Effects of Menstrual Cycle and Stress on Spatial Navigational Strategies:

A pilot study

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Abstract

Previous research indicates significant effects of menstrual cycle phase, and of stress, on spatial navigation, yet no published study has explored the possible effects of their interaction on navigational strategy use. Such exploration is important given that, under naturalistic conditions, women experience stressful events throughout the different menstrual cycle phases. Hence, I recruited 18 women (aged 18-30) in different cycle phases: non-Luteal (n = 11); Luteal (n = 7). Ten participants were randomly assigned to the Stress condition and eight to the Non-stress condition. All participants completed differing versions of the Paced Auditory Serial Addition Task (PASAT). Stress condition participants had to rapidly add pairs of verbally presented digits at increasing speed intervals, whereas the Non-stress condition participants added at a constant, slower between-digit speed. Thereafter, all participants completed a computerized navigation task that was solvable by using either a spatial (landmark-based cognitive map) or a response (based on cues within or responses to the environment) strategy. Results suggest PASAT successfully induced psychological stress but was too mild to induce physiological stress. Nevertheless, a mixed linear model analysis revealed that stress had a significant main effect on strategy selection with Non-stress participants using a spatial strategy more frequently. Although the model detected no significant cycle phase effect, the result pattern is consistent with previous literature. Additionally, while the interaction was non-significant, this pilot study's results suggest that, stressed women in the luteal cycle phase tend to use relatively inefficient response strategies when navigating. These findings encourage further and larger-scale exploration.

Keywords: Navigational Strategy Selection, Menstrual Cycle, Induced Stress, PASAT, Virtual Navigation Task

Research on spatial cognition tends to overlook how a woman's performance may change under different conditions, such as across her menstrual cycle or after exposure to stress. Previous research investigating the effect of menstrual cycle phase on spatial cognition has linked differences between women to the activational effects of female sex hormones (Cashdan & Gaulin, 2016; Hausmann, Slabbekoom, Van Goozen, Cohen-Kettenis, & Guntiirkun, 2000; McCormick & Teillon, 2001). However, most studies investigate performance on mental rotation and similar non-navigational tasks (Hampson, 2018; Voyer, Voyer, & Bryden, 1995; Zhu, Kelly, Curry, Lal, & Joseph, 2015). Few studies share the specific focus of this study: how women's spatial navigational strategies might vary across the menstrual cycle (i.e., as levels of sex hormones change).

The term *navigational strategy* refers to the method individuals employ to navigate within their environment (Iaria, Petrides, Dagher, Pike, & Bohbot, 2003; Roche, Mangaoang, Commins, & O'Mara, 2005). There are two main strategies, each relying on a separate memory system: a non-spatial *response strategy*, and a *spatial strategy.* The response strategy is egocentric in nature, and relies on cognitive processing that involves either computing and using distances from specific landmarks to the target location, or basing navigation decisions on the landmark-independent stimulus-response associations formed by physical turns at specific locations within the environment (Foreman & Gillet, 1997; Hussain, Hanafi, Konishi, Brake, & Bohbot, 2016). The caudate nucleus has been implicated in the cognitive processing underlying this strategy (Iaria et al., 2003; Packard, Hirsh, & White, 1989). The spatial strategy, in contrast, is more allocentric in nature as it relies on cognitive processing involving the formation of stimulus-stimulus associations between notable landmarks, that in turn, create cognitive maps of the environment (O'Keefe & Nadel, 1978; Sholl, 1996). The hippocampus has been strongly implicated in the cognitive processing underlying this strategy (Iaria et al., 2003; O'Keefe & Nadel, 1978). Hippocampal functioning is influenced by levels of the female sex hormones progesterone and estrogen, and by the secretion of cortisol during the physiological stress response.

Variation in Navigational Strategies across the Menstrual Cycle

Research suggests that women use different navigational strategies across the three main phases of their cycle: the early follicular phase, categorized by low estrogen and low progesterone levels; the ovulatory phase, categorized by high estrogen and low progesterone levels; and the mid/late luteal phase, categorized by intermediate estrogen levels and high progesterone levels. For instance, Hussain et al. (2016) asked 45 naturally-cycling young

women to complete a virtual reality (VR) navigation task using either a response or a spatial strategy, depending on their preference. Results suggested that those in the mid/late luteal phase preferred a spatial strategy, whereas those in the early follicular and ovulatory phases preferred using a response strategy. Similarly, Scheuringer and Pletzer (2017) asked 51 men and 49 women to complete a VR navigation task. Within this task, participants were shown a virtual environment from two perspectives: an allocentric one, characterized by a focus on cardinal directions, and an egocentric one, characterized by a focus on personal directions. Participants could then solve the task using either a spatial or a response strategy. Results indicated that women in the luteal phase, compared to those in the follicular phase, had significantly better navigational performance when using the spatial strategy.

