.4. Descriptive statistics of measures by semester and group for Sample 2

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Fall 2022	Non-OC group	SBPS	495	3.50	1.05	0.07	-0.61
		DECE	495	4.14	1.24	-0.01	-0.52
		DECI	495	4.02	1.19	0.17	-0.08
		DASS-Dep	495	1.01	0.76	0.70	-0.32
		DASS-Anx	495	1.02	0.72	0.59	-0.42
		DASS-Stress	495	1.17	0.69	0.40	-0.42
	OC group	SBPS	86	3.33	1.10	0.31	-0.49
		DECE	86	3.99	1.20	0.02	-0.44
		DECI	86	3.83	1.21	0.11	-0.51
		DASS-Dep	86	0.84	0.68	1.00	0.57
		DASS-Anx	86	0.93	0.78	0.80	-0.46
		DASS-Stress	86	1.20	0.71	0.25	-0.85
Winter 2023	Non-OC group	SBPS	357	3.65	1.10	-0.04	-0.68
		DECE	357	4.16	1.29	−0.03	−0.35
		DECI	357	4.15	1.25	-0.03	-0.40
		DASS-Dep	357	1.03	0.73	0.47	-0.55
		DASS-Anx	357	0.98	0.70	0.58	-0.32
		DASS-Stress	357	1.15	0.68	0.20	-0.65
	OC group	SBPS	76	3.04	0.93	0.88	0.56
		DECE	76	4.38	1.07	-0.16	-0.68
		DECI	76	4.17	1.13	-0.01	0.10
		DASS-Dep	76	0.76	0.58	0.68	-0.36
		DASS-Anx	76	0.74	0.60	0.97	0.27
		DASS-Stress	76	1.11	0.65	0.45	-0.54

Note. SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 3.5. Cronbach alphas (left panel) and Pearson correlations (right panel) of the OC group (above the diagonal; N=162) and non-OC group (below the diagonal; N = 852)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*
1. SBPS	.86	.85	--	-.36 **	-.39 **	.56 **	.46 **	.45 **
2. DECE	.96	.95	-.35 **	--	.42 **	-.26 *	-.34 **	-.26 *
3. DECI	.95	.94	-.28 **	.43 **	--	-.29 **	-.27 **	-.32 **
4.DASS-Depression	.87	.90	.54 **	-.23 **	-.16 **	--	.59 **	.67 **
5. DASS-Anxiety	.84	.82	.40 **	-.19 **	-.15 **	.70 **	--	.74 **
6. DASS-Stress	.84	.85	.48 **	-.22 **	-.18 **	.73 **	.80 **	--

Note. SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.
* p = .05, ** p < .001

Planned Comparisons. Boxplots depicting each of the measures as a function of OC use condition (averaged across semesters) are shown in Figure 3.2. To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .017 (.05 / 3). When we collapsed across semesters, we found that OC users reported significantly less boredom proneness than non-users, $t(232.9) = 4.16$, $p < .001$, $d = 0.35$, $BF_{10} = 251.18$. This comparison follows the same pattern of results found for boredom proneness in Sample 1 (though this comparison was not statistically significant in Sample 1). The Bayes Factor indicates there is extreme evidence for the alternative hypothesis. Also, as in Sample 1, there were no significant differences between groups on the DECE, $t(239.3) = 0.25$, $p = .807$, $d = 0.02$, $BF_{10} = 0.10$, or DECI, $t(230.5) = 0.87$, $p = .387$, $d = 0.07$, $BF_{10} = 0.14$. For these flow measures, Bayes Factors indicate there is moderate evidence for the null hypothesis.

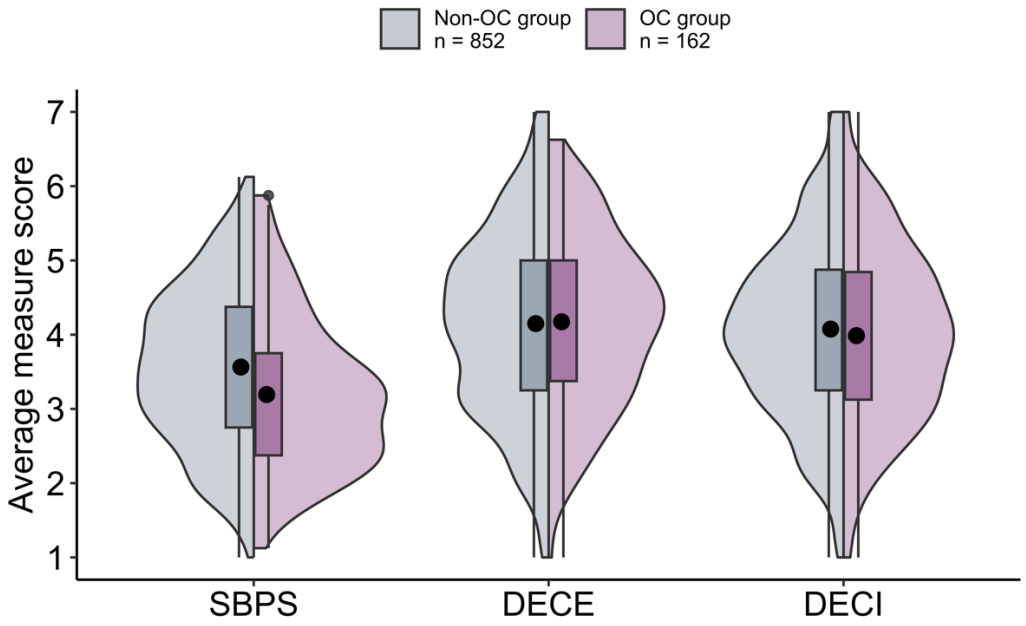


Figure 3.2. Split violin plot with box and whisker plots (boxplots) for each of the measures (SBPS, DECE, and DECI) as a function of OC group (Non-OC vs. OC) in Sample 2.

Regressions. To mirror our analyses of Sample 1 and to further investigate the differences in boredom proneness found in the present Sample, we conducted a series of hierarchical regressions predicting scores on our boredom and flow measures. We entered the semester of data collection and depression symptoms (measured on the DASS) as predictors in Step 1 and then added OC use as a predictor in the second step (see Table 3.6). In Step 1, the semester of data collection and depression symptoms together accounted for an overall significant amount of variance in each dependent measure. When the unique variance explained by each measure was considered, depression was a unique predictor of all measures, while semester (Winter 2023) only uniquely predicted internal flow (measured by the DECI). When OC use was added as a predictor

in Step 2, its predictiveness varied across the dependent measures. Specifically, when boredom proneness was the dependent measure, the inclusion of OC use in Step 2 improved the model, with OC use and depression – but not semester of data collection – accounting for unique variance. This outcome differed from Sample 1. Consistent with Sample 1, however, for external flow (indexed by the DECE) we found that the addition of OC use in the second step did not explain additional variance. In this step, depression continued to be the only predictor of unique variance. When predicting internal flow (indexed by the DECI) we found the addition of OC use in Step 2 did not explain additional variance; both semester of data collection and depression symptoms continued to be unique predictors of DECI as they were in Step 1 (see ΔR^2 in Table 3.6).

Table 3.6. Regression model statistics for Sample 2

		Beta	*SE*	*p*
DV: SBPS		**R^2 = .297 , F = 213.50, SE = 0.90, Model *p* < .001**		
Step 1	Intercept	3.48	0.04	< .001
	Winter 2023	0.07	0.06	.236
	DASS-Dep	0.80	0.04	< .001
Step 2		**R^2 = .302 , F = 145.50, SE = 0.90, Model *p* < .001**		
		ΔR^2 = .005, *p for* ΔR^2 = .009		
	Intercept	3.51	0.04	< .001
	Winter 2023	0.07	0.06	.198
	DASS-Dep	0.79	0.04	< .001
	OC status	-0.20	0.08	.009
DV: DECE		**R^2 = .056 , F = 29.74, SE = 1.21, Model *p* < .001**		
Step 1	Intercept	4.12	0.05	< .001
	Winter 2022	0.08	0.08	.303
	DASS-Dep	-0.39	0.05	< .001
Step 2		**R^2 = .056 , F = 19.95, SE = 1.21, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .532		
	Intercept	4.13	0.05	< .001
	Winter 2023	0.08	0.08	.292
	DASS-Dep	-0.40	0.05	< .001
	OC status	-0.07	0.10	.532
DV: DECI		**R^2 = .036 , F = 18.72, SE = 1.19, Model *p* < .001**		
Step 1	Intercept	3.99	0.05	< .001
	Winter 2023	0.17	0.08	.027
	DASS-Dep	-0.29	0.05	< .001
Step 2		**R^2 = .038 , F = 13.32, SE = 1.19, Model *p* < .001**		
		ΔR^2 = .002, *p for* ΔR^2 = .116		
	Intercept	4.01	0.05	< .001
	Winter 2022	0.17	0.08	.023
	DASS-Dep	-0.30	0.05	< .001
	OC status	-0.16	0.10	.116

Note 1: DV = Dependent variable; SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale
Note 2: Step 1 included semester of data collection and depression symptoms as predictors. In Step 2, OC use was added to the model.

3.4 Combined Analyses

While there are advantages to separating the overall data set into two samples as we did above, there are also benefits to combining the data and analyzing them as a single sample. Specifically, combining the data into a single sample has the advantage of 1) increasing statistical power to detect smaller effects and 2) allowing us to observe the overall outcome for effects that

were inconsistent across samples. Accordingly, we combined the two samples and conducted the same analyses as were conducted on each sample individually. We were particularly interested in determining whether the difference in boredom proneness between OC users and non-users found to be statistically significant in Sample 2 and only numerically in Sample 1 would emerge as a statistically significant difference in the combined sample. Furthermore, although we did not find significant differences across OC users and non-users for internal or external flow proneness in either sample, we entertained the possibility that when the samples are combined into one large sample there might be sufficient statistical power to detect such differences. The combined sample included all participants from Samples 1 and 2 who met the inclusion criteria resulting in a sample of 2547 participants, with 504 OC users and 2043 non-users[7].

3.4.1 Results and Discussion

Analyses were performed in R (R Core Team 2019) using the same packages as in Samples 1 and 2.

3.4.1.1 Descriptive Statistics

In the combined sample all scales had Cronbach alphas of .82 or greater (see Table 3.7; left panel), indicating high reliabilities. Pearson correlations between the measures (collapsed across all semesters) within each group are presented in Table 3.7 (right panel).

[7] Like in Samples 1 and 2, we also conducted the combined analyses with the inclusion of participants undergoing treatment for depression, anxiety, and/or psychosis. This again did not meaningfully change the results.

Table 3.7. Cronbach alphas (left panel) and Pearson correlations (right panel) of the OC group (above the diagonal; N = 505) and non-OC group (below the diagonal; N = 2043)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*
1. SBPS	.88	.87	--	-.36 **	-.32 **	.61 **	.45 **	.45 **
2. DECE	.96	.96	-.35 **	--	.47 **	-.27 **	-.25 **	-.27 **
3. DECI	.95	.95	-.30 **	.46 **	--	-.26 **	-.18 *	-.25 **
4.DASS-Depression	.90	.90	.54 **	-.20 **	-.15 **	--	.68 **	.71 **
5. DASS-Anxiety	.83	.82	.39 **	-.16 **	-.14 **	.68 **	--	.77 **
6. DASS-Stress	.84	.85	.43 **	-.18 **	-.16 **	.73 **	.78 **	--

Note. SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.
* p = .05, ** p < .001

Planned Comparisons. Figure 3.3 shows the mean of each measure (SBPS, DECE, and DECI) as a function of OC use averaged across all semesters. To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .017 (.05 / 3). When the data were collapsed this way, OC users reported significantly less boredom proneness (on the SBPS) than non-users, $t(791.4) = 3.98$, $p < .001$, $d = 0.19$, with the Bayes Factor indicating extreme evidence for the alternative hypothesis, $BF_{10} = 102.71$. The analyses also revealed no significant differences between OC users and non-users in their reports of external flow (DECE), $t(797.02) = 0.67$, $p = .502$, $d = 0.03$, or internal flow (DECI), $t(779.8) = 0.51$, $p = .609$, $d = 0.03$, with the Bayes Factors for external ($BF_{10} = 0.07$) and internal ($BF_{10} = 0.06$) flow indicating strong evidence for the null hypotheses.

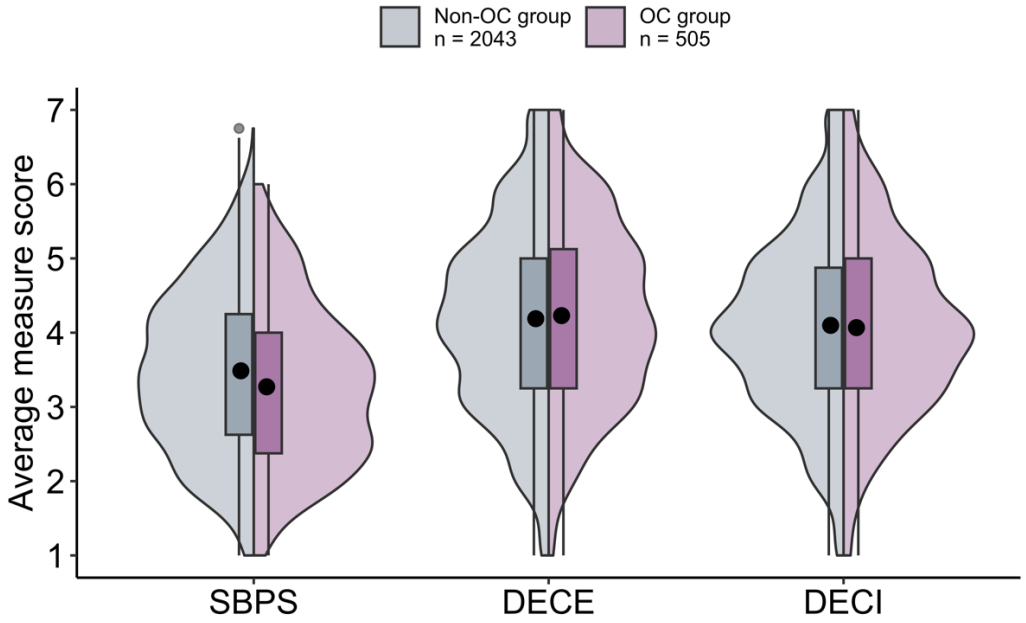


Figure 3.3. Split violin plot with box and whisker plots (boxplots) for each of the measures (SBPS, DECE, and DECI) as a function of OC group (Non-OC vs. OC) collapsed across Samples 1 and 2.

Regressions. We again conducted regression analyses to examine whether OC use could predict our boredom and flow measures over the above the semester of data collection and depression symptoms. The sample and depression symptoms were entered in the first step and OC use was added in the second step. In Step 1, all three models predicting our measures of interest accounted for a significant amount of variance (see Table 3.8). In this step, depression symptoms predicted unique variance in each measure, while both winter semesters (Winter 2022 and 2023) also predicted unique variance in SBPS. Only Winter 2022 predicted unique variance in DECE, however no semester predicted unique variance in DECI. When OC use was added in the second step, OC use did not explain significant additional variance in any of our measures. Symptoms of depression remained the only unique predictor of all measures. The Winter semesters continued to

predict unique variance in SBPS, Winter 2022 explained unique variance in DECE and semester did not predict unique variance in DECI. However, when predicting boredom proneness, the beta for OC use was close to, but did not reach significance (β = -0.09, p = .059).

Table 3.8. Regression model statistics for Combined Sample (Samples 1 and 2)

		Beta	*SE*	*p*
DV: SBPS		**R^2 = .313, F = 289.20, SE = 0.92, Model *p* < .001**		
Step 1	Intercept	3.39	0.03	< .001
	Winter 2022	0.10	0.05	.030
	Fall 2022	0.05	0.05	.334
	Winter 2023	0.12	0.05	.033
	DASS-Dep	0.84	0.02	< .001
Step 2		**R^2 = .314, F = 232.30, SE = 0.92, Model *p* < .001**		
		ΔR^2 = .001, *p for* ΔR^2 = .059		
	Intercept	3.40	0.03	< .001
	Winter 2022	0.10	0.05	.028
	Fall 2022	0.04	0.05	.398
	Winter 2023	0.11	0.05	.039
	DASS-Dep	0.83	0.02	< .001
	OC status	-0.09	0.05	.059
DV: DECE		**R^2 = .048, F = 32.04, SE = 1.25, Model *p* < .001**		
Step 1	Intercept	4.15	0.04	< .001
	Winter 2022	0.14	0.06	.034
	Fall 2022	-0.02	0.07	.806
	Winter 2023	0.06	0.07	.394
	DASS-Dep	-0.37	0.03	< .001
Step 2		**R^2 = .048, F = 25.64, SE = 1.25, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .732		
	Intercept	4.16	0.04	< .001
	Winter 2022	0.14	0.06	.034
	Fall 2022	-0.02	0.07	.790
	Winter 2023	0.06	0.07	.401
	DASS-Dep	-0.37	0.03	< .001
	OC status	-0.02	0.06	.732
DV: DECI		**R^2 = .033, F = 21.26, SE = 1.19, Model *p* < .001**		
Step 1	Intercept	4.08	0.04	< .001
	Winter 2022	0.06	0.06	.321
	Fall 2022	-0.07	0.06	.249
	Winter 2023	0.09	0.07	.181
	DASS-Dep	-0.28	0.03	< .001
Step 2		**R^2 = .033, F = 17.38, SE = 1.19, Model *p* < .001**		
		ΔR^2 = .001, *p for* ΔR^2 = .175		
	Intercept	4.09	0.04	< .001
	Winter 2022	0.06	0.06	.315
	Fall 2022	-0.08	0.06	.217
	Winter 2023	0.09	0.07	.197
	DASS-Dep	-0.28	0.03	< .001
	OC status	-0.08	0.06	.175

Note 1: DV = Dependent variable; SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale
Note 2: Step 1 included semester of data collection and depression symptoms as predictors. In Step 2, OC use was added to the model.

3.5 General Discussion

In Chapter 3, we explored the relations between OC use and the tendency to experience boredom and internal and external flow (defined as deep, effortless concentration). To examine these relations, we conducted a secondary analysis on a large data set collected across four semesters at an undergraduate institution, first splitting the data into two reasonably large samples, and then analyzing all the data as one large sample. While there were some differences in outcomes across samples, overall our analyses suggest that OC users report lower levels of boredom proneness than do non-users and that there are no differences between groups in their self-reported experiences of flow. The difference in boredom proneness between OC users and non-users was statistically significant in Sample 2 and when the two samples were combined, but not in Sample 1. Furthermore, regression analyses revealed that depression was a reliable predictor of both boredom and flow, and when depression and semester of data collection were entered as predictors, OC use was a significant unique predictor of boredom only in Sample 2, and not in Sample 1 or when the samples were combined. These results suggest that OC use may be associated with lower experiences of boredom, and that this relation could be explained by a third correlated variable, namely depression.

These findings extend prior work that examined the link between hormonal contraceptive use and cognition (see Gurvich et al., 2023 for a review) and particularly studies of OC-use and aspects of attention (Raymond et al., 2019; Chapter 2). Early findings in the domain of attention suggested that OC use might be associated with increased inattention in the form of mind wandering (Raymond et al., 2019). If interpreted in a causal way, these findings would suggest

that OC use is concerningly detrimental to attention. However, as noted earlier, in Chapter 2, we found that OC use was associated with a lower propensity to experience spontaneous and deliberate mind wandering as well as fewer attention related errors (i.e., better everyday attention). These effects did not replicate in a second independent sample, which showed no significant differences between OC users and non-users. More consistent with Chapter 2 than with Raymond et al. (2019) we find no significant differences between OC users and non-users in terms of the propensity to experience internal and external flow, and *lower* levels of boredom in OC users than non-users. Thus, our work suggests that OC use might be associated with either no changes in attention, or perhaps modest improvements in some attention-related domains. However, we hasten to remind the reader that the extant relations are correlational and in some cases complicated by correlated variations in depression.

Echoing the suggestions made in Chapter 2, this work points to several future directions. First, future work could examine flow and boredom proneness either as a function of OC type and/or in more homogeneous OC users to better understand how these differences may contribute to attention. Second given that the present studies examined the relation between OC use and the trait-level tendencies to experience boredom and flow, future work could also examine whether OC use is also associated with differences in boredom and flow at the state-level during a cognitive task. Studies such as these will bring us closer to a more complete understanding of the relations between OC use and various cognitive functions.

Chapter 4: Revisiting the relation between oral contraceptive use and attentional engagement in everyday life: The role of formulation

4.1 Introduction

The studies described in Chapters 2 and 3 revealed that OC use does not relate to a variety of attention-related factors (i.e., attention-related errors, attention lapses, spontaneous and deliberate mind wandering, and internal and external flow), with perhaps the exception of the trait propensity to experience boredom (Chapter 3). One potentially important limitation of both studies was a lack of information about the formulations of the OCs being used by those in the OC groups as well as their length of use. OC brands are known to vary in the doses of the synthetic hormones they include, dosing schedule, and estrogenic, progestenic, and androgenic activity. By not considering the various formulations of the OCs used, we may have obscured effects that are specific to particular formulations. To address this limitation, in the present study we collected data regarding OC brand and use duration in order to determine whether there were effects of specific formulations on attentional engagement. As in our previous studies, we collected self-report trait-level measures of attention related errors, spontaneous and deliberate mind wandering, attention lapses, boredom proneness, and flow. We were also able to analyze a measure of depression (as part of the Depression Anxiety Stress Scale-21; Antony et al., 1998), which allowed us to examine the above relations controlling for symptoms of depression. Finally, we aggregate data across two semesters of data (Fall 2023 and Winter 2024) to achieve a larger sample.

4.2 Method

Participants

Participants were undergraduate students enrolled in at least one psychology course at the University of Waterloo who indicated their sex as female. In exchange for completing the Pre-screen and Mass Testing surveys (see below), participants received partial course credit. Participants were excluded from each semester based on the criteria outlined in the Data Cleaning section below. The Fall 2023 sample included 1546 females, of which 650 were excluded. Eight hundred and ninety-six remained with 151 using OCs and 745 non-users. The sample in Winter 2024 included 1371 females and excluded 873 (including 389 participants who had already been included in the Fall 2023 sample). This left us with 498 participants, of which 50 were OC users and 447 were non-users. We collapsed across both semesters for a total of 1394 participants, with 201 OC users and 1192 were non-users.

Pre-screen and Mass Testing Surveys

Data was collected at the University of Waterloo as a part of the Pre-screen and Mass Testing surveys, which are questionnaires completed the beginning of each semester by undergraduates enrolled in psychology courses. The Pre-screen survey included items asking about sex, gender, age, current hormonal birth control use, length of current birth control use, current hormonal birth control brand name, past hormonal birth control use, and current pregnancy/breastfeeding. The hormonal birth control item was, “Are you currently using one of the following methods of birth control?” Participants responded by selecting from a list that included: oral contraception (i.e., birth control or “the pill”), birth control patch, vaginal ring, birth control injection, copper IUD, hormonal IUD, hormonal implant, none of the above, and prefer

not to answer. We used the OC brand provided by participants to derive the composition (the type and dose of ethinyl estradiol and/or progestin), the dosing schedule (monophasic, triphasic, or progestin only), as well as the estrogenic, progestenic, and androgenic activity of each OC (Dickey, 2021). Participants also responded to items on current treatment for depression and anxiety. The Mass Testing survey contains a large battery of questionnaires which included 6 questionnaires relevant to the present study: 1) the Attention Related Errors Scale (Carriere et al., 2008; Cheyne et al., 2006), 2) the Mindful Attention and Awareness Scale – Lapses Only (Carriere et al., 2008; Brown and Ryan, 2003), 3) the Mind Wandering – Spontaneous scale, and the Mind Wandering – Deliberate scale (Carriere et al., 2013), 4) the Short Boredom Proneness Scale (Struk et al., 2017), 5) the Deep Effortless Concentration – Internal, and the Deep Effortless Concentration – External scales (Marty-Dugas & Smilek, 2019), and 6) the Depression Anxiety and Stress Scale-21 (Antony et al., 1998).

Data Cleaning

We utilized a similar data cleaning procedure as in our prior work (see Chapters 2 and 3). Exclusion criteria were determined a priori unless otherwise stated. In Fall 2023, participants were excluded for 1) use of a hormonal contraceptive other than OCs (N = 21), 2) use of an IUD (Copper N = 7, Hormonal N = 82), 3) failing to disclose whether or not they used a hormonal contraceptive (N = 60), 4) current pregnancy or breastfeeding (N = 60), or 5) failing to disclose whether they were pregnant or breastfeeding (N = 38). To avoid the possible confound of mental health[8],

[8] Similar to the analyses in Chapter 2 and 3, we also analyzed the data in the present chapter with the inclusion of participants currently receiving treatment for a mental health concern. This did not meaningfully change the results with two exceptions. These effects will be noted in the results where they arise.

participants who reported that they were currently receiving treatment for depression (N = 148; OC N = 50, non-OC N = 98) or anxiety (N = 75; OC N = 22; non-OC N = 53) were excluded. Participants who did not respond to the items related to the reception of treatment for depression and anxiety were also excluded (N = 24). Data quality checks were conducted to eliminate poor quality data based on participants' patterns of responses. Participants were removed prior to analyses if a) the number of clicks they made was fewer than the number of responses per page of a survey (N = 0), b) their responses were faster than 1-second per scale item on more than 50% of the scales of interest (N = 61; to respond in good faith, we reasoned participants needed at least 1-second per item to read and respond. If they were faster than this on >50% of the scales we removed them because this may indicate they were responding randomly), and c) participants responded to fewer than half of the items on a scale of interest (N = 4; responses on items for a given scale were averaged to calculate scale scores). We analyzed the data with and without exclusions based on age (to target participants of reproductive age; 18-45 years old). This did not change the results in a meaningful way. The below analyses exclude participants who were older than 45 (N = 3) or did not report their year of birth (N = 3).

In Winter 2024, we applied the same exclusion criteria as Fall 2023 with one additional criterion: participants who were already included in the Fall 2023 samples were removed to ensure participants were not double counted (N = 389). Nineteen participants were excluded for use of a hormonal contraceptive other than OCs and 64 participants were removed for use of an IUD (Copper N = 12, Hormonal N = 52). Thirty-nine participants were excluded for failing to disclose whether or not they used a hormonal contraceptive. One hundred and thirteen participants were

removed because they indicated they were currently pregnant or breastfeeding and 16 were excluded for failing to disclose whether they were pregnant or breastfeeding. We excluded 105 participants (OC N = 24, non-OC N = 81) because they were currently receiving treatment for depression as well as 6 participants for not responding to this item. Fifty-seven participants were removed for receiving treatment for anxiety (OC N = 17, non-OC N = 40) and 3 participants were excluded for failing to disclose whether or not they were being treated for anxiety. We excluded participants with poor data quality based on the same criterion described for the Fall 2023 sample. Seventy-five participants were removed for speeded responses on the survey and 4 participants were excluded because they failed to respond to at least 50% of the items on the DASS or the ARCES. Like in Fall 2023, we analyzed the data with and without exclusions based on age (to target participants of reproductive age; 18-45 years old). This did not change the results in a meaningful way. The below analyses exclude participants who were older than 45 (N = 4) or did not report their year of birth (N = 2).

Materials

Here we utilize the same materials described in Chapters 2 (ARCES, MAASLO, MWS, MWD, and the DASS) and 3 (SBPS, DECI, DECE, and the DASS).

OC Formulations

In order to conduct our analyses by OC formulation, we collected the brand participants were using via the Pre-screen survey. Past work (e.g., Beltz et al., 2022; Hampson et al., 2022) has used information reported by Dickey (2021) to link OC brand names with composition, however, Dickey (2021) lists the United States' Food and Drug Administration (FDA) approved OCs, some

of which have different names in Canada. To identify the formulation and dosing schedule associated with a brand name, we conducted an internet search (using Google) for each brand name with the word "monograph" to locate each OC's product monograph[9] (usually available through the pharmaceutical manufacturers website), which contained each OCs' formulation and dosing schedule. In most cases, the ethinyl estradiol dose was noted in micrograms (mcg), while the progestin dose varied between milligrams (mg) and mcg. To ensure all doses were on the same scale, we converted progestin doses in mg to mcg (1 mg = 1000 mcg). Once we had the formulation and dosing schedule, we used the information reported by Dickey (2021) in Table 5 to identify the formulation equivalent (by matching the dose, dosing schedule, and type of ethinyl estradiol and/or progestin). Since OCs have undergone four major formulaic iterations ("generations") in the type of progestin used, we also sought to account for this variance in composition. The generations differ from one another in their molecular structure (the addition or removal of methyl or ethyl groups) which alter the biological activity of the progestin. Since earlier progestins (generations 1-3) were synthesized from testosterone, they have both progestenic and androgenic activity (i.e., they can bind to receptors for both progesterone and testosterone), while more modern progestins (generation 4) are synthesized to be anti-androgenic (i.e., made to bind specifically to progesterone receptors while preventing binding to testosterone receptors) (Dickey, 2021; p. 20-21). To identify these generations, we referred to Dickey (2021; p. 20-21), which noted the progestin name and corresponding generation. While generations can be helpful to better understand the activity of OCs, the estrogenicity, progestenicity, and androgenicity of each formulation can be examined on

[9] A drug monograph is a factual and scientific document that lists its name, classification, pharmacology, and indication, as well as dosage and administration (Government of Canada, 2020).

a finer, more continuous scale by taking into account the dose and potency of hormones used in each formulation. These hormonal activities were determined from assays conducted in human and rodent tissue (Dickey, 2021; Table 7)[10]. These activity values can also be ranked as low, intermediate low, intermediate high, or high (Dickey, 2021; Table 8).

We will first use the OC formulation data to investigate the link between OC formulation and trait-level attentional engagement to determine whether particular formulations are related to differences in attention. We will then collapse across OC compositions and compare OC users and non-users to test the replicability of our prior work.

4.3 Results

All analyses were conducted using R (R Core Team 2019). To perform Null Hypothesis Significance Tests we used the psych, stats, and basic R packages. To calculate Bayes Factors (BFs), we utilized the Bayes Factor package.

Our analyses consist of two parts: First, we conducted analyses considering only OC users, examining the link between OC composition and our trait-level attention measures to determine whether particular formulations are related to differences in attention; second, we conducted planned comparisons between OC users (collapsing across different OC compositions) and non-users to test the replicability of our prior findings.

Descriptive Statistics

[10] Estrogenic activity was derived from mouse uterine assays, progestenic activity from endometrial responses in humans, and androgenic activity from rat prostate assays (Dickey, 2021).

Descriptive statistics for each measure as a function of semester (Fall 2023 vs. Winter 2024) and group (OC vs. Non-OC) are presented in Table 4.1. All scales showed high reliabilities, with Cronbach alphas of .81 or greater (Table 4.2; left panel). Pearson correlations between the measures within each group are provided in Table 4.2 (right panel).

Table 4.1. Descriptive statistics of measures by semester and OC status

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Fall 2023	Non-OC group	ARCES	745	3.13	0.73	0.19	0.20
		MAASLO	745	3.42	0.81	-0.19	0.37
		MWS	745	4.62	1.36	-0.32	-0.21
		MWD	745	4.76	1.45	-0.38	-0.41
		SBPS	745	3.58	1.23	0.20	-0.60
		DECE	745	4.10	1.27	0.06	-0.37
		DECI	745	4.09	1.17	0.10	-0.32
		DASS-Dep	745	0.99	0.80	0.66	-0.47
		DASS-Anx	745	0.93	0.73	0.61	-0.43
		DASS-Stress	745	1.13	0.70	0.43	-0.40
	OC group	ARCES	151	3.12	0.76	0.12	−0.46
		MAASLO	151	3.49	0.80	0.02	-0.62
		MWS	151	4.57	1.37	-0.53	-0.14
		MWD	151	4.55	1.51	-0.17	-0.83
		SBPS	151	3.50	1.20	0.27	-0.40
		DECE	151	4.16	1.22	-0.16	-0.47
		DECI	151	3.90	1.23	0.04	-0.50
		DASS-Dep	151	0.86	0.75	0.92	0.04
		DASS-Anx	151	0.82	0.69	0.88	0.13
		DASS-Stress	151	1.08	0.65	0.43	-0.40
Winter 2024	Non-OC group	ARCES	447	3.07	0.67	0.07	0.28
		MAASLO	447	3.43	0.82	0.05	0.50
		MWS	447	4.59	1.25	-0.34	-0.08
		MWD	447	4.70	1.41	-0.30	-0.32
		SBPS	447	3.54	1.12	0.23	-0.32
		DECE	447	4.16	1.15	0.10	-0.21
		DECI	447	4.17	1.22	0.05	-0.08
		DASS-Dep	447	0.97	0.76	0.57	-0.64
		DASS-Anx	447	0.92	0.67	0.51	-0.50
		DASS-Stress	447	1.07	0.67	0.23	-0.69
	OC group	ARCES	50	3.10	0.65	0.24	-0.24
		MAASLO	50	3.56	0.72	0.04	4.15
		MWS	50	4.69	1.39	-0.49	0.67
		MWD	50	4.79	1.53	-0.41	-0.26
		SBPS	50	3.31	1.04	0.26	-0.47

DECE	50	4.13	1.15	0.17	-0.92
DECI	50	4.17	1.22	0.05	-0.08
DASS-Dep	50	0.79	0.63	0.75	-0.12
DASS-Anx	50	0.94	0.69	0.39	-1.18
DASS-Stress	50	1.19	0.59	0.13	-0.83

Note. ARCES = Attention Related and Cognitive Errors Scale, MAASLO = Mindful Attention Awareness Scale – Lapses Only, MWS = Mind Wandering Spontaneous scale, MWD = Mind Wandering Deliberate scale, SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 4.2. Cronbach alphas (left panel) and pearson correlations (right panel) of the OC group (above the diagonal; N=201) and non-OC group (below the diagonal; N = 1192)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1. MW-S	.90	.89	--	.46**	.45**	.61**	.40**	-.35**	-.26**	.30**	.29**	.33**
2. MW-D	.93	.90	.42**	--	.18 *	.34**	.20*	-.10	.01	.20 *	.19 *	.16 *
3. MAAS-LO	.88	.88	.47**	.16**	--	.55**	.34**	-.26**	-.22*	.25**	.29**	.38**
4. ARCES	.92	.91	.51**	.21**	.57**	--	.38**	-.35**	-.19*	.32**	.41**	.44**
5. SBPS	.88	.88	.44**	.15**	.55**	.45	--	-.32**	-.13	.62**	.47**	.45**
6. DECE	.93	.96	-.28**	-.01	-.24**	-.28**	-.33**	--	.49**	-.28**	-.26**	-.29**
7. DECI	.96	.95	-.25**	.04	-.21**	-.28**	-.24**	.48**	--	-.20*	-.13**	-.19**
8.DASS-Depression	.95	.92	.36**	.15**	.47**	.37**	.59**	-.24**	-.17**	--	.66**	.71**
9. DASS-Anxiety	.81	.82	.32**	.16**	.44**	.40**	.48**	-.19**	-.13**	.74**	--	.77**
10. DASS-Stress	.83	.85	.35**	.11**	.48**	.38**	.50**	-.21**	-.17**	.78**	.79**	--

Note. ARCES = Attention Related and Cognitive Errors Scale, MAASLO = Mindful Attention Awareness Scale – Lapses Only, MWS = Mind Wandering Spontaneous scale, MWD = Mind Wandering Deliberate scale, SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.
* p = .05, ** p < .001

Describing OC Composition

We provide the brand name, formulation and dose, dosing schedule, and hormonal activity for each OC participants reported using, as well as the number of participants who reported using that formulation in Table 4.3. Of the 201 OC users in our sample, 137 reported the brand they used (68%). We were able to identify the formulation for all 23 brands reported. Some formulations were branded under multiple names so although 23 different brands were reported, in total there were only 12 different formulations which varied by the ethinyl estradiol dose, progestin type, and/or progestin dose (Table 4.3).

We use these different ways of categorizing OCs to analyze the relation between OC use and attention. Most OCs consist of a package of 28 pills which includes 21-24 days of 'active' pills containing ethinyl estradiol and/or progestin and 4-7 days of inactive or placebo pills (though some brands only contain the active pills and patients are instructed not to take a pill for 4-7 days before starting a new package). The majority of OC users in our sample reported using a monophasic OC (111 / 137; 81%) in which patients receive a consistent dose of ethinyl estradiol and progestin in each their active pills. Fewer OC users reported use of a triphasic OC (19 / 137; 14%), in which patients receive a consistent dose of ethinyl estradiol across their active pills but an increasing dose of progestin each week (i.e., dose of progestin changes twice in a pack). A small number of OC users also reported using progestin only OCs (7 / 137; 5%) which contain no ethinyl estradiol, only a progestin (Table 4.3).

Within these different dosing schedules, OCs can vary further by other aspects of their formulation. While all monophasic and triphasic OCs are composed of both ethinyl estradiol and

progestin, ethinyl estradiol can vary by dose and estrogenic activity and the progestin can vary by type, dose, progestenic activity, and androgenic activity (since some progestins are synthesized from testosterone). Progestin only OCs are composed of only progestin and can vary by the type, dose, progestenic activity, and androgenic activity of the progestin. As we note earlier, estrogenic, progestenic, and androgenic activities range from low to high (Table 4.3). Two formulations (used by 4 participants) of OCs were not included in Dickey (2021) and as such, we could not determine the activity levels for those OCs. The participants without these activity levels are omitted from analyses by activity level.

We also assigned a generation for each progestin type. Most OCs in our sample were synthesized with a third generation progestin (104 / 137; 76%), while only 18 participants reported using an OC with a first generation progestin (13%), no participants reported using an OC with a second generation progestin (0%), and 15 participants using an OC containing a fourth generation progestin (11%).

Table 4.3. Oral contraceptive formulations by formulation and dose, dosing schedule, and estrogenic, progestenic, and androgenic activity

Brand name(s)	Dosing schedule	Formulation and dose	Progestin Generation	Estrogenic activity / rating	Progestenic activity / rating	Androgenic activity / rating	N
Freya, Mirvala, Marvelon	Monophasic	Ethinyl estradiol 30 mcg / Desogestrel 150 mcg	3	30 / intermediate low	1.5 / high	0.17 / intermediate low	9
Yasmin	Monophasic	Ethinyl estradiol 30 mcg / Drospirenone 3000 mcg	4	30 / intermediate high	1.5 / high	0 / low	3
Portia, Indayo, Seasonale, Microglynon 3, Ovima	Monophasic	Ethinyl estradiol 30 mcg / Levonorgestrel 150 mcg	3	25 / intermediate low	0.8 / intermediate low	0.45 / intermediate high	5
Mya, Yaz	Monophasic	Ethinyl estradiol 20 mcg / Drospirenone 3000 mcg	4	20 / intermediate low	1.5 / high	0 / low	10
Alysena, Alesse, Aviane	Monophasic	Ethinyl estradiol 20 mcg / Levonorgestrel 100 mcg	3	17 / low	0.5 / intermediate low	0.31 / intermediate high	71
Lolo	Monophasic	Ethinyl estradiol 10 mcg / Norethindrone Acetate 1000 mcg	1	12 / low	1.4 / high	0.64 / high	11
Diane-35, Teva-Cyproterone	Monophasic	Ethinyl estradiol 35 mcg / Cyproterone Acetate 2000 mcg	1	Could not categorize (formulation not in Dickey, 2021)			2
Linessa	Triphasic	Ethinyl estradiol 25 mcg / Desogestrel 100, 125, 150 mcg	3	25 / intermediate low	1.2 / intermediate high	0.14 / low	9
Tricira Lo	Triphasic	Ethinyl estradiol 25 mcg / Norgestimate 180, 215, 250 mcg	3	25 / low intermediate	0.3 / low	0.15 / low	9
Tri-Jordyna 28	Triphasic	Ethinyl estradiol 35 mcg / Norgestimate 180, 215, 250 mcg	3	35 / high	0.2 / low	0.15 / low	1
Movisse, Jencycla	Progestin Only	Norethindrone 250 mcg	1	0 / low	0.4 / low	0.13 / low	5
Slynd	Progestin Only	Drospirenone 4000 mcg	4	Could not categorize (formulation not in Dickey, 2021)			2
Not reported	Unknown	Unknown	Unknown	Unknown			64

OC Composition and Attention

Dosing Schedule

We conducted seven one-way analyses of variance (ANOVA) to determine whether differences in dosing schedules predicted our attention measures. We entered dosing schedule (monophasic, triphasic or progestin only) as a between participants factor and conducted an ANOVA with each attention measure as the dependent variable (Figure 4.1). Given that we had 111 monophasic OC users, but only 19 triphasic OC users and 9 progestin only OC users, we were under-powered to detect differences in the triphasic and progestin only groups. As such, these results should be interpreted with caution. There was no significant main effect of dosing schedule on attention related errors (as indexed by the ARCES), $F(2, 134) = 0.37$, MSE = 0.56, $p = .691$, $\eta_p^2 = 0.01$, no significant main effect of dosing schedule on attention lapses (as indexed by the MAASLO), $F(2, 134) = 1.05$, MSE = 0.57, $p = .354$, $\eta_p^2 = 0.02$, spontaneous mind wandering (as indexed by the MWS), $F(2, 134) = 0.26$, MSE = 2.07, $p = .771$, $\eta_p^2 = 0.00$, deliberate mind wandering (as indexed by the MWD), $F(2, 134) = 0.89$, MSE = 2.46, $p = .412$, $\eta_p^2 = 0.01$, boredom proneness (as indexed by the SBPS), $F(2, 134) = 0.55$, MSE = 1.30, $p = .581$, $\eta_p^2 = 0.01$, and internal flow (as indexed by the DECI), $F(2, 134) = 1.33$, MSE = 1.36, $p = .267$, $\eta_p^2 = 0.02$. There was, however, a significant main effect of dosing schedule on external flow (as indexed by the DECE), $F(2, 134) = 3.29$, MSE = 1.38, $p = .040$, $\eta_p^2 = 0.05$. Post-hoc tests revealed there were no significant differences between any of the dosing schedules: monophasic v. triphasic, $t(23.5) = 1.71$, $p = .101$, $d = .45$, monophasic v. progestin only, $t(6.4) = 1.59$, $p = .160$, $d = .79$, and triphasic v. progestin only, $t(9.2) = 0.62$, $p = .550$, $d = .30$. There were numerical differences such that monophasic OC users reported lower external flow than triphasic and progestin only users.

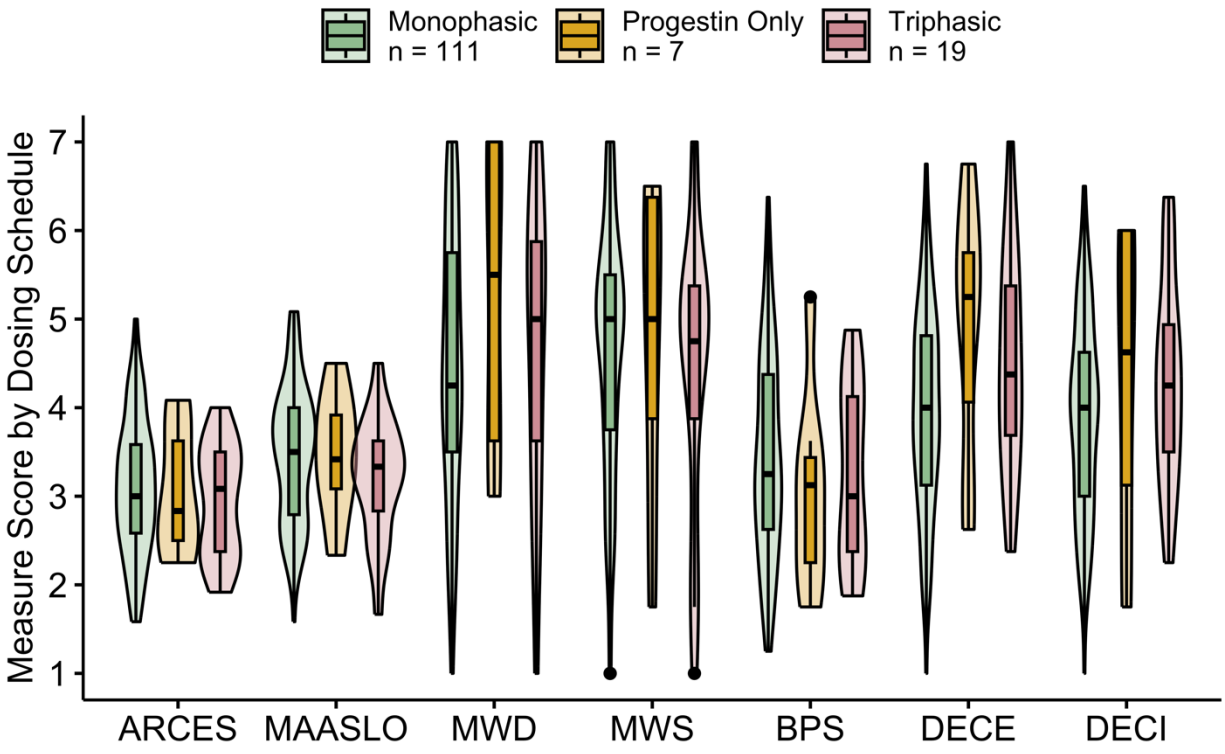


Figure 4.1. Violin plots with box and whisker plots (boxplots) for each of the measures (ARCES, MAASLO, MWD, MWS, SBPS, DECE, and DECI) as a function of OC dosing schedule.

Correlating Ethinyl-Estradiol Dose and Attention

To determine whether ethinyl-estradiol (EE) dose was related to differences in attention, we conducted seven spearman correlations. One correlation between EE and each attention measure (ARCES, MAASLO, MWS, MWD, SBPS, DECE, and DECI). We included all OC users who reported their brand (N = 137) regardless of dose and dosing schedule (including participants using progestin only OCs because they represented a true zero in terms of EE dose). Spearman correlations were chosen because the distribution of EE doses was not normal. There were no significant correlations between EE dose and any of our attention measures (Table 4.4). When

correlations were computed with only monophasic OC users included (N = 111), there was a significant positive correlation between EE dose and external flow $r(109) = .21$, $p = .025$, while all other correlations did not reach significance, rs < .15, all ps > .122. We lacked adequate power to compute meaningful correlations within the triphasic or progestin only groups (n's < 20).