Navigational Strategies and Stress

Although the few previous studies conducted in this field suggest there is a relationship between navigational strategy and menstrual cycle phase, existing research has tended to ignore the potential mediating effects of environmental factors, such as the possible life-related stress being experienced by women completing the navigational task.

In psychological literature, *stress* is defined as a body's physiological response to an (applied or implied) external threat (Kemeny, 2003; Lupien, Maheu, Tu, Fiocco, & Schramek, 2007). Once the organism appraises an event as threatening, the hypothalamic-pituitary-adrenal (HPA) axis is activated. This activation results in hypothalamic neurons releasing corticotropin-releasing hormone (CRH), in turn triggering the release of adrenocorticotropin (ACTH) from the pituitary gland. ACTH travels through the vascular system to the adrenal glands inducing the secretion of stress hormones. These stress hormones are distinguished into two main classes: the glucocorticoids, of which cortisol is the primary type in humans, and the catecholamines, adrenaline and noradrenaline. During physiological stress reactions, glucocorticoids cross the blood-brain barrier and bind to receptors in specific brain regions (Alderson & Novack, 2002; Kemeny, 2003). Three important brain regions containing glucocorticoid receptors are the hippocampus, the amygdala, and the prefrontal cortex – all of which are involved in learning and memory processes (Arnsten, 2009; Lupien et al., 2007). Given the ability of cortisol to bind to hippocampal receptors, and thus influence spatial memory processes, the physiological stress response may influence the use of navigational strategies in humans.

Every day, while stressed, people make spatial decisions, and use their spatial abilities to navigate their immediate environment. Yet, only a few published studies investigate the

relationship between stress and spatial cognition, with fewer investigating the effect of stress on navigational strategies specifically. In one such study, Richardson and Tomasulo (2011) found that participants exposed to an acute psychosocial stressor performed slower than those in a Non-stress condition on a VR navigation task. They proposed that this relatively impaired performance could be accounted for by participants switching from a spatial strategy to a response strategy when under stress.

Furthermore, some previous research suggests that stress exposure preferentially impairs map-based spatial strategies. For instance, Thomas, Laurance, Nadel, and Jacobs (2010) showed that exposure to acute psychosocial stress impaired allocentric, but not egocentric, spatial navigational performance in young adult women. In contrast, however, van Gerven, Ferguson, and Skelton (2016) showed that, when stressed, female participants preferred using an allocentric spatial strategy to solve a VR navigation task. Unfortunately, while noting that female sex hormones may mediate the relationship between stress and navigational strategies, neither Thomas and colleagues nor van Gerven et al. specified their female participants' menstrual cycle phases during testing.

Summary, Rationale and Hypotheses

Recent research suggests that variations in female sex hormones across the menstrual cycle affect which navigational strategies are used. A separate line of research suggests that the experience of stress also affects which navigational strategies are favored. Given that variations in levels of female sex hormones across the menstrual cycle do not occur independently from external environmental factors (and, specifically, that women at any phase of their cycle may encounter stress-provoking events), this pilot study investigated whether there are interacting effects of exposure to acute psychosocial stress and menstrual cycle phase on navigational strategy use. To date, no study investigating this specific question has been published. It was beyond the scope of this pilot study to explore variations across the three main phase groups, hence the early follicular and ovulatory phases were combined into one Non-Luteal phase group.

The study tested the following hypotheses:

1. Menstrual cycle phase will have a significant main effect on navigational strategy use: Participants in the Non-Luteal phase will tend to use a response strategy, whereas those in the Luteal phase will tend to use a spatial strategy.
2. Laboratory-induced stress will have a significant main effect on navigational strategy use: Participants exposed to an acute psychosocial stressor, but not

those unexposed, will tend to use a response strategy, rather than a spatial strategy.