Table 4.4. Spearman correlations of trait-level attentional engagement, ethinyl-estradiol dose, and progestin dose

Measure	*r* with EE dose	*r* with P dose
ARCES	$r(135) = -.13$, $p = .144$	$r(116) = -.02$, $p = .794$
MAASLO	$r(135) = -.08$, $p = .378$	$r(116) = -.02$, $p = .808$
MWS	$r(135) = -.12$, $p = .155$	$r(116) = .00$, $p = .973$
MWD	$r(135) = -.04$, $p = .674$	$r(116) = .08$, $p = .404$
SBPS	$r(135) = -.01$, $p = .887$	$r(116) = .01$, $p = .920$
DECE	$r(135) = -.14$, $p = .115$	$r(116) = .10$, $p = .303$
DECI	$r(135) = -.11$, $p = .196$	$r(116) = .14$, $p = .137$

Note. ARCES = Attention Related and Cognitive Errors Scale, MAASLO = Mindful Attention Awareness Scale – Lapses Only, MWS = Mind Wandering Spontaneous scale, MWD = Mind Wandering Deliberate scale, SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale; EE = Ethinyl-Estradiol; P = Progestin

Correlating Progestin Dose and Attention

We also investigated whether progestin dose was related to differences in attention by again computing seven Spearman correlations between progestin dose (which was non-normally distributed) and each of the attention measures. Since triphasic OC users receive 3 different doses of progestin in their pack, we excluded these participants (N = 19) from this analysis as it was unclear which dose to include in this correlation. As such, these correlations include monophasic and progestin only OC users (N = 118). We found no significant correlations between progestin

dose and reports of attention (Table 4.4). When examining only monophasic OC users, these correlations remained non-significant all *r*s < .12, all *p*s > .232. Again, since the triphasic and progestin only groups were small, we opted not to calculate these correlations with those groups individually.

OC Activity and Attention

Besides examining the relation between EE and progestin dose and attention, we also examined how the estrogenic, progestenic, and androgenic activity of OCs related to our attention measures. The benefit of examining this activity (rather than just dose) is that it takes into account both the dose and the potency of the composite hormones. Activity values range on a continuous scale (with higher numbers indicating a greater potency; see Dickey, 2021; Table 7). These values have also been categorized into 4 levels (ranging from low to high; see Dickey, 2021; Table 8). Since little work has been conducted using these activity levels (to our knowledge Beltz et al., 2022 was the first to conduct such an analysis) we planned to analyze our data both using the continuous activity values in regression analyses predicting each attention measure of interest as well as using the activity level categories (4 levels; low to high; as per Beltz et al., 2022) as predictors in separate regression analyses of each attention measure. However, collapsing activity levels into categories created multicollinearity between two levels of activity (intermediate high androgenicity and intermediate low progesticity), which violated the independence assumption of regression. As such, we only include the regression analyses for the continuous activity levels below.

To investigate the role of (continuous) activity levels we regressed estrogenic activity, progestenic activity, and androgenic activity on each of our attention measures of interest. Activity did not predict a significant amount of variance in any of our attention measures (Table 4.5). The one significant unique predictor was observed when predicting internal flow (DECI), wherein androgenic activity was a significant negative predictor; however, we interpret this with caution given that the overall regression model was not significant.

Table 4.5. Regression models using continuous hormonal activity values to predict each attention measure

	Beta	***SE***	***p***
DV: ARCES	**R^2 = .02 , F = 0.90, SE = 0.75, Model *p* = .443**		
Intercept	3.08	0.06	< .001
Est. Activity	-0.02	0.01	.191
Prog. Activity	0.09	0.16	.562
And. Activity	0.18	< .001	.696
DV: MAASLO	**R^2 = .01, F = 0.49, SE = 0.76, Model *p* = .686**		
Intercept	3.45	0.07	<.001
Est. Activity	-0.01	0.01	.638
Prog. Activity	0.19	0.16	.231
And. Activity	0.04	0.47	.940
DV: MWS	**R^2 = .02, F = 0.95, SE = 1.40, Model *p* = .418**		
Intercept	4.66	0.12	<.001
Est. Activity	-0.04	0.02	.098[11]
Prog. Activity	0.15	0.29	.604
And. Activity	-0.35	0.86	.685
DV: MWD	**R^2 = .04, F = 1.61, SE = 1.56, Model *p* = .190**		
Intercept	4.56	0.13	<.001
Est. Activity	-0.04	0.02	.101
Prog. Activity	0.30	0.32	.357
And. Activity	-1.77	0.95	.065
DV: SBPS	**R^2 = .02, F = 0.83, SE = 1.15, Model *p* = .478**		
Intercept	3.42	0.09	<.001
Est. Activity	0.00	0.02	.793
Prog. Activity	0.29	0.24	.231
And. Activity	0.68	0.70	.337
DV: DECE	**R^2 = .01, F = 0.50, SE = 1.17, Model *p* = .684**		
Intercept	3.94	0.10	<.001
Est. Activity	0.00	0.02	.825
Prog. Activity	0.05	0.24	.852
And. Activity	-0.68	0.72	.342
DV: DECI	**R^2 = .04, F = 1.76, SE = 1.17, Model *p* = .158**		
Intercept	4.05	0.10	<.001
Est. Activity	0.00	0.02	.974

[11] When participants receiving treatment for depression, anxiety, and/or psychosis are included, estrogenic activity becomes a significant and unique predictor of spontaneous wandering ($\beta = 0.04$, $p = .047$).

Prog. Activity	0.08	0.24	.756
And. Activity	-1.45	0.71	.045 *

Note 1: DV = Dependent variable; ARCES = Attention Related Errors Scale, MAASLO = Mindful Attention Awareness Scale – Lapses Only, MWD = Mind Wandering Deliberate scale, MWS = Mind Wandering Spontaneous scale, SBPS = Boredom Proneness Scale – Short Form, DECE = Deep Effortless Concentration – External Scale, DECI = Deep Effortless Concentration – Internal Scale, Est. Activity = Estrogenic Activity, Prog. Activity = Progestenic Activity, And. Activity = Androgenic Activity
Note 2: Activity values were standardized and centered prior to regression analyses

Generation

Finally, to determine whether progestin generation predicted the attention measures we conducted seven one-way ANOVAs entering progestin generation as a between participants factor and each attention measure as the dependent variable in a separate ANOVA. We note that we are likely under-powered to detect small or medium sized differences in those using a first or fourth generation progestin since these groups at quite small (ns $\leq$ 16). We also lack data on second generation progestins since none of our participants reported use of OCs with this type of progestin. As such, the following results should be considered to be preliminary.

There was no significant main effect of generation on attention related errors, $F(2, 134) = 0.20$, MSE = 0.56, $p = .815$, $\eta_p^2 = 0.00$, attention lapses, $F(2, 134) = 0.28$, MSE = 0.58, $p = .759$, $\eta_p^2 = 0.00$, spontaneous mind wandering, $F(2, 134) = 0.15$, MSE = 2.07, $p = .861$, $\eta_p^2 = 0.00$, deliberate mind wandering, $F(2, 134) = 0.85$, MSE = 2.46, $p = .430$, $\eta_p^2 = 0.01$, boredom proneness, $F(2, 134) = 0.11$, MSE = 1.31, $p = .892$, $\eta_p^2 = 0.00$, external flow, $F(2, 134) = 0.33$, MSE = 1.44, $p = .719$, $\eta_p^2 = 0.01$, or internal flow, $F(2, 134) = 0.89$, MSE = 1.37, $p = .415$, $\eta_p^2 = 0.01$ (Figure 4.2).

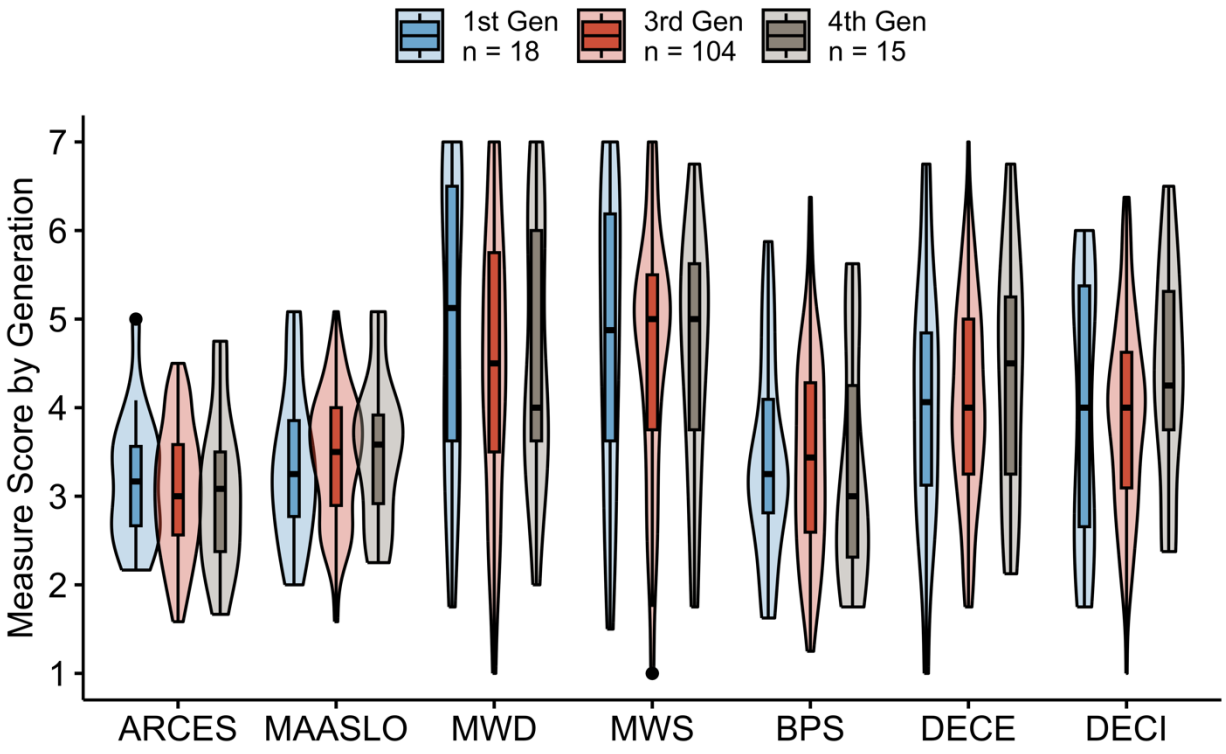


Figure 4.2. Violin plots with box and whisker plots (boxplots) for each of the measures (ARCES, MAASLO, MWD, MWS, SBPS, DECE, and DECI) as a function of OC generation (Gen).

Comparing OC users who reported brand versus OC users who did not report brand

Since we found no significant differences between OC users (by dosing schedule, ethinyl-estradiol dose, progestin dose, activity level, or generation), we determined it was appropriate to collapse across OC users who reported their brand. However, given that it was possible that OC users who reported their brand differed from those who did not report their brand, we also sought to compare these two groups. To do this, we conducted seven planned comparisons (one on each of attention measures) comparing OC users who reported their brand (n = 137) to OC users who did not report their brand (n = 64). To control for multiple comparisons, we utilized a Bonferroni

correction, setting alpha at .007 (.05 / 7). As can be seen in Figure 4.3, we found OC users who reported their brand did not significantly differ from OC users who did not report their brand the ARCES, $t(128.3) = 1.18$, $p = .240$, $d = .18$, MAASLO, $t(114.9) = 1.70$, $p = .092$, $d = .26$, MWS, $t(138.5) = 0.26$, $p = .794$, $d = .04$, MWD, $t(135.0) = 0.63$, $p = .531$, $d = .09$, SBPS, $t(114.7) = 0.97$, $p = .334$, $d = .15$, DECE, $t(120.8) = 0.88$, $p = .379$, $d = .13$, and DECI, $t(108.4) = 0.07$, $p = .944$, $d = .01$.

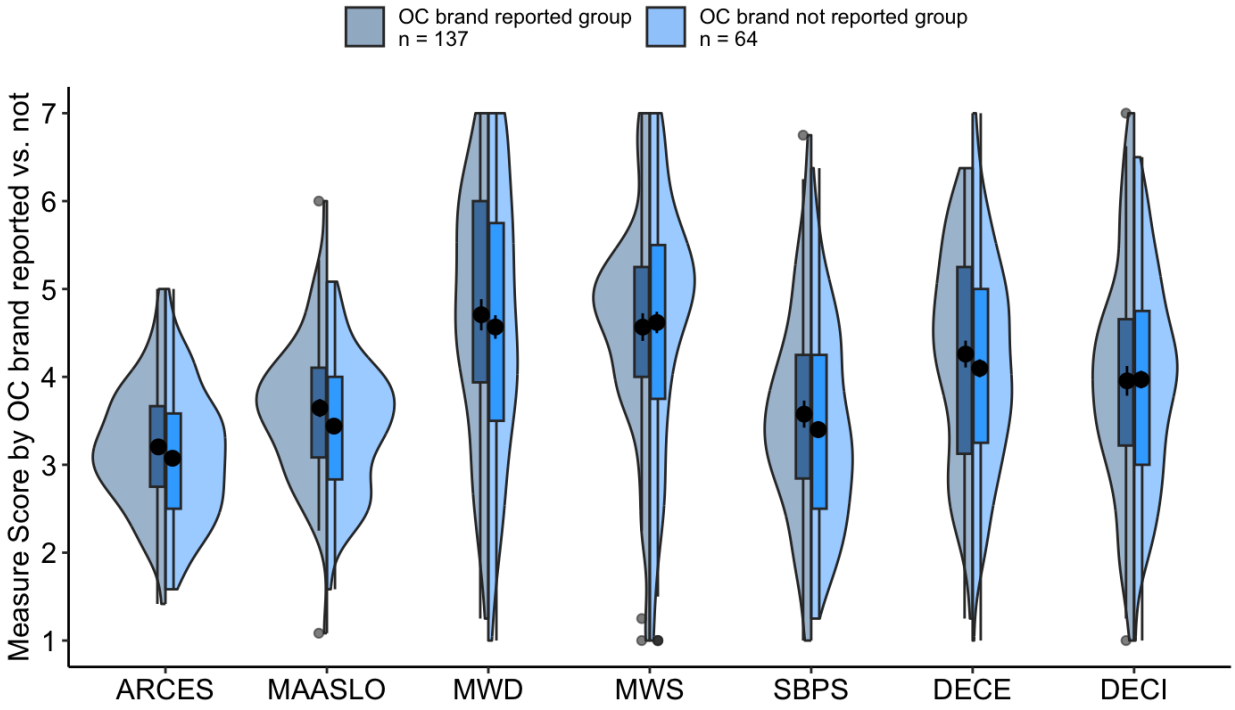


Figure 4.3. Split violin plots with box and whisker plots (boxplots) for each of the measures (ARCES, MAASLO, MWD, MWS, SBPS, DECE, and DECI) as a function of OC brand reported vs. not.

OC use and Attention

Since we found no significant differences between OC users (by dosing schedule, ethinyl-estradiol dose, progestin dose, activity level, generation, or reporting of brand), we collapsed across OC users to create one homogenous group of OC users. This allowed us the opportunity to again attempt to replicate our prior findings examining attention related errors, attention lapses, spontaneous and deliberate mind wandering, boredom, and flow in OC users and non-users.

To do this, we conducted seven planned comparisons, comparing OC users and non-users on each of our attention measures of interest. To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .007 (.05 / 7). We found no significant differences between groups on attention related errors, $t(265.8) = 0.16$, $p = .871$, $d = .01$, attention lapses, $t(278.5) = 1.37$, $p = .172$, $d = .10$, spontaneous mind wandering, $t(265.7) = 0.04$, $p = .970$, $d = .00$, deliberate mind wandering, $t(263.7) = 1.08$, $p = .283$, $d = .09$[12], boredom, $t(274.4) = 1.24$, $p = .217$, $d = .09$, internal flow, $t(264.7) = 1.61$, $p = .109$, $d = .13$, or external flow, $t(274.8) = 0.29$, $p = .773$, $d = .02$ (Figure 4.4).

[12] When participants currently receiving mental health treatment are included, there is a significant difference between groups on deliberate mind wandering, such that OC users report significantly less deliberate mind wandering than non-users ($p = .004$, $d = .19$). A similar numerical difference was observed on spontaneous mind wandering but this difference was not statistically significant. Interestingly, similar effects were found in Chapter 2 (Study 1). No other comparisons meaningfully changed.

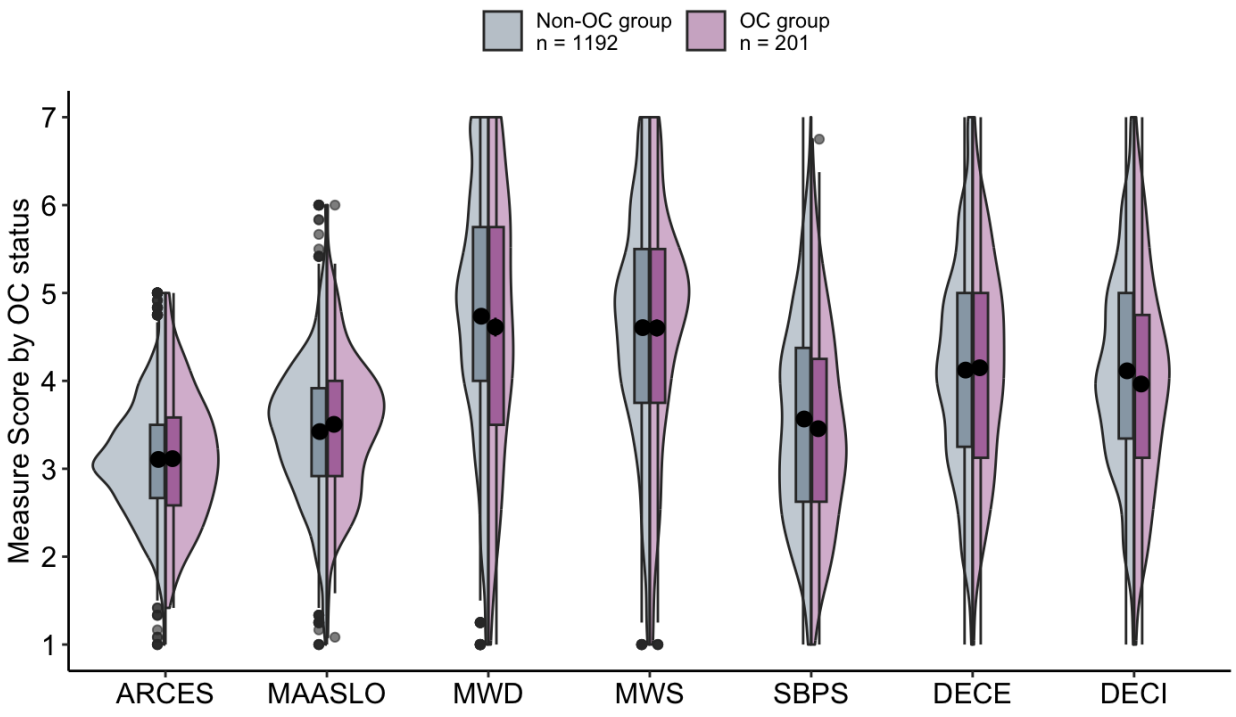


Figure 4.4. Split violin plots with box and whisker plots (boxplots) for each of the measures (ARCES, MAASLO, MWD, MWS, SBPS, DECE, and DECI) as a function of OC use or non-use.

4.4 Discussion

In the present study, we extended our prior work examining the relation between OC use and attention by exploring how different aspects of OC use formulation may be associated with everyday attention. Specifically, within OC users, we investigated whether ethinyl-estradiol dose, progestin dose, dosing schedule, generation, and hormonal activity were related to attention. Our findings indicated that none of these aspects of OC formulation were related to significant differences in attention. However, when we split our OC group based on factors such as dosing schedule and generation, some of the subgroups were quite small (triphasic and progestin only OC users; OC users using a first, second, and fourth generation OC). As such, we lacked sufficient

power to detect medium and small sized effects in attention that may exist between subgroups. Given that we relied on participants' reports of OC brand to determine formulation, we also tested whether OC users who reported their brand significantly differed on our attention measures of interest from OC users who did not report their brand. We again found no significant differences between groups. Because our overall sample was reasonably large and comparable to those used in our previous studies, the present results suggest that our previous findings—which were based on comparisons of OC non-users and OC users without distinguishing between OC formulations—were likely not influenced by differences in OC formulation across individuals in the OC users.

Since we found no differences among OC users, we collapsed across all OCs to create one homogeneous OC group in order to attempt to replicate our prior work (Chapters 2 and 3) investigating whether there were differences in attention between OC users and non-users. We replicated most of this work, showing that there were no significant differences in attention related errors, attention lapses, spontaneous and deliberate mind wandering, and flow between OC users and non-users. We failed to replicate our prior work demonstrating that OC users tended to be significantly less boredom prone than non-users, however, in the present study we did find a nominal difference in boredom proneness between groups in this same direction that we observed before.

There were a few limitations of this study that could be addressed in future work. First, as we noted earlier, some subgroups of OC dosing schedule and generation were small. When examining dosing schedule, we had a large group of monophasic OC users but very small groups of triphasic and progestin only OC users. Most OC users used a third generation OC, with few

using a first or fourth generation OC and no participants using a second generation OC. So while we did not find differences in attention by OC dosing schedule or generation, it makes it difficult to conclude whether those differences do not exist or whether those differences have a medium or small effect size, which would require larger samples to detect.

Chapter 5: Oral Contraceptive Use and Sustained Attention

5.1 Introduction

Sustained attention can be construed as the process of maintaining limited resources necessary for conscious awareness on a specific stimulus or task for an extended period of time (Parasuraman & Davies, 1982). This process is critical for successful behavior in many everyday contexts, including learning (López et al., 2005), driving (Walker & Trick, 2018), reading (Segal, 2023), and playing a sport (Swann et al., 2012). Some evidence that OC might be associated with levels of sustained attention comes from several studies exploring whether OC users and non-users differ in their trait-level tendency to remain engaged during everyday tasks (Raymond et al., 2019; Chapters 2 and 4). These studies have used questionnaire measures and relied on participants' subjective reports of their recollected levels of attentional engagement during the day-to-day lives. Together, these studies suggest that OC use is not strongly and reliably linked with tendency to experience inattention in everyday life.

While the aforementioned studies examining the link between OC use and self-reported everyday attention are certainly informative, a more direct assessment of the relation between OC use and sustained attention would involve observing performance and self-reports of sustained attention of OC users and non-users during well-established sustained attention tasks. While no such studies have been reported to date, there are a couple of reports (Silber et al., 1987; Grikšienė & Rukšėnas, 2009) in which OC use has been examined in the context of reaction time tasks in which participants made speeded responses to stimulus onset; presumably, overall performance in these tasks requires sustained attention. Silber et al. (1987) examined a group of women who were administered OCs for a month and abstained from OCs for another month, showing that there were

no significant differences in performance on a response time task between the two time points (on vs. off OCs). However, the sample was small (N = 20) and accuracy data were not reported, making the findings difficult to interpret. Grikšienė and Rukšėnas (2009) had OC users and non-users complete a reaction time task, in which participants responded to auditory or visual stimuli, as well as a speeded letter cancellation task, in which participants crossed out as many target letters on a page within a one-minute time limit. OC users responded significantly faster than non-users on the reaction time task, but the groups did not significantly differ on performance on the speeded letter cancellation task. However, again, Grikšienė and Rukšėnas' sample was small (OC N = 10, non-OC N = 15). Critically, the tasks in the abovementioned studies were note well suited for isolating sustained attention processes, either because the tasks were relatively short (the letter cancellation task was 1 minute) and/or because the data were reported in the aggregate, precluding an assessment of how attention sustains over time on task.