3. Induced stress and menstrual cycle phase will have a significant interactional effect on navigational strategy use, particularly among participants in the Luteal phase. For instance, participants in that phase who are exposed to an acute psychosocial stressor will tend to use a response strategy, whereas those who are in that phase but not exposed to the stressor will tend to use a spatial strategy.

Methods

Design and Setting

This quasi-experimental study followed a 2 x 2 factorial design. The independent variables were: (1) menstrual cycle phase (two levels: Non-Luteal or Luteal), and (2) experimental condition (two levels: Stress or Non-stress). The dependent variable was the preferred navigational strategy (spatial or response), as determined by performance on a VR navigation task.

The study was conducted in the Department of Psychology at the University of Cape Town (UCT). Ethical approval for study procedures was granted by the UCT Psychology Department's Research Ethics Committee (reference: PSY2018-026).

Participants

Recruitment. Convenience sampling recruited 28 female undergraduate students. Of that number, 16 were recruited via the UCT Psychology Department's Student Research Participation Programme (SRPP). These women were awarded 3 SRPP points upon completion of the full study, contributing to their duly performed certificate. If excluded after the screening questionnaire, they were awarded 1 SRPP point. The other 12 participants were recruited via a Department of Student Affairs Research Invitation email. These women were entered into a raffle, with four possible gift-voucher prizes (R750, R500, R300, and R250).

Eligibility criteria. Only regularly-cycling women (i.e., with a menstrual cycle of between 25 and 34 days), aged 18-30 years, in the early follicular and ovulatory (comprising the Non-Luteal phase group), or luteal phases of their menstrual cycles were included. Furthermore, and consistent with similar studies, participants were excluded if they (a) had taken, within 3 months of testing, any hormonal contraceptive medication; (b) had prior

history of neurological illness or substance abuse; (c) were experiencing any mood, anxiety or endocrine disorder; (d) were taking any mood/anxiety stabilizing drugs; (e) had been pregnant within the past 2 years; or (f) were currently breastfeeding. All these factors can significantly affect the natural cycle and hormone levels (De Leo, Musacchio, Cappelli, Piomboni, & Morgante, 2016; Liu, Gold, Lasley, & Johnson, 2004).

After applying these criteria, I excluded 9 participants from participation. Data from one enrolled participant were excluded due to software error. Hence, thus the final sample consisted of 18 participants. The four experimental groups were: Non-Luteal Stress group (n = 6); Luteal Stress group (n = 4); Non-Luteal Non-stress group (n = 5); Luteal Non-stress group (n = 3). Mean ages ranged from 20.38 to 21 years, and average years of education ranged from 12.71 to 14 years.

Materials and Apparatus

Screening questionnaire. This self-report questionnaire (Appendix A), which is similar to that used by Hussain et al. (2016), helped determine study eligibility, ensured between-group demographic similarity, and gathered information regarding menstrual cycle phase.

Santa-Barbara Sense-Of-Direction Scale (SBSOD). This instrument (Appendix B) gathered data on participants' self-perceived spatial ability. SBSOD scores correlate well with various objective measures of performance on spatial cognition tasks, and the scale has high internal (α = .88) and test-retest reliability (r = .91; Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002).

Stress manipulation. Following van Gerven et al. (2016), I used a modified version of the Paced Auditory Serial Addition Task (PASAT), a well-known neuropsychological test, to induce stress (see also Lustyk, Olson, Gerrish, Holder, & Widman, 2010; Mathias, Stanford, & Houston, 2004). This task requires participants to rapidly add a series of single-digit numbers, presented sequentially and verbally to them on a standard desktop computer monitor via Inquisit (Version 5) software. Participants are instructed to add each number to the number that precedes it (e.g., if the presented sequence is 3-5-9-2, the correct responses should be 8-14-11).

In this study, as in van Gerven et al. (2016), the task included a practice block, consisting of 14 digits, and four test blocks, each consisting of 60 digits. During the practice

block, digits were presented with an inter-stimulus interval (ISI) of 2.7s, whereas in the test blocks they were presented with ISIs of 2.1s, 1.7s, 1.3s, and 0.9s, respectively.

I administered the '*un*-Paced Serial Addition Task' (U-PASAT; van Gerven et al., 2016) as a control condition. This task is identical to the aforementioned PASAT, except all digits, across all blocks, were presented with ISIs of 3s.

Both tasks took approximately 10 minutes to complete.