A more suitable task for assessing the relation between OC use and sustained attention would be the widely used Sustained Attention to Response Task (SART; Robertson et al., 1997), which was designed to elicit and index sustained attention failures within a relatively short timeframe. In the SART, participants are presented digits from 1 to 9 one at a time at a constant rate on a computer screen. Participants are required to respond to each digit presented with a key press (go trials; ~90% of trials), except when that digit is 3 in which case participants are asked to withhold a response (no-go trials; ~10% of trials). Performance on the SART is measured by examining the proportion of no-go trials in which participants fail to withhold a response (commission errors), the proportion of go trials in which participants fail to respond (omission errors), go trial reaction time. A skill index, which takes into account possible trade-offs between

commission errors and reaction time, can also be computed (Seli et al., 2015; Seli 2016). Poorer performance on the SART (i.e., speeded reaction times, more errors) has been linked with greater self-reports of attention lapses and attention related errors in everyday life (Cheyne et al., 2006).

To gain a more complete picture of attentional states during cognitive tasks, researchers have also measured subjective reports of attentional engagement. One such approach involves inserting intermittent thought probes during a task that asks participants to report on their level of attentiveness just before the probe appeared (Giambra, 1995). For example, Seli et al., (2016) included within the SART task intermittent probes that inquired whether participants were on task, intentionally mind wandering, or unintentionally mind wandering. The differentiation between intentional and unintentional mind wandering has turned out to be important for two reasons: First, prior work has shown that participants engage in intentional and unintentional mind wandering in the laboratory tasks (e.g., Giambra, 1995; Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Wammes, Risko, & Smilek, 2015) and in everyday life (e.g., Carriere, Seli, & Smilek, 2013; Seli, Carriere, & Smilek, 2015; Seli, Smallwood, Cheyne, & Smilek, 2015); and second, these different types of mind wandering have different consequences for performance (e.g., Seli et al., 2016; Wammes et al., 2016; Seli, Wammes et al., 2016). A complementary approach involves asking participants after a task is completed to retrospectively report on other their level of attention during the task. For example, some researchers (Drody et al., 2023; Albert & Smilek, 2023) have asked participants whether they were engaging with task-irrelevant content (i.e., media multitasking) while they completed the primary experimental task. In this type of design, task performance (e.g., SART performance) provides behavioural metrics of attentional engagement,

while the thought probes and retrospective questions provide additional subjective measures of attention (Seli et al., 2015; Seli 2016; Drody et al., 2023; Albert & Smilek, 2023).

Building on previous research, here we aimed to examine whether OC use is associated with differences in subjective reports of attentional engagement and performance on a sustained attention task. To examine this question, we recruited a large sample of undergraduate females at the University of Waterloo to complete the SART online. As in previous studies, throughout the SART, participants also responded to intermittent thought probes, which asked participants whether they were on task, intentionally mind wandering, or unintentionally mind wandering just before the probe appeared. Participants were also asked to retrospectively report on their media multitasking behaviour after completing the SART. We used SART performance, thought probe responses, and post-task media multitasking reports as separate but convergent measures of attention during the task.

Also following the SART, as part of a post-study questionnaire, participants were asked to report on their experiences with pre-menstrual dysphoric disorder (PMDD; assessed with the Pre-menstrual Screening Symptom Tool; PSST; Studies 1 and 2), symptoms of depression, anxiety, and stress (assessed by the Depression, Anxiety, and Stress Scale-21; DASS-21; Study 2), and their current and past hormonal contraceptive use. We assessed PMDD because prior work had suggested that artificial changes in estrogen and progesterone in naturally cycling women with PMDD led to increases in their symptoms, including negative mood and impaired functioning (Schmidt et al., 1998). Given this association, we thought it would be prudent to control for PMDD symptoms in our analyses of OC use and attention. Given that OC use has been associated variously with increased positive mood (Hamstra et al., 2017; Keyes et al., 2013; Toffol et al.,

2012), or increased negative mood (Anderl et al., 2020; 2022; Skovlund et al., 2016), or no changes in mood (Duke et al., 2007; Cheslack-Postava et al., 2015), in Study 2 we measured depression to examine the relation between OC use and attention while controlling for symptoms of depression. Finally, we also asked about current and past hormonal contraceptive groups to be able to categorize participants as current OC users, prior OC users, and never OC users as some work has suggested that even prior use of an OC may be associated with an enduring increased risk of depression (Anderl et al., 2020; 2022), which could affect attentional performance (Seli et al., 2019).

5.2 Study 1

5.2.1 Method

5.2.1.1 Participants

Participants were undergraduate students at the University of Waterloo who indicated their sex as female and reported either using oral contraceptives or not using any form of hormonal contraceptives (non-users were then split into those who had never used hormonal contraceptives and those who were prior OC users). Participants received partial course credit in exchange for completing the study. Five hundred participants were recruited to complete the study between March 2021 and March 2022. Fifty-one participants were removed prior to the data analyses because they completed the study more than once[13]. We excluded 27 participants because we could not link their task data to their responses on the post-study questionnaire, as well as 114

[13] Due to a coding error, when participants completed the study a second (or third) time, the data from previous attempts was overridden. Because we did not have the data from their first attempt at the task, we opted to exclude these participants.

participants with more than 10% omission errors (this included 30 OC users, 69 never OC users, and 15 prior OC users). Omission errors are a typical exclusion criterion when analyzing SART performance data (see Seli et al., 2013), as high error rates likely indicate task non-compliance (i.e., participants did not understand task instructions and/or were not completing the study in good faith). This left us with a final sample of 308 participants: 80 participants currently using OCs (OC users), 189 participants who had never used OCs (Never OC users; participants who has never used any type of hormonal contraceptive), and 39 participants who were not currently using OCs but had used OCs in the past (Prior OC users; participants who are not currently using an OC but have in the past).

5.2.1.2 Pre-screen Surveys

Data for this study were collected as a part of a Pre-screen survey at the University of Waterloo. This survey collects information about sex, gender, age, and to answer the following question about hormonal birth control use: "Are you currently using one of the following methods of birth control?" Participants responded by selecting from a list that included: oral contraception (i.e., birth control or "the pill"), birth control patch, vaginal ring, birth control injection, IUD, hormonal implant, none of the above, and prefer not to answer. This allowed us to recruit participants who indicated their sex as female who were either using OCs or no other form of hormonal contraceptives. All participants completed this Pre-screen survey prior to the study session and were not aware of the criterion that made them eligible for our study. Participants were recruited under the guise of a study interested in individual differences in sustained attention.

5.2.1.3 Materials

***Sustained Attention to Response Task* (SART).** The SART is a widely used and valid measure of sustained attention (Robertson et al., 1997). In the SART, participants are presented a digit (1-9) on a screen for 250 milliseconds (ms) one at a time. Following this, a mask is presented for 900 ms, and then the next digit is presented. Participants are asked to respond with a key press to each presented digit except for the digit 3, in which case, they are asked to withhold a response. Participants completed 955 trials of the SART, which included 840 go trials and 105 no-go trials.

Thought Probes during the SART. Throughout the SART, participants were also asked to respond to 15 intermittent thought probes. These probes appeared at fixed intervals once every 63 trials. The thought probes were as follows:

> *STOP! Which of the following best characterizes your mental state JUST BEFORE this screen appeared:*
>
> *(1) On task*
> *(2) Intentional mind wandering*
> *(3) Unintentionally mind wandering*
>
> *Please select the response option that best describes your mental state just before this screen appeared.*

Participants used the numbers on the keyboard to indicate their response. After responding to each probe, the SART continued.

Post-Study Questionnaire. Following the SART, participants completed a brief post-survey questionnaire. Participants were asked about the proportion of the time they spent visually media multitasking and engaging in other activities during the study task, as well as being asked about their current and past hormonal contraceptive use (including length of use). Participants also

completed the Pre-menstrual Screening Symptom Tool (PSST) before being debriefed about the true purpose of the study.

The Pre-menstrual Screening Symptom Tool (PSST) is a questionnaire used to measure symptoms of Premenstrual Syndrome (PMS) or Premenstrual Dysphoric Disorder (PMDD) (Steiner et al., 2003). It consists of 19 items total. The first 14 items assess premenstrual symptoms that start before your period and stop within a few days of bleeding such as anxiety/tension and overeating/food cravings. These items are rated on a scale from "not at all" (1) to "severe" (4). The last 5 items ask the participant to rate whether the symptoms experienced interfere with work productivity, relationships with coworkers, relationships with family, social life activities, and home responsibilities from "not at all" (1) to "severe" (4). Higher scores indicate more symptoms of PMS or PMDD.

5.2.2 Results and Discussion

All analyses were performed in R (R Core Team 2019). We used the psych and basic R packages to perform the Null Hypothesis Significance Tests. To analyze whether there were differences in sustained attention performance, we split the SART into three time bins, with five thought probes per bin. We then analyzed SART performance (i.e., reaction times, commission errors, omission errors, and skill index) and probe responses (i.e., on task, intentionally mind wandering, and unintentionally mind wandering) as a function of time (beginning, middle, and end of the task), OC status, or an interaction of time and OC status.

5.2.2.1 SART Performance

To examine whether OC status was associated with differences in SART performance, we conducted 4 permutation tests[14] (since our data was not normally distributed; Figure 5.1) to predict reaction times, commission errors, omission errors, and skill index entering OC status as the between-participant factor, time bin as the within-participant factor, and an interaction term of OC status and time bin. As shown in Figure 5.1, when predicting go-trial reaction time, there was no significant main effect of OC status, $F(2, 305) = 0.04$, $p = .960$. There was however, a significant main effect of time, $F(2, 610) = 97.37$, $p < .001$, but no significant interaction between OC status and time, $F(4, 610) = 1.21$, $p = .301$. On commission errors, there was no significant main effect of OC status, $F(2, 305) = 0.21$, $p = .817$, and a significant main effect of time, $F(2, 610) = 30.09$, $p < .001$. There was no significant interaction between OC status and time, $F(4, 610) = 0.22$, $p = .929$. Omission errors showed a similar pattern with no significant main effect of OC status, $F(2, 305) = 0.94$, $p = .394$, a significant main effect of time, $F(2, 610) = 47.22$, $p < .001$, and no significant interaction, $F(4, 610) = 0.16$, $p = .954$. When predicting skill index, there was again no significant main effect of OC status, $F(2, 305) = 0.20$, $p = .818$, a significant main effect of time, $F(2, 610) = 96.18$, $p < .001$, and no significant interaction between OC status and time, $F(4, 610) = 0.52$, $p = .729$.

[14] Permutation tests are similar to an Analysis of Variance (ANOVA) but are non-parametric tests and do not assume normal distributions. The test is based on the assumption that observations are exchangeable and is a form of null hypothesis testing which assumes that any difference is only due to random sampling. Permutation tests randomly sample the data (without replacement; similar to bootstrapping) to create many different possible iterations of data for each group and tests how often the group means significantly differ from one another.

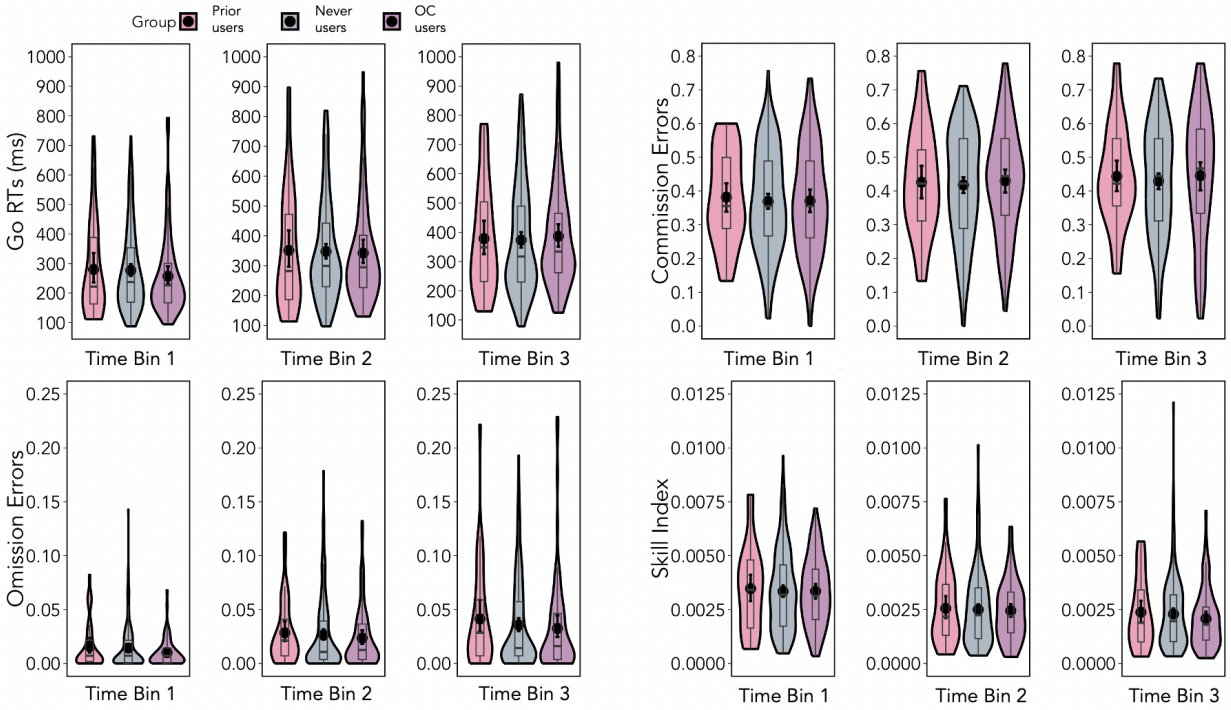


Figure 5.1. Violin plots with box and whisker plots (boxplots) for each SART performance metric (go trial reaction times (RTs), proportion of commission errors, proportion of omission errors, and skill index) by time bin and OC status in Study 1.

5.2.2.2 Thought Probe Responses

To investigate whether mind wandering thought probe responses varied by OC status, we again conducted three permutation tests (this data was also not normally distributed; Figure 5.2), one for each type of probe response. Similar to the SART performance analyses, we entered OC status as the between-participant factor, time bin as the within-participant factor, as well as an interaction term of OC status and time bin to predict each probe response (on-task, intentional mind wandering, and unintentional mind wandering). For on-task reports, there was no significant main effect of OC status, $F(2, 305) = 1.93$, $p = .152$, a significant main effect of time, $F(2, 610) = 43.62$, $p < .001$, and no significant interaction, $F(4, 610) = 0.52$, $p = .520$. When predicting

intentional mind wandering, there was no significant main effect of OC status, $F(2, 305) = 0.84$, $p = .433$, a significant main effect of time, $F(2, 610) = 34.94$, $p < .001$, and no significant interaction, $F(4, 610) = 1.21$, $p = .294$. For unintentional mind wandering, there was a significant main effect of OC status, $F(2, 305) = 5.37$, $p = .006$, a significant main effect of time, $F(2, 610) = 4.22$, $p = .015$, and a significant interaction between OC status and time, $F(4, 610) = 3.32$, $p = .014$.

To probe the foregoing interaction found when analyzing unintentional mind wandering responses, we calculated bootstrapped 95% confidence intervals of effect size comparing the OC groups to one another within each time bin. Effect sizes did not significantly differ between groups in time bin 1 when comparing OC users and never users, 95% CI [-0.47, 0.05], OC users and prior users, 95% CI [-0.40, 0.39], and never users and prior users, 95% CI [-0.17, 0.57]. There were also no significant differences in effect size between groups in time bin 2 when comparing OC users and never users, 95% CI [-0.30, 0.24], OC users and prior users, 95% CI [-0.20, 0.58], and never users and prior users, 95% CI [-0.14, 0.58]. However, there were significant differences in effect size in time bin 3, such that near the end of the task OC users reported greater unintentional mind wandering than never users, 95% CI [-0.83, -0.28] and prior users reported significantly greater unintentional mind wandering than never users, 95% CI [0.11, 0.83]. There were no significant differences in effect size between OC users and prior users, 95% CI [-0.46, 0.34].

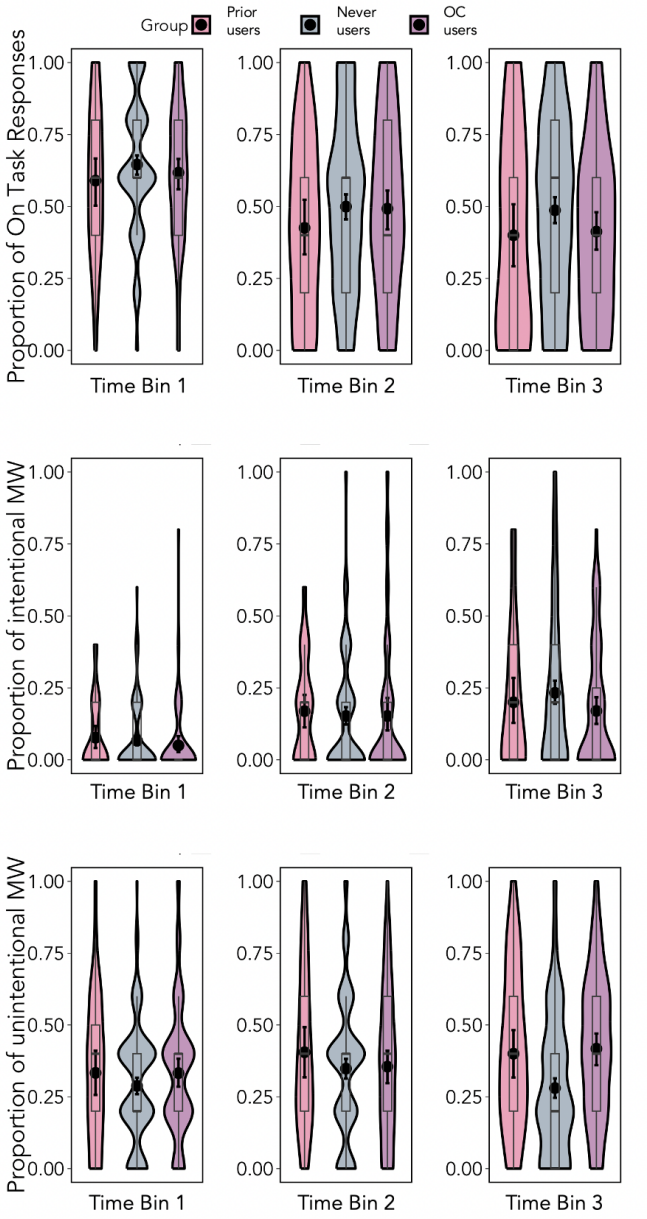


Figure 5.2. Violin plots with box and whisker plots (boxplots) for probe responses by time bin (tercile) and OC status in Study 1.

5.2.2.3 Media Multitasking Responses

Since media multitasking was only assessed retrospectively, we could not examine this behaviour over time on task. To determine whether media multitasking varied by OC status, we

ran 2 Kruskal-Wallis tests (because media multitasking data were positively skewed; Figure 5.3) predicting the proportion of the time spent visual media multitasking and the other predicting the proportion of time spent on activities outside of the experiment. In both tests, we entered OC status as the between-participants factor. Nine participants did not respond to the item asking about visual media multitasking, while 2 participants did not respond to the item on time spent on activities outside of the experiment. These participants were excluded from the analyses below. There was no significant main effect of OC use on visual media multitasking, χ^2 (2, N = 299) = 1.20, p = .550, and there was also no significant main effect of OC use on time spent on activities outside of the experiment, χ^2 (2, N = 306) = 0.98, p = .613.

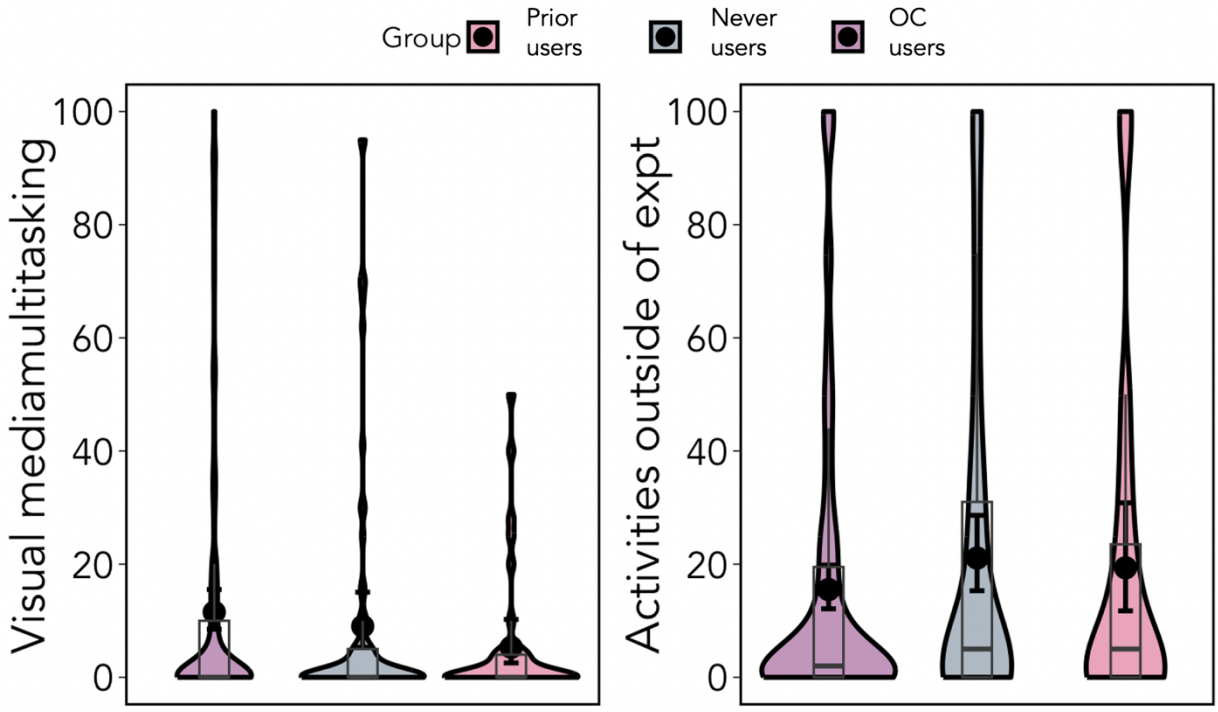


Figure 5.3. Violin plots with box and whisker plots (boxplots) for reports of media multitasking by OC status in Study 1.

5.2.2.4 Pre-menstrual Screening Symptom Tool

To determine whether pre-menstrual screening symptoms varied by OC status, 2 Kruskal-Wallis tests using OC status to predict the severity of pre-menstrual symptoms and another predicting the severity of symptom inference (Table 5.1). Kruskal-Wallis tests were used because pre-menstrual symptom severity data was bi-modally distributed and severity of symptom inference data was positively skewed. Two participants did not respond to items on pre-menstrual symptoms severity and one participant did not respond to the items indexing symptom interference. These participants were excluded from the analyses. There was no significant main effect of OC status on the severity of pre-menstrual symptoms, χ^2 (2, N = 306) = 2.45, p = .293, and there was no significant main effect of OC use on the severity of symptom inference, χ^2 (2, N = 307) = 1.13, p = .569.

Table 5.1. Means and standard deviations for PSST scores by group for Study 1

Group	Measure	N	Mean	SD
Never OC users	PSST symp.	187	2.22	0.67
	PSST interference	188	1.88	0.63
Current OC users	PSST symp.	80	2.30	0.64
	PSST interference	80	1.83	0.64
Prior OC users	PSST symp.	39	2.40	0.67
	PSST interference	39	2.01	0.79

Note 1. PSST symp. = pre-menstrual symptom severity;
PSST interference = severity of pre-menstrual symptom interference
Note 2. The DASS was not administered in Study 1

Summary of Findings

In Study 1, we found no significant differences between OC groups in terms of SART performance (assessed by the go-trial reaction time, commission errors, omission errors, and skill index), and media multitasking. No differences between groups were also observed when it came

to on-task and intentional mind wandering thought probe reports. We did, however, find significant differences between OC groups in unintentional mind wandering in the third tercile of the task. Specifically, unintentional mind wandering was higher in OC users and prior users than never users. Also, consistent with prior studies of sustained attention, overall, performance and attention to the task decreased over time on task (i.e., over terciles of the task). To test the replicability of these findings, we collected the data presented Study 2.

5.3 Study 2

In Study 2 we sought to determine whether the results of Study 1 would replicate in a different sample of undergraduate women. We used the same method as Study 1, with additional items included in the post-study survey. Mainly these additional items included the Depression, Anxiety and Stress Scale (DASS) to assess symptoms of depression and asking OC users the type of pill they took on the day of the study (active vs. placebo; for details see below). By assessing depression, it was possible to extend Study 1 by examining the link between OC use and our sustained attention measures while controlling for depression.

5.3.1 Method

5.3.1.1 Participants

Seven hundred and sixty participants were recruited to complete the study between October 2022 and August 2023. We removed 29 participants prior to the data analyses because they completed the study more than once and/or we could not link their task performance data and post-study questionnaire (this was critical because we confirmed participants OC use status in the post-

study questionnaire)[15] and 143 participants were excluded because they either indicated they did not menstruate or did not disclose whether or not they menstruated. Forty-one participants were removed because they indicated use of a hormonal contraceptive other than OCs or did not disclose their hormonal contraceptive use status (in the post-study questionnaire where we confirmed OC status). We also excluded 19 participants because they had a history of hormonal contraceptive use other than OCs. Participants with more than 10% omission errors (N = 180; 31 OC users, 131 never OC users, and 18 prior OC users) were also removed. The final analyses included 348 participants (79 OC users, 236 never OC users, and 33 prior OC users).

5.3.1.2 Pre-screen Surveys

Data for this study were collected as a part of a Pre-screen survey at the University of Waterloo. This survey items of interest were the same as those used in Study 1. The Pre-screen survey was again completed prior to the study session and participants were unaware of the criterion that determined their study eligibility. Like Study 1, recruitment was conducted under the guise that we were interested in individual differences in sustained attention.

5.3.1.3 Materials

Study materials were the same as Study 1 except for the Post-Study Questionnaire (see below).

[15] Due to a coding error, when participants completed the study a second (or third) time (N = 89), the data from previous attempts was overridden. Because we did not have the data from their first attempt at the task, we opted to exclude these participants. Of the 89 duplicate participants we identified, we could only link the task and post-study questionnaire data for 29 participants. As such, we excluded those 29 participants.

Post-Study Questionnaire. Following the SART, participants completed the same brief post-survey questionnaire as Study 1 with the addition of a few items: 1) an item asking participants whether or not they menstruate (since we recruit female participants based on sex (not gender), it is possible some participants do not menstruate. We added this item to include participants who menstruate regardless of gender identity), 2) an item asking OC users whether they had taken (or would take) an active pill (i.e., a pill with exogenous hormones vs. a placebo pill or no pill) on the day they completed the study, and 3) the items of the DASS so we can control for depression symptoms in our analyses.

The DASS is a 21-item measure assessing symptoms of depression, anxiety, and stress over the previous week (Antony et al., 1998). Participants rate items such as "I felt that I had nothing to look forward to" (depression), "I was worried about situations in which I might panic and make a fool of myself" (anxiety), and "I found it hard to wind down" (stress) on a scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). The scale contains seven items related to each of depression, anxiety, and stress and higher scores on the scale items indicate higher levels of these experiences.

5.3.2 Results and Discussion

All analyses were performed in R (R Core Team 2019). We used the psych and basic R packages to perform the Null Hypothesis Significance Tests.

5.3.2.1 SART Performance

Like Study 1, we investigated whether OC use was associated with differences in performance on the SART. Data was again not normally distributed (Figure 5.4) so we conducted

4 permutation tests to predict go-trial reaction times, commission errors, omission errors, and skill index entering OC status as the between-participant factor, time bin as the within-participant factor, and an interaction term of OC status and time bin. When predicting reaction time, there was no significant main effect of OC status, $F(2, 345) = 0.39$, $p = .684$, a significant main effect of time, $F(2, 690) = 63.49$, $p < .001$, and no significant interaction, $F(4, 690) = 1.22$, $p = .303$. For commission errors, there was no significant main effect of OC status, $F(2, 345) = 1.16$, $p = .306$, a significant main effect of time, $F(2, 690) = 33.13$, $p < .001$, and no significant interaction, $F(4, 690) = 1.26$, $p = .283$. There was a similar pattern for omission errors, with no significant main effect of OC status, $F(2, 345) = 0.03$, $p = .972$, and a significant main effect of time, $F(2, 690) = 34.65$, $p < .001$. There was no significant interaction, $F(4, 690) = 1.28$, $p = .275$. Skill index also showed no significant main effect of OC status, $F(2, 345) = 2.05$, $p = .136$, a significant main effect of time, $F(2, 690) = 65.01$, $p < .001$, and no significant interaction, $F(2, 690) = 0.93$, $p = .441$.

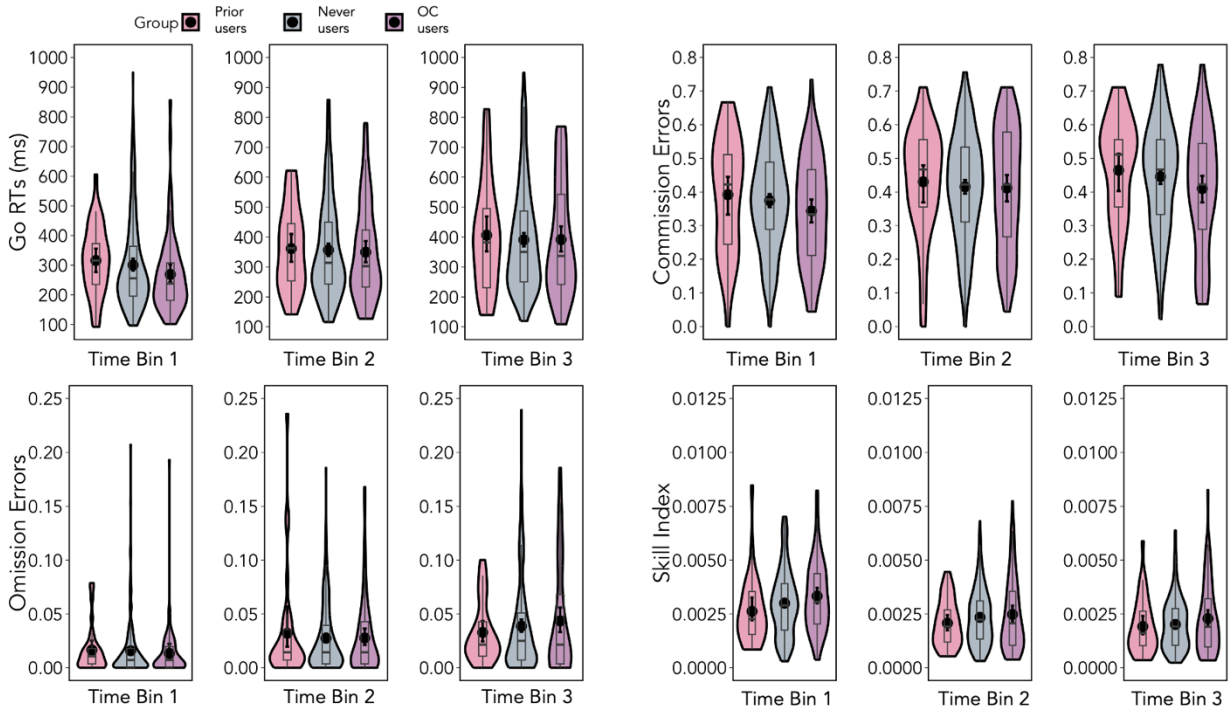


Figure 5.4. Violin plots with box and whisker plots (boxplots) for each SART performance metric (go trial reaction times (RTs), proportion of commission errors, proportion of omission errors, and skill index) by time bin and OC status in Study 2.

5.3.2.2 Thought Probe Responses

We also again examined whether OC status was associated with differences in thought probe responses by time bin and/or OC status. As in Study 1, we conducted three permutation tests predicting each of the possible probe responses (on-task, intentional mind wandering, and unintentional mind wandering; Figure 5.5). We entered OC status as the between participant factor, time as a within participant factor, and examined whether there was an interaction between these two factors. On on-task reports, there was no significant main effect of OC status, $F(2, 345) = 0.60$, $p = .559$, a significant main effect of time, $F(2, 690) = 42.65$, $p < .001$, and no significant interaction, $F(4, 610) = 0.97$, $p = .435$. When predicting intentional mind wandering, there was no

significant main effect of OC status, $F(2, 345) = 0.22$, $p = .818$, a significant main effect of time, $F(2, 610) = 38.12$, $p < .001$, and no significant interaction, $F(4, 610) = 0.20$, $p = .940$. Unintentional mind wandering showed a different pattern from Study 1, with no significant main effect of OC status, $F(2, 345) = 1.22$, $p = .299$, no significant main effect of time, $F(2, 610) = 2.79$, $p = .059$, and no significant interaction, $F(4, 610) = 0.57$, $p = .686$.

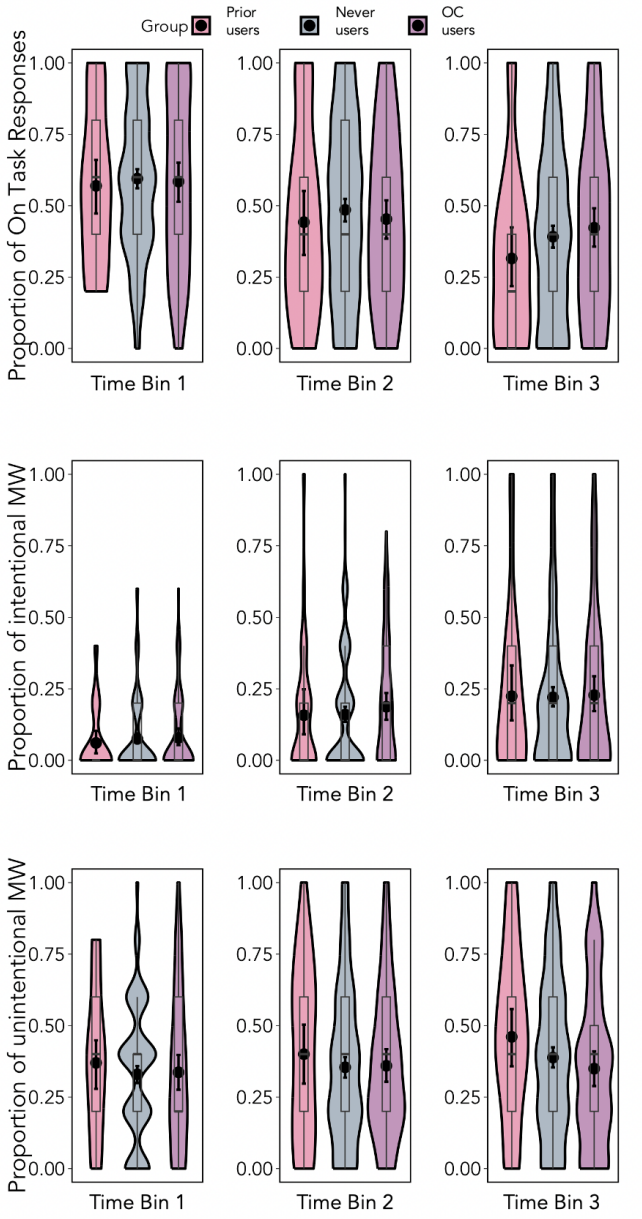


Figure 5.5. Violin plots with box and whisker plots (boxplots) for probe responses by time bin (tercile) and OC status in Study 2.

5.3.2.3 Media Multitasking Responses

Similar to Study 1, we aimed to examine whether media multitasking varied by OC status. To do so we conducted 2 Kruskal-Wallis tests (media multitasking data was positively skewed). OC status was entered as the between-participants factor predicting the proportion of the time spent visual media multitasking and the other predicting the proportion of time spent on activities outside of the experiment. Fourteen participants (including 2 OC users, 1 prior user, and 9 never users) did not respond to the item asking about visual media multitasking, while 8 participants (including 2 OC users and 6 never users) did not respond to the item on time spent on activities outside of the experiment. These participants were excluded from the below analyses. There was no significant main effect of OC use on visual media multitasking, χ^2 (2, N = 334) = 0.23, p = .890. There was also no significant main effect of OC use on time spent on activities outside of the experiment, χ^2 (2, N = 340) = 4.38, p = .112.

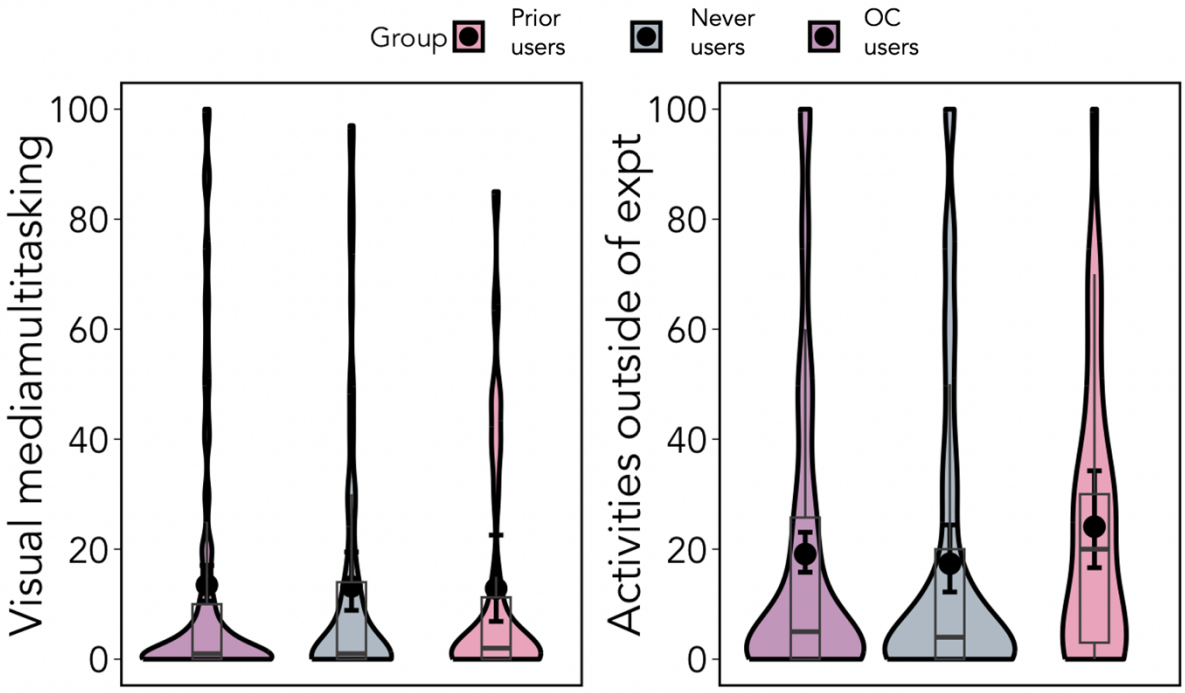


Figure 5.6. Violin plots with box and whisker plots (boxplots) for media multitasking by OC status in Study 2.

5.3.2.4 Pre-menstrual Screening Symptom Tool

To determine whether pre-menstrual screening symptoms varied by OC status, we conducted two Kruskal-Wallis tests (these distributions were also not normally distributed; see means and standard deviations in Table 5.2) entering OC status as the between-participants factor. Four participants (including 1 OC user, 1 prior user, and 2 never users) were excluded because they did not respond to the items assessing the severity of pre-menstrual symptoms. We also removed one participant (1 never user) for not responding to the items related to symptom interference. There was no significant main effect of the severity pre-menstrual symptoms by OC status, χ^2 (2, N = 344) = 1.64, p = .440, as well as no significant main effect of OC use on symptom interference, χ^2 (2, N = 347) = 5.39, p = .067.

Table 5.2. Means and standard deviations for PSST scores by group for Study 2

Group	Measure	N	Mean	SD
Never users	PSST symp.	234	2.41	0.69
	PSST interference	235	1.93	0.65
	DASS-Dep	236	1.06	0.85
	DASS-Anx	236	0.90	0.72
	DASS-Stress	236	1.20	0.73
OC users	PSST symp.	78	2.32	0.74
	PSST interference	79	1.85	0.71
	DASS-Dep	79	0.95	0.79
	DASS-Anx	79	0.86	0.82
	DASS-Stress	79	1.22	0.85
Prior OC users	PSST symp.	32	2.52	0.68
	PSST interference	33	2.15	0.70
	DASS-Dep	33	0.95	0.87
	DASS-Anx	33	0.93	0.70
	DASS-Stress	33	1.28	0.77

Note. PSST symp. = Pre-menstrual symptom severity; PSST interference = Pre-menstrual symptom severity of interference; DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

5.3.2.5 Depression, Anxiety, and Stress Scale

While it was not a primary goal of the study, we also conducted three Kruskal-Wallis tests using OC status to predict depression, anxiety, and stress (data were again not normally distributed; see means and standard deviations in Figure 5.2). There was no significant main effect of OC status on depression symptoms, χ^2 (2, N = 348) = 1.25, p = .534, anxiety symptoms, χ^2 (2, N = 348) = 0.90, p = .638, or stress symptoms, χ^2 (2, N = 348) = 0.36, p = .837.

5.3.2.6 Predicting SART Performance and Probes Responses Controlling for Depression Symptoms: Exploratory Analyses

While in Study 2 we did not replicate the differences in thought probe responses between OC users and prior users compared to never users that we found in Study 1, we still aimed to explore whether OC use predicted SART performance and/or probe responses while controlling for depression symptoms. Given the non-normality of the data, it would be proper to use a non-

parametric regression, however non-parametric regressions require "astronomically large" datasets (at least 500 participants; Yatchew 1998), which we did not have. Some work has suggested that linear regression can provide good estimates even if the normality assumption is violated (e.g., Li et al., 2012) so we aimed to explore whether OC use could predict SART performance and probe responses controlling for depression symptoms using linear regressions on an exploratory basis. To do this, we constructed seven regression models (predicting SART RT, commission errors, omission errors, and skill index, as well as thought probe reports of being on-task, unintentionally mind wandering and intentionally mind wandering) entering depression symptoms in the first step and OC status in the second step (Table 5.3). None of the models predicting SART performance metrics accounted for significant variance at either Step 1 or Step 2. When predicting thought probe responses, on-task reports and unintentional mind wandering reports were significantly predicted by depression symptoms in Step 1. The addition of OC status in Step 2 did not account for significant additional variance. Depression symptoms remained the only significant predictor. Depression symptoms did not account for significant variance in intentional mind wandering in Step 1 or 2, nor did the addition of OC status in Step 2 predict significant variance.

Table 5.3. Regression model statistics for Study 2

		Beta	*SE*	*p*
DV: SART-RT		**R^2 = .00, F = 0.03, SE = 143.50, Model *p* = .734**		
Step 1	Intercept	345.46	7.69	< .001
	DASS-Dep	2.62	7.70	.734
Step 2		**R^2 = .00, F = 0.31, SE = 143.70, Model *p* = .816**		
		ΔR^2 = .00, *p for* ΔR^2 = .663		
	Intercept	347.33	9.36	< .001
	DASS-Dep	2.44	7.73	.752
	OC users	-13.15	18.71	.483
	Prior OC users	11.75	26.73	.661
DV: SART-CE		**R^2 = .00, F = 2.97, SE = 0.18, Model *p* = .086**		
Step 1	Intercept	0.52	0.01	< .001
	DASS-Dep	0.02	0.01	.086
Step 2		**R^2 = .01, F = 1.72, SE = 0.18, Model *p* = .163**		
		ΔR^2 = .01, *p for* ΔR^2 = .337		
	Intercept	0.53	0.01	< .001
	DASS-Dep	0.02	0.01	.093
	OC users	-0.03	0.02	.249
	Prior OC users	0.02	0.03	.483
DV: SART-OE		**R^2 = .00, F = 0.27, SE = 0.03, Model *p* = .601**		
Step 1	Intercept	0.03	0.00	< .001
	DASS-Dep	0.00	0.00	.600
Step 2		**R^2 = .00, F = 0.12, SE = 0.03, Model *p* = .949**		
		ΔR^2 = .00, *p for* ΔR^2 = .960		
	Intercept	0.03	0.00	< .001
	DASS-Dep	0.00	0.00	.593
	OC users	0.00	0.00	.779
	Prior OC users	0.00	0.01	.995
DV: SART-SI		**R^2 = .01, F = 3.46, SE = 0.00, Model *p* = .064**		
Step 1	Intercept	0.00	0.00	< .001
	DASS-Dep	0.00	0.00	.108
Step 2		**R^2 = .02, F = 2.54, SE = 0.00, Model *p* = .057**		
		ΔR^2 = .01, *p for* ΔR^2 = .129		
	Intercept	0.00	0.00	< .001
	DASS-Dep	-0.00	0.00	.073
	OC users	0.00	0.00	.083
	Prior OC users	-0.00	0.00	.466
DV: TB-On Task		**R^2 = .03, F = 11.64, SE = 0.23, Model *p* < .001**		
Step 1	Intercept	0.49	0.01	< .001
	DASS-Dep	-0.04	0.01	< .001
Step 2		**R^2 = .04, F = 4.38, SE = 0.23, Model *p* = .004**		
		ΔR^2 = .00, *p for* ΔR^2 = .469		
	Intercept	0.49	0.02	< .001
	DASS-Dep	-0.04	0.01	< .001
	OC users	-0.01	0.03	.756
	Prior OC users	-0.05	0.04	.220
DV: TB-Int-MW		**R^2 = .01, F = 1.89, SE = 0.16, Model *p* = .170**		
Step 1	Intercept	0.15	0.01	< .001
	DASS-Dep	0.01	0.01	.170

Step 2		**R^2 = .01, F = 0.80, SE = 0.16, Model *p* = .494**		
		ΔR^2 = .00, *p for* ΔR^2 = .771		
	Intercept	0.15	0.01	< .001
	DASS-Dep	0.01	0.01	.162
	OC users	0.01	0.02	.494
	Prior OC users	-0.00	0.03	.918
DV: TB-Unint-MW		**R^2 = .03, F = 8.91, SE = 0.20, Model *p* = .003**		
Step 1	Intercept	0.36	0.01	< .001
	DASS-Dep	0.03	0.01	.003
Step 2		**R^2 = .03, F = 3.86, SE = 0.20, Model *p* = .010**		
		ΔR^2 = .01, *p for* ΔR^2 = .266		
	Intercept	0.36	0.01	< .001
	DASS-Dep	0.03	0.01	.003
	OC users	-0.00	0.03	.855
	Prior OC users	0.06	0.04	.119

Note 1: DV = Dependent variable; SART-RT = Sustained Attention to Response Task Reaction Time; SART-CE = Sustained Attention to Response Task Commission Errors; SART-OE = Sustained Attention to Response Task Omission Errors; SART-SI = Sustained Attention to Response Task Skill Index; TB-On Task = Thought Probe On Task Reports; TB-Int-MW = Thought Probe Intentional Mind Wandering Reports; TB-Unint-MW = Thought Probe Unintentional Mind Wandering Reports
Note 2: Depression symptoms are entered in Step 1. In Step 2, OC status is added to the model.
Note 3: ΔR^2 values may not exactly represent Step 2 R^2 – Step 1 R^2 due to rounding.

Summary of Results

In the present study, our findings indicated that like Study 1, SART performance (indexed by go-trial reaction time, commission errors, omission errors, and skill index) and media multitasking did not differ by OC status. On task and intentional mind wandering responses to thought probes also again did not differ between OC groups. However, we were unable to replicate the differences in unintentional mind wandering that were observed in Study 1 between OC users and prior users when compared to never users. Given the links between inattention and depression (e.g., Seli et al., 2019), as well as OC use and depression (e.g., Skovlund et al., 2016), we also controlled for depression symptoms by conducting hierarchical regressions predicting SART performance and probe responses. OC status did not predict variance over and above depression

on any measures. Nevertheless, we again found that SART performance and attention as indexed by thought probes declined over time on task.

5.4 General Discussion

In the present studies, we investigated whether OC users, prior OC users, or never OC users differed in their performance on an online version of the SART (indexed through go-trial reaction time, commission errors, omission errors, and the skill index). Throughout the SART, participants also responded to intermittent thought probes which asked whether they were on task, intentionally mind wandering, or unintentionally mind wandering just before the probe appeared. Following the SART, participants retrospectively reported on the proportion of the time they spent engaged in visual media multitasking as well as other activities during the task. In both studies, we found no significant differences between groups on any of the SART performance metrics (go-trial reaction time, commission errors, omission errors, and skill index) as well as no significant differences on media multitasking behaviour. With some qualification (discussed next), there were also no reliable differences between OC use groups on on-task and mind wandering reports. Regression analyses in Study 2 demonstrated that accounting for depression symptoms did not reveal any significant associations between OC status and SART performance or thought probe responses. Taken together, the results suggest that OC use does not have a meaningful relation with sustained attention.

Our conclusion that there is no reliable effect of OC use on probe responses needs further elaboration. In Study 1, our findings indicated there were no significant differences between groups on on-task reports and reports of intentional mind wandering. But we did find small but statistically significant differences between groups on unintentional mind wandering such that both

OC users and prior OC users reported significantly greater unintentional mind wandering than never OC users. OC users and prior OC users did not significantly differ from one another. However, in Study 2 we were unable to replicate these findings, with our results indicating that there were no significant differences between groups on any of the thought probe responses (on-task, intentional mind wandering, and unintentional mind wandering). Given that we did not find significant differences between groups on SART performance or media multitasking, and only small and unstable differences on thought probes responses, it seems the difference in mind wandering reports found in Study 1 is unlikely to represent a meaningful difference in mind wandering behaviour between groups. Consistent with our prior studies (Chapters 2-4) the present findings suggest there is considerable variability between cohorts and emphasizes the importance of recruiting large samples when investigating OC use and cognitive variables.

Our findings extend prior work examining OC use and state-level sustained attention task performance (Grikšienė & Rukšėnas, 2009; Silber et al., 1987) through the recruitment of larger samples, the use of a more suitable sustained attention task, and the comparison of OC users, prior users, and those who have never used hormonal contraceptives. Our results are inconsistent with those of Grikšienė and Rukšėnas (2009) who found that OC users had significantly faster reaction times. However, as we note earlier, Grikšienė and Rukšėnas' (2009) task may better measure selective attention or visual search ability instead of *sustained* attention. It is also likely that the study reported by Grikšienė and Rukšėnas (2009) was not adequately powered to yield stable results given that they utilized a small sample (OC N = 10, non-OC N = 15). The results of the present studies are consistent with the study reported by Silber et al. (1987), who also found no significant differences in reaction time between OC users and non-users.

These findings are also generally consistent with the results from large well-powered studies investigating OC use and the trait-level tendency to experience inattention (Chapters 2-4). As we mentioned earlier, that work found OC use was not related to trait-level everyday attentional engagement (i.e., OC use was either related to modest improvements in the tendency to experience inattention or not related to significant differences in inattention). Some may interpret the thought probe findings in Study 1 (OC users and prior users reporting greater unintentional mind wandering than never users) to be consistent with the trait-level attention findings from Raymond et al. (2019), which indicated that OC users reported greater tendency to mind wander. We would encourage these results be interpreted with the upmost caution as the effect in Study 1 did not replicate in a second sample and was observed during restrictions related to the COVID-19 pandemic. As such, there may have been other variables (e.g., more screen time, lack of ability to socialize in-person) that contributed to the manifestation of this effect beyond only the use of OCs.

Chapter 6: On the Relation Between Oral Contraceptive Use and Self-Control

6.1 Introduction

In Chapter 6 we build on this prior literature by exploring the relation between OC use and self-control, which is broadly construed as the ability to "override" one's own momentary impulses (e.g., Inzlicht et al., 2014; Tangney et al., 2004) in the service of pursuing one's valued goals (Mischel et al., 1996). Our interest in the relation between OCs and self-control also stemmed partly from the common use of OCs (which are the most frequently used hormonal contraceptive; United Nations, 2019), and partly from the large body of prior work showing that self-control is linked to success in a variety of domains of everyday life, such as maintaining positive relationships, achieving physical and mental health, performing well in academics, and building personal wealth (see Moffitt et al., 2011; Tangney et al., 2004; Tangney et al., 2018).

OC Use and Self Control

To date, few studies have directly investigated the relation between OC use and self-control. Perhaps the most relevant study was reported by Zethraeus and colleagues (2017). This study aimed to determine the influence of OC use on general well-being, and in so doing, included a putative measure of self-control as part of the Psychological General Well-Being Index (PGWBI; Chassany et al., 2004). In the study, women (aged 18-30 with regular menstrual cycles) willing to start using OCs were randomly assigned to three months of treatment with either an OC or a placebo. Participants completed the PGWBI prior to beginning treatment (baseline) and again after the 3-month treatment period. Results showed that scores on the measure of self-control (in the PGWBI) after treatment were significantly lower than baseline in the OC group, but not in the placebo (non-OC) group, suggesting that OC use reduces self-control. While these results are

intriguing, there are several key limitations to this study as it pertains to the relation between OC use and self-control. First, the items of the PGWBI assessing self-control do not uniquely index self-control, but seem to assess aspects of mental *stability* as well[16]. Second, there was no direct statistical comparison of the pre- to post-treatment change scores between the OC and placebo groups, nor was there a statistical comparison of the levels of self-control following treatment across groups. And third, there was no attempt to control for symptoms of depression, which are known to vary with OC use (Skovlund et al., 2016). Unfortunately, these limitations preclude any strong conclusions about the relation between OC use and self-control from the study reported by Zethraeus et al. (2017).

Other work has examined the relation between OC use and various constructs that are related to self-control (e.g., Bradshaw et al., 2020; Raymond et al., 2019; Gravelsins et al., 2021). For example, Bradshaw et al. (2020) examined the relation between hormonal contraceptive (HC) use (including OCs) and *perseverance* during self-paced cognitive tasks, which is relevant because presumably, perseverance involves some degree of self-control (e.g., Gordeeva et al., 2017; Duckworth & Kern, 2011). In one of their studies, participants were presented with two similar images side-by-side and asked to "find the differences between the left and right images" (Bradshaw et al., 2020; p. 3). They were then told they could move to the next page whenever they wanted. The time participants spent searching for differences between the images was

[16] Three items assessed self-control: "I was emotionally stable and sure of myself during the past month" (rated from 0 = none of the time to 5 = all of the time), "Have you been in firm control of your behaviour, thoughts, emotions or feelings during the past month?" (rated from 0 = yes, definitely so to 5 = no, and I am very disturbed), and "Have you had any reason to wonder if you were losing your mind, or losing control over the way you act, talk, think, feel or of your memory during the past month?" (rated from 0 = not at all to 5 = yes, very much so and I am very concerned).

operationalized as perseverance, while the number of differences correctly identified was taken as an index performance. For present purposes, the key finding was that compared to the non-HC users, HC users persevered *less* (i.e., spent less time on the task), and as a result, these individuals performed significantly worse (detected fewer differences between images) (cf. Byg et al., 2023). While there might be many reasons why HC users persevered less than non-HC users, one explanation is that HC users have poorer self-control than non-users.

Evidence suggesting a possible relation between OC use and self-control also comes from neuroimaging studies. Brain imaging and stimulation studies have implicated the prefrontal cortex (PFC) in the execution of self-control (Knoch & Fehr, 2007; Figner et al., 2010; Tanaka et al., 2020), and there is evidence of different functional connectivity within this region when self-control is engaged successfully versus when it fails (Hare et al., 2009). Interestingly, the PFC also has a dense population of sex hormone (e.g., estrogen and progesterone) receptors (MacLusky et al., 1986; Bixo et al., 1995; Almey et al., 2015; Brinton et al., 2008), suggesting that the PFC – and perhaps its related functions (such as self-control) – may be sensitive to changes in these hormone levels. There is also evidence that use of hormonal contraceptives is associated with differences in functional connectivity involving the PFC (Petersen et al., 2014; Sharma et al., 2020).

The Present Studies

Building on previous research, in the present studies we sought to directly explore the relation between OC use and self-control. Our exploration involved a secondary data analysis of a large data set collected as part of a beginning-of-term survey completed by undergraduate students at the University of Waterloo. Included in this survey were measures of OC use as well as two

useful measures of self-control, which captured quite different aspects of the broad construct of self-control. One of the measures was the Brief Self-Control Scale (Tangney et al., 2004), which indexes a person's ability to inhibit or override his or her automatic impulses (i.e., *self-overriding*). The other measure was the Regulatory Mode Scale (Kruglanski et al., 2000), which assesses a person's tendency to self-regulate when pursuing his or her goals. Specifically, the Regulatory Mode Scale evaluates two dimensions of self-regulation: 1) *assessment*, which refers to a person's ability to evaluate, prioritize, and assess progress of competing goals; and 2) *locomotion*, which refers to a person's tendency to initiate and maintain goal pursuit. While there are limitations to using self-report measures, there is evidence that self-reports of self-control are better predictors of self-control related behaviours (e.g., physical activity) than some behavioural measures (Allom et al., 2016).

Fortunately, the data set also included a measure of depression (as part of the Depression Anxiety Stress Scale-21; Antony et al., 1998), which allowed us to examine the relation between OC use and self-control while controlling for symptoms of depression. Controlling for depression in this context is important given previously established relations between mood and self-control (e.g., Fishbach & Labroo, 2007), as well as between mood (particularly depression) and OC use (Skovlund et al., 2016; Hamstra et al., 2017; Keyes et al., 2013; Toffol et al., 2012; Duke et al., 2007; Cheslack-Postava et al., 2015). In any case, given these possible associations, we thought it would be prudent to control for depressive symptoms when assessing the link between OC use and the self-control measures included in our samples.

Finally, as the measures relevant to our study were included in multiple semesters of data collection, it was possible to aggregate the data to achieve reasonably large samples and also to

test for replicability. Accordingly, Study 1 focused on analyses of data collected during the Winter and Spring semesters of 2020, which then served as the foundation for a pre-registered replication. Study 2 was the replication and focused on analyses of data from Fall 2020 and Winter 2021. Because the data were collected across semesters as the COVID-19 pandemic was evolving, we statistically controlled for semester of data collection when assessing the links between self-control and OC use in each study.

6.2 Study 1

6.2.1 Method

6.2.1.1 Participants

Participants were undergraduate students at the University of Waterloo who indicated their sex as female. Participants received partial course credit in exchange for completing the Pre-screen and Mass Testing surveys (see below). Participants were excluded from each semester based on the criteria outlined in the Data Cleaning section. The cohort in Winter 2020 initially consisted of 1576 females, of which 509 participants were excluded leaving 1067 participants, with 315 using OCs and 752 naturally cycling. The Spring 2020 sample included 642 females. Three hundred and forty-six (346) were excluded, leaving 296 participants, of which 84 participants were using OCs and 212 were naturally cycling. Our final sample for Study 1 included a total of 1363 participants, with 399 using OCs and 964 naturally cycling and not using any form of hormonal contraceptives. These participants had a mean age of 20 years old.

6.2.1.2 Pre-screen and Mass Testing Surveys

Data for this study were collected as a part of a Pre-screen survey and the Mass Testing survey at the University of Waterloo. The Pre-screen and Mass Testing surveys include a series of questions administered online in close succession at the beginning of each semester using Qualtrics software. Undergraduates enrolled in psychology courses at the university were eligible to complete this survey. As part of the Pre-screen survey participants were asked to provide their biological sex, age, and to answer the following question about hormonal birth control use: "Are you currently using one of the following methods of birth control?" Participants responded by selecting from a list that included: oral contraception (i.e., birth control or "the pill"), birth control patch, vaginal ring, birth control injection, IUD[17], hormonal implant, none of the above (in Winter 2020 this option was 'does not apply to me'), and prefer not to answer. Participants were also asked to specify whether they were currently being treated for depression or anxiety, whether they were currently using medications for psychosis, and the date of their last menstruation. The Mass Testing survey involved the administration of a large battery of questionnaires, among which were the Brief Self-Control Scale, the Regulatory Mode Scale, and the Depression Anxiety and Stress Scale-21 (see descriptions below). Data was collected online at the University of Waterloo at the beginning of two semesters: Winter 2020 (January-February) and Spring 2020 (May-June).

6.2.1.3 Data Cleaning

For the present study, we utilized a similar data cleaning procedure as in our prior work (Chapters 2-4). The data cleaning procedure and exclusion criteria were determined a priori and

[17] The IUD item did not differentiate between hormonal and copper in the Winter and Spring 2020 semesters.

were as follows: First, participants who were included in multiple semesters of data were only included in the analyses for the first semester in which they met the inclusion criteria. In subsequent semesters they were excluded from the analyses (to ensure each semester was an independent sample). Since Winter 2020 was the first semester of data cleaned, all participants were retained for this criterion. In Spring 2020, we excluded 138 participants who were included in the Winter 2020 sample. Participants were also excluded if they did not respond to the item inquiring about hormonal contraceptive use (N = 195; Winter 2020: N = 138; Spring 2020: N = 57), if they indicated they used a hormonal contraceptive other than the oral contraceptive pill (e.g., an injection, patch; N = 30; Winter 2020: N = 20; Spring 2020: N = 10), or if they indicated use of an IUD (N = 127; Winter 2020: N = 88; Spring 2020: N = 39). We then addressed minor variations in the wording of response options for the questions included in the present study. For instance, in one sample a response to a question about the use of birth control was "does not apply to me", while the corresponding alternative the other samples was "none of the above". These were treated as the same response. To avoid the potential confound of mental health, we then excluded participants who reported currently receiving treatment for depression, anxiety, or used anti-psychotic medications[18]. One hundred and ninety-three participants were excluded for currently receiving treatment for depression (Winter 2020: N = 139; OC N = 76, non-OC N = 63; Spring 2020: N = 54; OC N = 25, non-OC N = 29), or declining to disclose whether or not they were currently receiving treatment for depression (Winter 2020: N = 12; Spring 2020: N = 5). Seventy-eight were excluded because they were currently receiving treatment for anxiety (Winter 2020: N

[18] Though including these participants receiving mental health treatment does not meaningful change the results.

= 55; OC N = 25, non-OC N = 30; Spring 2020: N = 23; OC N = 11, non-OC N = 12) and 9 were excluded for not disclosing whether or not they were currently receiving treatment for anxiety (Winter 2020: N = 7; Spring 2020: N = 2). Two participants (Winter 2020: N = 1; Spring 2020: N = 1) using anti-psychotics were also excluded. Next, we checked for and eliminated poor quality data based on participants' patterns of responses. Participants were excluded from the analyses if 1) the number of clicks they made was fewer than the number of required responses per page of a survey (N = 1; Winter 2020: N = 0; Spring 2020: N = 1), 2) their responses were faster than 1-second per scale item (N = 35; Winter 2020: N = 25; Spring 2020: N = 10), and if 3) participants responded to fewer than half of the items on a scale (N = 9; Winter 2020: N = 9; Spring 2020: N = 0; note: responses on items for a given scale were averaged to arrive at the scale scores). We analyzed the data with and without exclusions based on age (to target participants of reproductive age; 18-45 years old). This did not change the results in a meaningful way. The below analyses exclude participants who did not report their birth year (N = 13) or were older than 45 years of age (N = 8).

6.2.1.4 Materials

***Brief Self-Control Scale* (BSCS).** The Brief Self-Control Scale is a 13-item measure used to assess self-control (Tangney et al., 2004). Participants respond to statements such as "I am good at resisting temptation" and "I often act without thinking through all the alternatives" and rate them on how typical the statements are of themselves on a 5-point scale that included anchors such as 1 – *not at all* to 5 – *very much*. Eight items are reverse coded. Higher scores indicate more self-control.

Regulatory Mode Scale **(RMS)**. The RMS is a trait-level measure of self-regulation strategies. It includes twenty-four items that are scored on a scale from 1 – strongly disagree to 6 – strongly agree. The RMS is scored on two sub-scales: locomotion and assessment. The locomotion subscale is scored from twelve items such as "I don't mind doing things even if they involve extra effort". Two of the twelve items are reverse coded. Higher scores indicate greater locomotion. The assessment subscale is scored from twelve items such as "I often critique work done by myself or others". Three of the twelve items are reverse coded. Higher scores indicate greater assessment.

Depression Anxiety Stress Scale-21 **(DASS-21).** The DASS is a 21-item measure assessing symptoms of depression, anxiety, and stress over the previous week (Antony et al., 1998). Participants rate items such as "I felt that I had nothing to look forward to" (depression), "I was worried about situations in which I might panic and make a fool of myself" (anxiety), and "I found it hard to wind down" (stress) on a scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much or most of the time*). The scale contains seven items related to each of depression, anxiety, and stress and higher scores on the scale items indicate higher levels of these experiences.

6.2.2 Results and Discussion

All analyses were performed in R (R Core Team 2019). We used the psych and basic R packages to perform the Null Hypothesis Significance Tests. We also used the Bayes Factor package to calculate Bayes Factors. The Bayes Factor package calculates the BFs as the ratio of the alternative to null hypothesis, such that smaller BFs indicate evidence for the null hypothesis, while larger BFs are evidence for the alternative hypothesis. We interpret Bayes Factors based on

Andraszewicz et al. (2014). To determine whether there were differences between OC users and non-users we first conducted a series of planned comparisons using t-tests comparing those using OCs and those not using OCs on each of our measures of self-control[19]. To account for symptoms of depression and the semester of data collection, we conducted a series of hierarchical regressions predicting each of the measures of self-control with OC use while statistically controlling for symptoms of depression and semester of data collection.

6.2.2.1 Descriptive Statistics

Table 6.1 includes the descriptive statistics for each measure as a function of semester (Winter 2020 vs. Spring 2020) and group (OC vs. Non-OC). All scales showed high reliabilities, with Cronbach alphas of .76 or greater. Cronbach alpha values and Pearson correlations between the measures within each group are provided in Table 6.2. Boxplots depicting each of the attention measures as a function of OC use condition (averaged across semesters) are shown in Figure 6.1.

[19] We also compared depression, anxiety, and stress symptoms across OC and non-OC groups. However, since this was not a research question of interest in the current chapter, these analyses are included in the Appendix A: Supplementary Data.

Table 6.1. Descriptive statistics of measures by semester and group

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Winter 2020	Non-OC group	BSCS	752	3.11	0.65	0.08	-0.13
		RMS-Loc	752	3.98	0.68	-0.33	0.39
		RMS-Assess	752	4.01	0.66	-0.08	0.06
		DASS-Dep	752	0.80	0.74	0.94	0.04
		DASS-Anx	752	0.72	0.66	0.97	0.23
		DASS-Stress	752	0.90	0.66	0.59	-0.34
	OC group	BSCS	315	3.11	0.69	0.07	-0.23
		RMS-Loc	315	4.13	0.67	0.03	−0.62
		RMS-Assess	315	3.98	0.71	-0.08	-0.36
		DASS-Dep	315	0.73	0.73	1.20	0.74
		DASS-Anx	315	0.68	0.64	1.15	0.94
		DASS-Stress	315	0.94	0.69	0.79	0.11
Spring 2020	Non-OC group	BSCS	212	3.06	0.63	-0.14	-0.46
		RMS-Loc	212	4.00	0.74	−0.21	−0.48
		RMS-Assess	212	4.09	0.59	0.19	0.10
		DASS-Dep	212	0.81	0.66	0.87	-0.11
		DASS-Anx	212	0.60	0.50	1.03	0.61
		DASS-Stress	212	0.87	0.58	0.64	0.04
	OC group	BSCS	84	3.29	0.68	0.13	-0.65
		RMS-Loc	84	4.31	0.65	0.39	-0.64
		RMS-Assess	84	4.09	0.81	-0.32	-0.37
		DASS-Dep	84	0.69	0.68	1.32	1.22
		DASS-Anx	84	0.55	0.51	0.95	0.30
		DASS-Stress	84	0.87	0.60	1.14	1.42

Note. BSCS = Brief Self-Control Scale, RMS-Loc = Regulatory Mode Scale – Locomotion Subscale, RMS-Assess = Regulatory Mode Scale – Assessment Subscale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 6.2. Cronbach alphas (left panel) and pearson correlations (right panel) of the OC group (above the diagonal; N=399) and non-OC group (below the diagonal; N = 964)

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. RMS-Loc	.87	.84	--	.10 *	.45 **	-.19 **	-.15 *	-.08	--
2. RMS-Assess	.82	.76	.16 **	--	-.27 **	.28 **	.26 **	.37 **	.16 **
3. BSCS	.83	.83	.40 **	-.19 **	--	-.41 **	-.32 **	-.38 **	.40 **
4.DASS-Depression	.92	.91	-.23 **	.22 **	-.37 **	--	.68 **	.77 **	-.23 **
5. DASS-Anxiety	.81	.82	-.07 *	.23 **	-.27 **	.68 **	--	.73 **	-.07 *
6. DASS-Stress	.87	.85	-.03	.28 **	-.34 **	.74 **	.76 **	--	-.03

Note. BSCS = Brief Self-Control Scale; RMS-Assess = Regulatory Mode Scale – Assessment subscale; RMS-Loc = Regulatory Mode Scale – Locomotion subscale.
* p = .05, ** p < .001

6.2.2.2 Planned Comparisons

To examine whether there were differences in self-control between OC users and non-users, we collapsed across semesters and conducted a series of independent sample t-tests comparing OC users and non-users on each of the three measures of self-control (Figure 6.1). To control for multiple comparisons, we utilized a Bonferroni correction, setting alpha at .017 (.05 / 3). Our findings indicated that individuals using OCs reported significantly higher locomotion (as measured by the Locomotion subscale of the RMS) than those not using OCs, $t(761.0) = 4.51$, $p < .001$, $d = .27$, $BF_{10} = 1145.89$ (extreme evidence for the alternative hypothesis). There were no significant differences between groups on assessment (which we measured using the Assessment subscale of the RMS), $t(665.4) = 0.54$, $p = .586$, $d = .03$, $BF_{10} = 0.08$ (strong evidence for the null

hypothesis) and self-overriding (as measured by the BSCS), $t(701.4) = 1.01$, $p = .315$, $d = .06$, $BF_{10} = 0.11$ (moderate evidence for the null hypothesis).

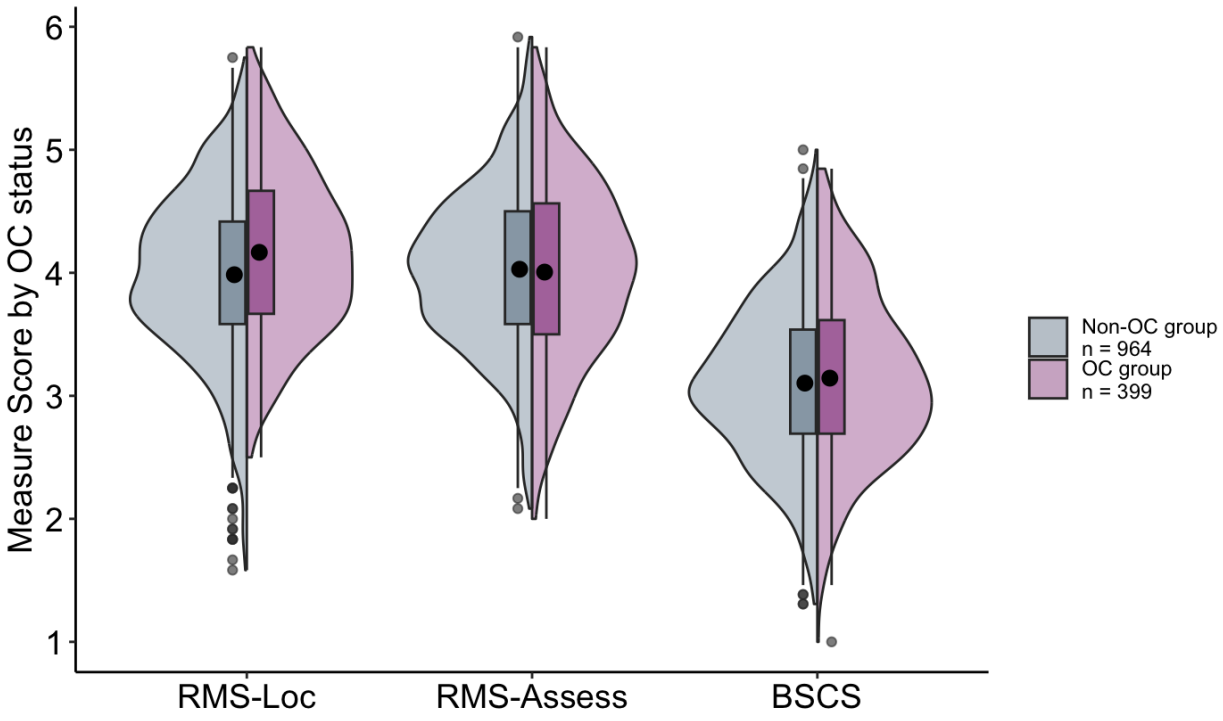


Figure 6.1. Violin plots with box and whisker plots (boxplots) for each of the measures (RMS-Locomotion, RMS-Assessment, and BSCS) as a function of OC use in Study 1.

6.2.2.3 Regressions

We also aimed to determine whether oral contraceptive use could predict our measures of self-control over and above symptoms of depression and the semester of data collection. To control for these variables, we conducted a series of hierarchical regressions entering semester and DASS-depression as predictors in the first step and adding oral contraceptive use in the second step. The R^2 and ΔR^2 associated with each regression are shown in Table 6.3.

As can be seen in Table 6.3, entering semester and depression symptoms in Step 1 accounted for a significant amount of overall variance in each outcome variable. More specifically, for self-overriding, only depression symptoms (and not semester) accounted for a significant amount of unique variance in Step 1. When predicting locomotion and assessment, both depression symptoms and semester were unique and significant predictors. In Step 2, OC use explained a significant amount of additional variance (over and above semester and depression) only in locomotion, such that OC use uniquely predicted greater locomotion. OC use did not explain additional variance in assessment or self-overriding (see ΔR^2 in Table 6.3). After OC use was added in Step 2, semester became a non-significant predictor for locomotion and remained non-significant for self-overriding, while depression symptoms continued to predict unique variance in all outcome measures. Semester continued to only predict significant variance in assessment.

Table 6.3. Regression model statistics for Study 1

		Beta	*SE*	*p*
DV: RMS-Loc		**R^2 = .052 , F = 37.33, SE = 0.67, Model *p* < .001**		
Step 1	Intercept	4.02	0.02	< .001
	Spring 2020	0.06	0.04	.014
	DASS-Dep	-0.16	0.02	< .001
Step 2		**R^2 = .064 , F = 30.94, SE = 0.67, Model *p* < .001**		
		ΔR^2 = .012, *p for* ΔR^2 < .001		
	Intercept	3.97	0.02	< .001
	Spring 2020	0.07	0.04	.129
	DASS-Dep	-0.15	0.02	< .001
	OC status	0.17	0.04	< .001
DV: RMS-Assess		**R^2 = .061 , F = 44.44, SE = 0.65, Model *p* < .001**		
Step 1	Intercept	4.00	0.02	< .001
	Spring 2020	0.08	0.04	.048
	DASS-Dep	0.16	0.02	< .001
Step 2		**R^2 = .061 , F = 29.61, SE = 0.65, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .920		
	Intercept	4.00	0.02	< .001
	Spring 2020	0.08	0.04	.048
	DASS-Dep	0.16	0.02	< .001
	OC status	-0.00	0.04	.920
DV: BSCS		**R^2 = .147 , F = 116.80, SE = 0.61, Model *p* < .001**		
Step 1	Intercept	3.11	0.02	< .001
	Spring 2020	0.01	0.04	.718
	DASS-Dep	-0.25	0.02	< .001
Step 2		**R^2 = .147 , F = 77.83, SE = 0.61, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .735		
	Intercept	3.11	0.02	< .001
	Spring 2020	0.01	0.04	.715
	DASS-Dep	-0.25	0.02	< .001
	OC status	0.01	0.04	.735

Note 1: DV = Dependent variable; BSCS = Brief Self-Control Scale, RMS-Loc = Regulatory Mode Scale – Locomotion Subscale, RMS-Assess = Regulatory Mode Scale – Assessment Subscale
Note 2: Step 1 included semester of data collection and depression symptoms as predictors. In Step 2, OC use was added to the model.
Note 3. ΔR^2 may not reflect exact numerical differences in R^2 values in the table due to rounding.

In summary, the findings from Study 1 revealed there were no significant differences between OC users and non-users in terms of self-overriding or self-regulatory assessment (i.e., the evaluation of goals and progress towards them). However, we did find a significant difference between OC users and non-users in self-regulatory locomotion (i.e., movement towards goals), such that those using OCs reported significantly greater locomotion than those

not using OCs. These patterns remained even when variance associated with semester of data collection and depression symptoms was statistically partialled out in regression analyses.

6.3 Study 2

In Study 2 we sought to determine whether the results of Study 1 would replicate in a different sample of undergraduate women.

6.3.1 Method

6.3.1.1 Participants

As in Study 1, all participants were female undergraduates, completed Mass Testing in exchange for partial course credit, and exclusions were made using the criteria outlined in the Data Cleaning section. In Fall 2020, data was collected from 1726 female participants. We excluded 940 participants according to the exclusion criteria outlined in Study 1. This resulted in 786 participants in Fall 2020, with 171 using OCs and 615 naturally cycling. Data was collected from 1573 females in Winter 2021. 1074 participants were excluded (including 443 participants who were already in the Study 1 sample), leaving 499 participants (117 using OCs and 382 naturally cycling). Thus, in total, Study 2 included 1285 participants, with 288 OC users and 997 non-users. Participants were an average of 19 years old.

6.3.1.2 Pre-screen and Mass Testing Surveys

The Pre-screen and Mass Testing procedure was identical to Study 1 with the exception that data was collected at the beginning of two different semesters: Fall 2020 (September –

October) and Winter 2021 (January – February). Participants who were included in the Study 1 sample were excluded if they were also present in the Study 2 sample (see Participants above).

6.3.1.3 Data Cleaning

The data cleaning procedure was identical to Study 1. As in Study 1, the data cleaning procedure and exclusion criteria were determined a priori. Below, we note the Ns for each exclusion criterion in Study 2. Four hundred and forty-three participants were excluded in Fall 2020 because they were included in Study 1 (in Winter or Spring 2020). We also excluded an additional 189 participants in Winter 2021 because they had been included in the Fall 2020 sample. Forty participants were excluded for using a hormonal contraceptive other than OCs (Fall 2020: N = 22; Winter 2021: N = 18), 158 were excluded because they used a hormonal IUD (Fall 2020: N = 85; Winter 2021: N = 73), 18 due to copper IUD use (Fall 2020: N = 6; Winter 2021: N = 12), or not disclosing whether or not they were using a hormonal contraceptive (N = 213; Fall 2020: N = 112; Winter 2021: N = 101). We also excluded 299 participants currently receiving treatment for depression[20] (Fall 2020: N = 150; OC N = 62, non-OC N = 88; Winter 2021: N = 149; OC N = 54, non-OC N = 95) and 38 for declining to disclose whether or not they were currently receiving treatment for depression (Fall 2020: N = 21; Winter 2021: N = 17). Ninety-three were excluded because they were currently receiving treatment for anxiety (Fall 2020: N = 55; OC N = 27, non-OC N = 28; Winter 2021: N = 38; OC N = 17, non-OC N = 21) and 14 were excluded for not disclosing whether they were currently receiving treatment for anxiety (Fall 2020: N = 9; Winter

[20] The inclusion of participants receiving treatment for depression, anxiety, or psychosis does not meaningfully change the results with two exceptions. These will be noted where relevant in the results section.

2021: N = 5). We excluded 3 participants (Fall 2020: N = 3; Winter 2021: N = 0) using anti-psychotics and 2 who did not disclose anti-psychotic use or non-use (Fall 2020: N = 1; Winter 2021: N = 1) were also excluded. These participants were excluded to avoid mental health issues as a possible confound. Thirty-one participants (Fall 2020: N = 15; Winter 2021: N = 16) were excluded for moving too fast through the survey (we reasoned that participants needed at least one second per item per scale to read the item and respond in good faith). Thus, if they were too quick (i.e., not reading items and likely responding randomly) we excluded them. We also excluded an additional 1 participant (Fall 2020: N = 0; Winter 2021: N = 1) because they completed fewer than 50% of the items on our scales of interest (since we averaged across items to score each scale). Data was analyzed with and without exclusions based on age (to target participants of reproductive age; 18-45 years old). This did not change the results in a meaningful way. The below analyses exclude participants who did not report their birth year were removed (N = 26) as well as participants who were older than 45 years of age (N = 3).

6.3.1.4 Materials

The materials were identical to those used in Study 1.

6.3.2 Results and Discussion

Analyses were again performed in R (R Core Team 2019) using the same packages as Study 1. We planned to conduct the same analyses implemented in Study 1 (analyses for Study 2 were pre-registered on OSF, see link above). As before, we compared OC users to non-users on each of the measures of self-control and we employed hierarchical regressions to determine

whether OC use could predict our measures of self-control over and above symptoms of depression and the semester of data collection.

6.3.2.1 Descriptive Statistics

Table 6.4 includes the descriptive statistics for both the OC and the non-OC groups. Scales again showed high reliabilities, with Cronbach alphas of .77 or greater (Table 6.5; left panel). We also include Pearson correlations between the measures within each group in Table 6.5 (right panel). Boxplots depicting each of the measures as a function of OC use condition (averaged across semesters) are shown in Figure 6.2.

Table 6.4. Descriptive statistics of measures by semester and group for Study 2

Semester	Group	Measure	N	Mean	SD	Skew	Kurtosis
Fall 2020	Non-OC group	BSCS	615	3.06	0.66	0.08	-0.17
		RMS-Loc	615	4.09	0.70	-0.10	-0.02
		RMS-Assess	615	4.17	0.67	-0.23	0.16
		DASS-Dep	615	0.93	0.75	0.83	-0.10
		DASS-Anx	615	0.77	0.66	1.02	0.54
		DASS-Stress	615	1.04	0.68	0.38	-0.54
	OC group	BSCS	171	3.18	0.64	-0.09	-0.30
		RMS-Loc	171	4.26	0.65	-0.13	0.08
		RMS-Assess	171	4.19	0.62	-0.54	0.89
		DASS-Dep	171	0.81	0.73	1.00	0.16
		DASS-Anx	171	0.76	0.67	0.92	0.00
		DASS-Stress	171	1.05	0.69	0.56	-0.35
Winter 2021	Non-OC group	BSCS	382	3.13	0.70	0.16	-0.16
		RMS-Loc	382	4.12	0.68	−0.02	−0.39
		RMS-Assess	382	4.05	0.67	-0.03	-0.22
		DASS-Dep	382	0.95	0.76	0.64	-0.50
		DASS-Anx	382	0.74	0.64	0.87	-0.04
		DASS-Stress	382	0.99	0.66	0.36	-0.63
	OC group	BSCS	117	3.12	0.69	-0.14	-0.41
		RMS-Loc	117	4.20	0.74	-0.02	-0.16
		RMS-Assess	117	4.17	0.67	0.14	-0.54
		DASS-Dep	117	0.81	0.74	1.15	0.95
		DASS-Anx	117	0.72	0.70	1.03	0.17
		DASS-Stress	117	1.01	0.66	0.59	-0.28

Note. BSCS = Brief Self-Control Scale, RMS-Loc = Regulatory Mode Scale – Locomotion Subscale, RMS-Assess = Regulatory Mode Scale – Assessment Subscale, DASS-Dep = DASS Depression Subscale, DASS-Anx = DASS Anxiety Subscale, DASS-Stress = DASS Stress Subscale.

Table 6.5. Cronbach alphas (left panel) and pearson correlations (right panel) of the OC group (above the diagonal; N=288) and non-OC group (below the diagonal; N = 997) for Study 2

Measure	*OC Cronbach α*	*Non-OC Cronbach α*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. RMS-Loc	.83	.84	--	.10	.46 **	-.29 **	-.14 *	-.14 *	--
2. RMS-Assess	.77	.78	.16	--	-.18 **	.20 **	.25 **	.29 **	.16
3. BSCS	.83	.82	.44 **	-.20 **	--	-.38 **	-.30 **	-.37 **	.44 **
4.DASS-Depression	.91	.90	-.21 **	.26 **	-.40 **	--	.64 **	.75 **	-.21 **
5. DASS-Anxiety	.84	.81	-.06 *	.19 **	-.27 **	.63 **	--	.78 **	-.06 *
6. DASS-Stress	.84	.84	-.01 *	.29 **	-.27 **	.69 **	.75 **	--	-.01 *

Note. BSCS = Brief Self-Control Scale; RMS-Assess = Regulatory Mode Scale – Assessment subscale; RMS-Loc = Regulatory Mode Scale – Locomotion subscale.
* p = .05, ** p < .001

6.3.2.2 Planned Comparisons

Collapsing across semesters with a Bonferroni correction (alpha = .017), we again found that OC users reported significantly greater locomotion on the RMS-Locomotion subscale than non-users, $t(468.1) = 2.86$, $p = .004$, $d = 0.19$, $BF_{10} = 3.98$ (moderate evidence for the alternative hypothesis)[21]. Also as in Study 1, we did not find significant differences between groups on the RMS-Assessment subscale, $t(482.5) = 1.38$, $p = .167$, $d = 0.09$, $BF_{10} = 0.18$ (moderate evidence

[21] This comparison of OC users and non-users is no longer statistically significant when we include participants receiving treatment for mental health concerns ($p = .103$, $d = .10$). Numerically, OC users report greater locomotion than non-users which is the same direction as Study 1. There were again no significant differences between groups on assessment or self-overriding.

for the null hypothesis), or the BSCS (i.e., self-overriding), $t(478.9) = 1.51$, $p = .132$, $d = 0.10$, $BF_{10} = 0.22$ (moderate evidence for the null hypothesis).

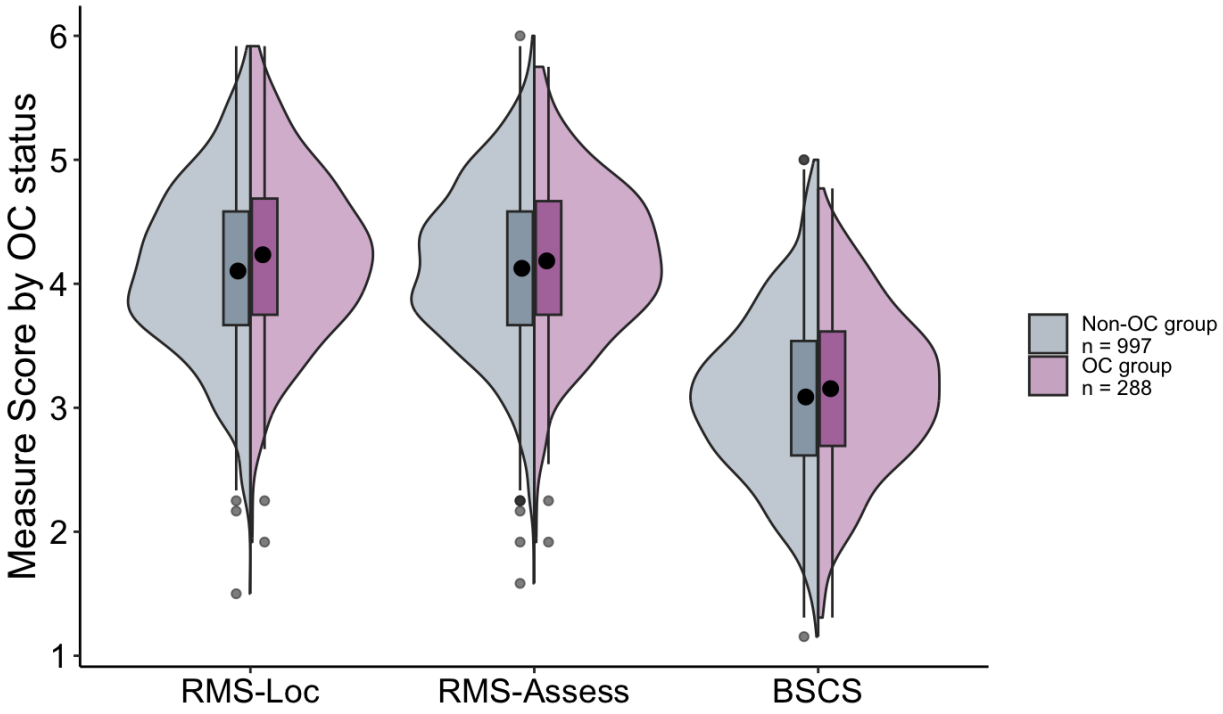


Figure 6.2. Violin plot with box and whisker plots (boxplots) for each of the measures (RMS-Locomotion, RMS-Assessment, and BSCS) as a function of OC group (Non-OC vs. OC) in Study 2.

6.3.2.3 Regressions

As in Study 1, we conducted a series of hierarchical regressions predicting the scores on the self-control scales with semester of data collection and DASS-depression as predictors in the first step, and then adding contraceptive use in the second step (Table 6.6). Together, depression symptoms and the semester of data collection accounted for a significant amount of variance in each measure. Depression predicted unique variance in each measure, while semester only

accounted for unique variance in self-regulatory assessment. Similar to Study 1, when considering self-regulatory locomotion as assessed by RMS-Locomotion, we found that adding OC use in Step 2 of the regression accounted for significant additional variance. In this second step, significant unique variance was explained by depression but not semester. Also consistent with Study 1, for self-overriding indexed via the BSCS, we again found that the addition of OC use in Step 2 did not explain additional variance and that in this step depression but not semester of data collection predicted a significant amount of unique variance. Finally, when predicting self-regulatory assessment via the RMS-Assessment subscale we found that the addition of OC use in Step 2 of the regression explained significant additional variance in assessment, whereby OC users reported greater self-regulatory assessment than non-users (see ΔR^2 in Table 6.6). This outcome differed from that of Study 1, which did not show such an effect. Also, after OC use was added, both depression and semester of data collection continued to explain a significant amount of unique variance in self-regulatory assessment.

Table 6.6. Regression model statistics for Study 2

		Beta	*SE*	*p*
DV: RMS-Loc		**R^2 = .055 , F = 37.34, SE = 0.67, Model *p* < .001**		
Step 1	Intercept	4.13	0.02	< .001
	Winter 2021	0.02	0.04	.669
	DASS-Dep	-0.16	0.02	< .001
Step 2		**R^2 = .059 , F = 26.79, SE = 0.67, Model *p* < .001**		
		ΔR^2 = .004, *p for* ΔR^2 < .020		
	Intercept	4.10	0.03	< .001
	Winter 2021	0.01	0.04	.704
	DASS-Dep	-0.16	0.02	< .001
	OC status	0.11	0.05	.020[22]
DV: RMS-Assess		**R^2 = .064 , F = 44.17, SE = 0.64, Model *p* < .001**		
Step 1	Intercept	4.17	0.02	< .001
	Winter 2021	-0.09	0.04	.010
	DASS-Dep	0.16	0.02	< .001
Step 2		**R^2 = .068 , F = 30.95, SE = 0.64, Model *p* < .001**		
		ΔR^2 = .003, *p for* ΔR^2 = .039		
	Intercept	4.16	0.02	< .001
	Winter 2021	-0.10	0.04	.009
	DASS-Dep	0.16	0.02	< .001
	OC status	0.09	0.04	.039
DV: BSCS		**R^2 = .158 , F = 120.70, SE = 0.62, Model *p* < .001**		
Step 1	Intercept	3.09	0.02	< .001
	Winter 2021	0.04	0.04	.221
	DASS-Dep	-0.27	0.02	< .001
Step 2		**R^2 = .159 , F = 80.50, SE = 0.62, Model *p* < .001**		
		ΔR^2 = .000, *p for* ΔR^2 = .594		
	Intercept	3.08	0.02	< .001
	Winter 2021	0.04	0.04	.225
	DASS-Dep	-0.27	0.02	< .001
	OC status	0.02	0.04	.594

Note 1: DV = Dependent variable; BSCS = Brief Self-Control Scale, RMS-Loc = Regulatory Mode Scale – Locomotion Subscale, RMS-Assess = Regulatory Mode Scale – Assessment Subscale

Note 2: Step 1 included semester of data collection and depression symptoms as predictors. In Step 2, OC use was added to the model.

Note 3. ΔR^2 may not reflect exact numerical differences in R^2 values in the table due to rounding.

[22] When participants undergoing treatment for depression, anxiety, and/or psychosis are included, the addition of OC use in the second step no longer explains significant additional variance in self-regulatory locomotion ($\beta = 0.06$, $p = .176$).

6.4 General Discussion

In the present studies, we investigated whether OC users and non-users differed in their levels of self-control, with a particular focus on self-control defined in terms of the ability to override impulses and the tendency to use two self-regulation strategies in goal attainment, namely, locomotion (the tendency to move towards goals) and assessment (the tendency to evaluate goals and goal attainment options). There were three notable findings. First, in both studies we found that OC users consistently reported significantly greater self-regulatory locomotion than non-users and this relation remained even after partialing out variance associated with semester of data collection and depression symptoms. Second, we found weak evidence of greater self-regulatory assessment for OC users than non-users, which persisted even when semester of data collection and depression were accounted for, but occurred only in Study 2. Third, we consistently found no evidence of differences between groups when it came to self-overriding.

At first glance, these findings may seem discordant with prior work investigating OC use, self-control, and related traits. As mentioned earlier, a randomized control trial by Zethraeus et al. (2017) found that participants' reports of self-control significantly decreased following OC use. Relatedly, Bradshaw et al., (2020), showed that hormonal contraceptive use (including OCs) was associated with decreased perseverance (but also see Byg et al., 2023). In contrast, our study showed OC use was associated with slightly higher levels of self-control (primarily locomotion and perhaps assessment). There are several possible explanations for these apparently conflicting results. For instance, the discordant conclusions may be the result of differences in the way aspects of self-control were operationalized and measured across studies. Our studies included measures of self-control (i.e., self-regulation and self-overriding) that were not measured in prior studies,

and as we noted, the relation between OC use and self-control may depend on the precise aspects of self-control measured. There are also substantial differences in sample sizes across studies, and it could be that the results from prior studies with smaller samples may be less stable or robust than results from larger samples, such as those included here. Clearly more work is needed to better understand the reasons for the different conclusions drawn from the available studies.

Returning to our main finding, there are several reasons why OC users may report greater locomotion than non-users. One possible explanation for this correlation is that OC use *causes* greater locomotion. As we mention earlier, there is a dense population of estrogen and progesterone receptors in the PFC (MacLusky et al., 1986; Bixo et al., 1995; Almey et al., 2015; Brinton et al., 2008). Given that the PFC has been implicated in self-control (Knoch & Fehr, 2007; Figner et al., 2010; Tanaka et al., 2020) and that OC users differ from non-users in their PFC connectivity (Petersen et al., 2014; Sharma et al., 2020) and grey matter volume (Heller et al., 2022), it is possible these differences in connectivity and morphology might manifest behaviourally as differences in locomotion. On the other hand, it is also possible that the difference in self-regulatory locomotion between OC users and non-users reflects a selection bias whereby women with higher levels of locomotion are more likely to use OCs. Specifically, women higher in self-regulatory locomotion (and perhaps to a lesser extent self-regulatory assessment) may strive to achieve goals that are incompatible with an unplanned pregnancy, which may drive them to be more likely to opt to use OCs. Indeed, the use of OCs could be interpreted as a 'locomotive action' used to support goal achievement. Yet another possibility is that the association between OC use and locomotion reflects a survivor effect. According to this account, women with lower levels of self-regulatory locomotion who choose to start taking OCs might be more likely to discontinue use

if they experience adverse effects from the OCs. Because these women with lower locomotion end up using OCs for only a short time, they are more likely to be included in the group of non-OC users in a research study than a group of OC users. Given this variety of possible explanations, identifying the precise explanation for the differences in self-regulation between OC and non-OC users should be a primary goal of future studies in this area.

The present findings suggest several additional lines of future research. First, self-regulatory locomotion may be an important third (mediating) variable to consider in studies examining the relation between OC use and various other cognitive functions (e.g., perseverance, sustained attention). Locomotion might serve as a useful mediator because it is closely related to motivation, which is known to be strongly related to cognitive performance (Seli et al., 2019; Mrazek et al., 2012, Study 3; Robison & Unsworth, 2018; Seli et al., 2016). Second, since locomotion is also positively correlated with conscientiousness, achievement orientation, and decisiveness (Kruglanski et al., 2000), future work could further examine the relation between OC use and these various traits related to goal achievement. Third, there are dimensions of self-control (e.g., control of emotions) that we did not have the opportunity to consider in the present studies, and future work could focus on exploring whether and how all of the various aspects of self-control are related to OC use. Fourth, while there is a growing interest in the relation between OC use and cognition, there remains a dearth of work on other hormonal (and non-hormonal) contraceptives such as intrauterine devices (IUDs; both hormonal and copper), which have yet to be explored in the context of cognition. Given the growing interest in these devices, assessing their influences on cognition might be another fruitful area for future research.

Finally, there are some limitations to the present findings. First, since participation in our study was optional, it is possible that those who opted to participate had better self-regulation tendencies than those who did not. However, there is no direct evidence of such a selection bias in our data, nor is it clear how such a selection bias would influence any differences between OC users and non-users. Second, because the cohort we studied was a sample of convenience, we again did not have access to information about the specific brands of OCs participants were using, nor their history of hormonal contraceptive use. Future explorations of the roles of OC formulation and reproductive history might shed light on the mechanism underlying the relation between OC use and self-control.

Chapter 7: General Discussion

General Summary of Findings

The work presented in this dissertation has contributed to our understanding of the association between OC use and several attention-related traits and states. Specifically, in Chapters 2, 3, and 4 the relation between OC use and trait-level attentional engagement is investigated. The studies in these chapters demonstrated that there was no consistent evidence that OC users and non-users differ in terms of their trait-level tendency to experience attention related errors, attention lapses, spontaneous and deliberate mind wandering, and internal and external flow. Intriguingly, OC users tended to consistently report lower boredom proneness, but that this effect tended to disappear after controlling for depression symptoms. This work also showed that differences in OC formulation were not related to differences in trait-level inattention, which suggests that it is appropriate to collapse across OC formulations when examining OC use and trait-level sustained attention.

Chapter 5 explored the relation between OC use and sustained attention performance during the SART in current OC users, prior OC users, and never OC users. Across two large samples, the results showed that these groups did not significantly differ from one another in SART performance (go RT, commission errors, omission errors, and skill index) either when performance was examined over time. While in Study 1 there were significant differences in subjective reports of unintentional mind wandering, such that current OC users and prior OC users reported greater unintentional mind wandering during the task than never users, this effect did not replicate in an independent sample in Study 2. Retrospective reports of media multitasking also did not significantly differ between groups in either study. We again concluded that there was little

evidence that OC use (or prior use) was associated with consistent differences in state-level sustained attention performance.

Finally, given the role of self-control in sustained attention, the relation between OC use and trait-level self-control was examined in two large samples in Chapter 6. The findings indicated there were no significant differences between groups on the self-overriding aspects of self-control or self-regulatory assessment, but there were differences in self-regulatory locomotion in both samples, whereby OC users reported significantly greater locomotion than non-users.

Thus, the overall finding of this comprehensive approach was that, contrary to some initial reports (Grikšienė & Rukšėnas, 2009; Raymond et al., 2019), OC use does not have a reliable and robust relation to most attention-related traits and states, although it is related to differences in the propensity to experience boredom and self-regulatory locomotion. While differences in boredom disappeared after accounting for depression, OC users remained higher in self-regulatory locomotion even after controlling for depression. The present studies improved upon prior literature by 1) testing large diverse samples, 2) attempting replication of the main findings, 3) examining a variety of attention-related factors, including attention lapses, attention-related errors, mind wandering, boredom, flow, and self-control, 4) examining some of these factors at the trait and state levels, 5) attempting to control for correlated experiences of depression, and 6) using a suite of valid and reliable self-report and behavioural measures. Taken together the present studies extend prior work on the relations between hormonal contraceptive use and various cognitive processes (see Gurvich et al., 2023 for a review).

The Variability in Outcomes Across Samples and Studies

One of the main themes that emerged across chapters in the thesis is that in a number of cases, the results varied as a function of study or sample. Since there were direct replications of many of the findings (Chapters 2, 3, and 5), we were able to observe that effects in one sample did not replicate in a second sample. The collection of a second independent sample critically informed interpretation of the data. For example, had data collection stopped after Study 1 in Chapter 2 (where OC users reported significantly less spontaneous and deliberate mind wandering than non-users), we would have missed that these effects were not replicable (Chapter 2, Study 2; Chapter 4). We also would not have observed that boredom proneness is consistently lower in OC users compared to non-users (Chapters 3 and 4). Direct replication provides a useful window into the stability and robustness of findings across different samples (even if these are relatively large).

The frequent failures to replicate some of our initial findings should perhaps not be surprising given the concerningly low rates of replication within psychology in general (Open Science Collaboration, 2015). Yet, direct replications are speculated to be rarely attempted (Pashler & Harris, 2014) and seldom published (e.g., Makel et al., 2012; Sterling, Rosenbaum, & Weinkam, 1995). One reason for this might be the anticipated difficulty in publishing both 'known' and null findings. Some have speculated that failures to replicate can be attributed to factors such as insufficient power (i.e., not an adequately large sample) and a focus on statistical significance (opposed to looking for numerical trends in the same direction as the original finding; Maxwell et al., 2015). In other cases, the failure to replicate might be due to researchers leveraging so-called "researcher degrees of freedom" (see Wicherts et al. 2016). However, this does not explain the instability in the data presented in this dissertation, as we were transparent in our

attempts to directly self-replicate. Instead, the failures to self-replicate seem to reflect natural variations between samples, and general instability of the patterns of outcomes under investigation, which likely arise primarily from measurement error. Indeed, based on data simulations, Stanley and Spence (2014, p. 315) have compellingly argued "that substantial variability in replication correlations can be expected as a result of measurement error alone."

This variability across our samples also mirrors the inconsistency in outcomes in the specific area of research examining the link between hormonal contraceptive use and cognition (e.g., mental rotation, difference detection; see Gurvich et al., 2023 for a review). Given this lack of consistency across studies purporting to address a given cognitive domain, it is important to further consider the possible factors that might lead to these outcomes. Several suggestions are provided below.

Sample Size. As alluded to above, one possible reason for the discordant results between studies concerns sample size. In Gurvich et al.'s (2023) review on OC use and cognition, most domains of cognition (including sustained attention and executive functioning) had an average OC group comprised of fewer than 30 participants. As Beltz (2023) points out in her review on OC use and cognition, this means that most studies examining OC use and cognition are only powered to detect large effects. Beltz (2023) highlights that at least 64 participants using OCs (as well as 64 non-OC users) would be required to detect even medium effects (Faul et al., 2007). Furthermore, small sample sizes typically lead to greater variability in findings across studies (see Stanley & Spence, 2014). It appears that researchers have generally assumed large effect sizes when studying the relations between OC use and cognition. This assumption (and the corresponding small sample sizes) seems to stem from studies which examined sex differences in

mental rotation task performance which have found large effects (e.g., Vandenberg & Kuse, 1978). However, sample sizes remain small in other domains of cognition which have not been shown to be associated with sex differences (e.g., sustained attention; Raymond et al., 2019; Silber et al., 1987; Grikšienė & Rukšėnas, 2009). Another possible reason why small samples are used is that after carefully screening a larger number of participants, only a small number of participants meet the inclusion criteria for the study (see inclusion criteria section below). Another possibility is that the time and monetary expense of continuing to collect data to reach a pre-determined large sample size are prohibitive. We too have experienced the large amount of time it takes to collect large samples in this domain: For example, data collection for Chapter 5 (OC use and performance on SART) took approximately 2 years to reach 80 participants in the OC group of each of the 2 samples (other cognitive studies reach an n = 80 in a matter of days or weeks). This makes it difficult for researchers to recruit sufficiently large samples to detect small and medium sized effects and/or to attempt self-replications to determine the robustness of their findings (or null effects).

Inclusion Criteria. Another possible reason for the observed variation in findings across studies may be that different studies have differing inclusion criteria. There is no clear consensus for inclusion criteria in studies assessing OC use and cognition. While studies within labs are sometimes similar, there is variability between studies and labs. We prioritized the generalizability of our work, opting to only exclude participants on criteria for which it was clear there was a potential confound (i.e., sex, age, other hormonal contraceptive use, depression/anxiety). Others have chosen to apply both more stringent and less stringent criteria (e.g., Raymond et al., 2019; Bradshaw et al., 2020). More stringent criteria can include the aforementioned criteria as well as

requiring participants to have no history of pregnancy, no history of neurological, psychiatric, or cardiovascular disorders (e.g., depression, traumatic brain injury, arrythmia), no drug or medication use (other than OCs in the OC group), no medical problems (including endocrine disorders), regular menstrual cycles, and/or non-smokers (Raymond et al., 2019; Beltz et al., 2022; Grikšienė & Rukšėnas, 2009). Less stringent criteria have involved only some of the above factors (e.g., excluding participants who are currently pregnant or breastfeeding, who have an endocrine disorder, and/or have used a hormonal contraceptive for less than 2 months; Bradshaw et al., 2020). Some earlier studies did not report their inclusion criteria (e.g., Silber et al., 1987). This variability in recruitment makes it difficult to compare results across samples because the application of these criteria will prioritize either greater internal validity (in the case of more strict criteria) or greater external validity (generalizability; in those who apply less strict criteria). It is also worth considering that a preference for applying stricter screening creates a very high bar for publication – and by extension (as frequently observed) a low bar in terms of sample size (as presumably fewer people will meet the criteria when there are many criterion that must be met for inclusion). It may be argued that this screening is a 'more rigorous' scientific approach (because it filters out many extraneous variables) but given the widespread use of OCs among women of diverse backgrounds, it may not always be the right choice to sacrifice external validity for internal validity.

Conceptualization of Measures. Another contributing factor to the mixed findings in the literature examining OC use and cognition is the poor conceptual categorization of the diverse measures used. Poor task categorization occurs when researchers use a task to assess a particular cognitive domain (or sub-domain) when that task is not well-suited to measure that domain (and perhaps better suited to measure another domain). As discussed earlier, Grikšienė and Rukšėnas

(2009) and Silber et al. (1987) used reaction time tasks to assess sustained attention. However, while reaction time tasks require participants to make speeded responses to stimuli over an extended period of time, and so likely do involve sustained attention, they are not the preferred method for measuring this aspect of cognition. In fact, reaction time tasks are also used to assess psychomotor performance (e.g., Becker et al., 1982). Similarly, go/no-go tasks have been used as a measure of both attention and decision-making (e.g., Gingnell et al., 2016; Mihalik et al. 2009), and digit span tasks have been used to assess attention and working memory (e.g., Gogs, 2013; Kuhlmann & Wolf, 2005; Gravelsins et al., 2021; Islam et al., 2008). This lack of construct validity makes it difficult to compare across studies claiming to assess a particular cognition domain because the different tasks used could actually be primarily measuring quite different cognitive processes. With questionable construct validity in play, it is challenging to pinpoint whether the source of the inconsistency across studies is due to the lack of construct validity, or measurement error, or something else entirely.

OC Formulation. Differences in OC formulation is also a source of variation between studies. As we discuss in Chapter 4, there is variation in OC formulation in terms of the ethinyl-estradiol and/or progestin dose, dosing schedule, progestin generation, and the estrogenic, progestenic, and androgenic activity. Many studies collapse across OC or hormonal contraceptive formulation (ours included; Chapters 2-3; Bradshaw et al., 2020; Raymond et al., 2019) and assume they constitute one homogenous group. However, as we mentioned earlier, this might obscure effects that may be specific to a particular formulation. While we did not find formulation to be related to differences in trait-level everyday attentional engagement (Chapter 4), others have found differences between formulations in the context of other cognitive domains (e.g., when

examining performance on a mental rotation task; Beltz et al., 2022). As a result of findings documenting the relevance of OC formulation, and due to increased interest in how cognitive performance might differ as a function of OC formulation, it is becoming more common for researchers to collect data regarding OC formulation and to analyze data with this factor in mind.

Confounding Variables. Few studies analyze their data to account for confounding ("third") variables (e.g., depression symptoms; Skovlund et al., 2016; Hamstra et al., 2017; Seli et al., 2019; McDermott & Ebmeier, 2009) that can lead to variation between studies. By controlling for these potential confounds in statistical analyses (such as hierarchical regressions), we are better able to understand whether the cognitive effects we observe are attributable to OC use and/or the additional variables measured. For example, in Chapter 3, when comparing OC users and non-users, OC users reported less boredom proneness. However, after accounting for depression symptoms in a hierarchical regression, these group differences were no longer statistically significant. Given this, it is possible that the differences in boredom between OC users and non-users are driven by differences in depression symptoms. It is also worth considering that prior to the data analysis, participants were excluded if they were currently receiving treatment for depression and/or anxiety. Yet this was not sufficient to ensure these symptoms did not impact our findings. We still had to statistically control for depression symptoms to reveal this nuanced effect.

Individual Differences. Finally, it is always worth considering that there are likely individual differences in women's responses to OCs. It is known that there are individual differences in the absolute levels of endogenous estrogen and progesterone produced by women across the menstrual cycle (Elmlinger et al., 2002). This suggests that if a group of women were administered the same OC (e.g., a monophasic OC containing ethinyl-estradiol and a progestin),

that OC might suppress endogenous estrogen and progesterone in all women, but it might suppress those hormones to a different degree in each woman depending on weight, hormone sensitivity, metabolism, or other individual differences in endocrine function. The main implication is that there could be individual differences in the cognitive effects experienced across individuals using OCs. This consideration may inform how future studies of OC use and cognition are designed. In the extant literature investigating OC use and cognition, the dominant approach is to utilize population level analyses that average across individuals. However, this approach may obscure cognitive effects that are specific to some sub-populations (e.g., those with a history of depression; those who are sedentary; those who have a different biological makeup). Going forward, it would be prudent to increase focus on the role of individual differences when examining the relations between OC use and cognition.

The Challenges of Studying OCs and Future Directions

There are several notable challenges when it comes to studying the influence of OC use that must be kept in mind. For example, one challenge inherent in most studies examining OC use is that in almost all such studies women are *not* randomly assigned to OC use and non-use groups (i.e., women self-select into groups). As such, it could be argued that any differences in attention between OC users and non-users could be due to pre-existing differences in these cohorts that lead them to choose to be OC users or non-users. For instance, one might argue that since OCs require a prescription, women using OCs might have better access to health care and/or are more health conscious, and that by extension these individuals may have better cognitive health and attention. Researchers have examined this 'health hypothesis' in cohort studies by comparing all-cause mortality rates of OC users and non-users. Most studies find no differences in all-cause mortality

across OC and non-OC users (e.g., Vessey, Yeates & Flynn, 2010; Beral et al., 1999), with some work finding a protective effect of OC use against all-cause mortality compared to those who have never used OCs (Charlton et al., 2014). Thus, this work seems to suggest that OC users are just as healthy as non-OC users – though we note that all-cause mortality may not capture all aspects of healthy living. Importantly, any positive effects of OC use could also be partly explained in terms of a 'survivor effect' whereby women who experience adverse effects of OCs might discontinue use (see Kay, 1984; Trussell & Kost, 1987; Chamberlain et al., 2020) and so be less likely to appear in the OC use condition in a study.

The present work suggests several avenues for future research. First, while the relation between different OC formulations and trait-level attentional engagement has been examined (see Chapter 4), the role of OC formulation must be explored further. Recall that there were no significant differences in trait-level attention as a function of OC formulation. However, when the data were subdivided into groups, there was a lack of power to detect small effects and to even explore some aspects of OC formulation (i.e., dosing schedule: monophasic vs. triphasic vs. progestin only; and progestin generation). Future work could examine these aspects of formulation and trait-level inattention in even larger samples. Relatedly, future studies could also investigate the relations between OC formulation and sustained attention during the SART (as well as other behavioural measures of sustained attention), and OC formulation and trait-level self-control. Second, it may be worth examining how varying inclusion criteria impacts the variability of findings. As noted earlier, inclusion criteria vary quite widely across studies and it is unclear how this impacts results. As such, it would be advisable to collect data from large diverse samples of OC users and non-users and analyze the data while varying inclusion criteria. Finally, the present

studies (and the majority of extant literature) on OC use and cognition examine this relation using population level inferential statistics that relies on averaging observations across individuals. Future work could utilize more precision (personalized) medicine approaches to better understand for whom OCs may have beneficial, detrimental, or neutral effects.

Concluding Remarks

Hormonal contraceptives are one of the most socially impactful inventions of all time. They have given women the opportunity to control their reproductive health. However, it is critical that we better understand the possible side effects of this class of medications more completely so that we not only have a comprehensive understanding of the medical side effects of OCs (e.g., heart attack, stroke; Roach et al., 2015) but also its impacts on cognition and brain. It seems odd that hormonal contraceptives have been on the market and widely used for decades, yet only now are researchers beginning to more thoroughly investigate their impact on brain and cognitive function. More broadly, neuroscientists have recently begun to draw attention to the fact that only 0.5% of neuroimaging studies focused on factors related to women's health (e.g., menopause, oral contraceptive use; Taylor et al., 2021; Jacobs 2023), indicating a massive gap in knowledge that likely extends into cognition. This dissertation is meant to be a step forward in our understanding of the relations between OC use and attention-related states and traits, and more generally, in our understanding of cognitive aspects of women's health.

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Appendix: Appendix A - Supplementary Data

Chapter 2

Study 1: DASS Scores

To determine if there were differences between groups on symptoms of depression, anxiety, and stress, we conducted a series of independent samples t-tests collapsing across semester. We found there was a significant differences between groups on symptoms of depression, $t(866.7) = 2.66$, $p = .008$, $d = .14$, such that those using OCs reported significantly fewer depression symptoms than non-OC users. There were no differences between groups on either symptoms of anxiety, $t(842.1) = 1.34$, $p = .181$, $d = .07$, or symptoms of stress, $t(814.3) = 0.37$, $p = .709$, $d = .02$.

Study 2: DASS Scores

To investigate whether there were differences in symptoms of depression, anxiety, and stress between those using OCs and those not, we conducted a series of independent samples t-tests collapsing across semester. We found no significant differences between groups on depression symptoms, $t(388.3) = 1.89$, $p = .059$, $d = .13$ (we note that OC users reported nominally fewer depression symptoms than non-users). We also did not find differences in symptoms of anxiety, $t(375.5) = 0.18$, $p = .860$, $d = .01$, nor symptoms of stress, $t(378.8) = 0.58$, $p = .565$, $d = .04$.

Chapter 3

Sample 1: DASS Scores

To determine if there were differences between groups on symptoms of depression, anxiety, and stress, we conducted a series of independent samples t-tests. We found a significant difference between groups on symptoms of depression, $t(570.7) = 2.48$, $p = .013$, $d = .15$, such that OC users reported significantly fewer depression symptoms than non-users. There were no significant differences between groups on either symptoms of anxiety, $t(560.5) = 0.46$, $p = .645$, $d = .03$, or symptoms of stress, $t(572.1) = 0.33$, $p = .742$, $d = .02$.

Sample 2: DASS Scores

To investigate whether there were differences in symptoms of depression, anxiety, and stress between those using OCs and those not, we conducted a series of independent samples t-tests. Our findings indicated that OC users reported significantly fewer depression symptoms than non-OC users, $t(254.9) = 3.85$, $p < .001$, $d = .29$ as well as significantly fewer symptoms of anxiety, $t(227.1) = 2.65$, $p = .008$, $d = .23$. We did not find differences in symptoms of stress, $t(227.9) = 0.15$, $p = .885$, $d = .01$.

Combined Samples: DASS Scores

There was again a significant difference between group on symptoms of depression, $t(820.1) = 4.37$, $p < .001$, $d = .21$, such that OC users reported significantly fewer symptoms of depression than non-users. There was also a significant difference in anxiety symptoms, $t(786.9) = 2.44$, $p = .015$, $d = .12$, with OC users reporting significantly fewer anxiety symptoms. There were no significant differences on stress symptoms, $t(791.1) = 0.73$, $p = .465$, $d = .04$.

Chapter 6

Study 1: DASS Scores

To determine if there were differences between groups on symptoms of depression, anxiety, and stress, we conducted a series of independent samples t-tests. We found no significant differences between groups on symptoms of depression, $t(745.7) = 1.89$, $p = .059$, $d = .11$, however those using OCs reported nominally fewer depression symptoms than non-OC users. There were also no differences between groups on either symptoms of anxiety, $t(758.0) = 1.13$, $p = .257$, $d = .07$, or symptoms of stress, $t(713.8) = 0.90$, $p = .369$, $d = .05$.

Study 2: DASS Scores

To investigate whether there were differences in symptoms of depression, anxiety, and stress between those using OCs and those not, we conducted a series of independent samples t-tests. Our findings indicated that OC users reported significantly fewer depression symptoms than non-OC users, $t(479.2) = 2.50$, $p = .013$, $d = .16$. We did not find differences in symptoms of anxiety, $t(451.7) = 0.44$, $p = .662$, $d = .03$, nor symptoms of stress, $t(460.3) = 0.23$, $p = .819$, $d = .02$.