Stress manipulation checks. Participant heart rate (HR) was measured using a Polar Electro h10 Heart Rate Sensor (Kempele, Finland) whereas blood pressure (BP) measurements were taken with a standard blood pressure cuff. Participants also completed the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983; see Appendix C). This instrument comprises two 20-item Likert-type scales, one measuring state anxiety (i.e., current anxiety level) and the other measuring trait anxiety (i.e., general anxiety levels). This standardized measure has excellent psychometric properties with a reliable factor structure, excellent construct and concurrent validity, and excellent internal consistency (Spielberger & Vagg, 1984).

Computer-Generated Arena. The CG Arena (Jacobs, Laurence, & Thomas, 1997; Jacobs, Thomas, Laurance, & Nadel, 1998; Thomas, Hsu, Laurance, Nadel, & Jacobs, 2001) is a non-immersive desktop virtual environment navigation task modeled on the Morris Water Maze (Morris, 1984). The participant is presented with a first-person view of a large square room with a low circular wall spanning its inner boundaries. In the Arena, participants shift their viewpoint using the computer keyboard, and can thereby use landmark or distal cues and the spatial relations between them, to locate and relocate specific locations on the Arena floor. In the current study, images were posted on the room's four walls (see Figure 1). These images served as distal cues (i.e., cues not directly connected to the target). There were also two cue objects, a red cube and a green cube, placed inside the room, above the arena wall, in the middle of the North West (NW) and South East (SE) quadrants respectively. These objects served as landmark cues (i.e., cues used to deduce one's position based on the distances and positions of these within-Arena objects).

I used a CG Arena protocol that replicated the navigation task described by van Gerven et al. (2016). First the participant entered into the waiting room, an environment featuring plain-colored walls and devoid of all distal and other cues. Exposure to the waiting room allows participants to become comfortable with navigating within the Arena before commencing task trials. Once comfortable, the participant completed four *visible target trials*

in which she had to navigate, as quickly and directly as possible, to a square plainly visible on the Arena floor. When the participant reached this target, a bell rang, and I pressed spacebar to end the trial. On these trials, the room featured no distal or landmark cues. After completing the set of visible target trials, the participant was administered 10 Standard Trials (STs) with 10 Inter-Trial Strategy Probe trials (ITSPs) interspersed between them, such that they alternated in pairs (i.e., ST – ITSP – ST – ITSP, and so on).

On each ST, the participant had to locate a square that was hidden until she moved over it. This target remained in the same location, in the NW quadrant of the arena, and in line with the red cube. When the participant moved over the target, it became visible, the bell rang, and the participant became trapped so that she could no longer move around the Arena. Once on the target, I pressed the spacebar to end the trial. The participant's starting position on each ST varied, although each starting point was close to the circular wall, at one of the Arena's cardinal points (Table 1). On the first three STs, the participant was encouraged to look around the Arena after finding the target and to try to remember her location.

ITSPs matched the formal structure of the STs, however the target was always hidden, and the cue objects swapped position (i.e., the green cue was in the NW quadrant, whereas the red cue was in the SE quadrant). Participants were informed that they should navigate to the location in which they believed the target had been located on the previous ST. They were informed that the target would not appear and that no feedback would be given. However, they were not informed that the cue objects had changed position. On the ITSPs, participant starting positions alternated between the NE and SW cardinal points, near the circular wall. Hence, the two goal locations were equidistant from the starting points. The trial ended when the participant indicated she had reached the target location. If she identified the target location as being in the NW quadrant (i.e., where the target had been located on the ST trial), she was classified as using a spatial strategy. If she identified the target location in the SE quadrant (where the red cue object was now placed), she was classified as using a response strategy. Thus, the ITSPs assessed navigational strategy selection of participants, on a trial-by-trial basis.

The CG Arena protocol concluded with a single Probe Trial (PT). This trial was formally similar to the STs, except the cue objects swapped positions (as they would in an ITSP trial) and there was no target. The participant was instructed to navigate to where the target should be but was not informed that it would not appear or that the cue objects had been moved. The trial lasted for 30s before the bell sounded and the task ended. The measure

on this trial was how long the participants stayed in the ‘correct’ quadrant, although here the ‘correct’ quadrant was determined by her predominant strategy use in the preceding ITSPs (e.g., if the participant had preferred a spatial strategy throughout the previous ITSPs, she should spend most of her PT time in the NW quadrant, whereas if she had mostly used a response strategy, she should spend the majority of the PT time in the SE quadrant where the red cue object was placed).

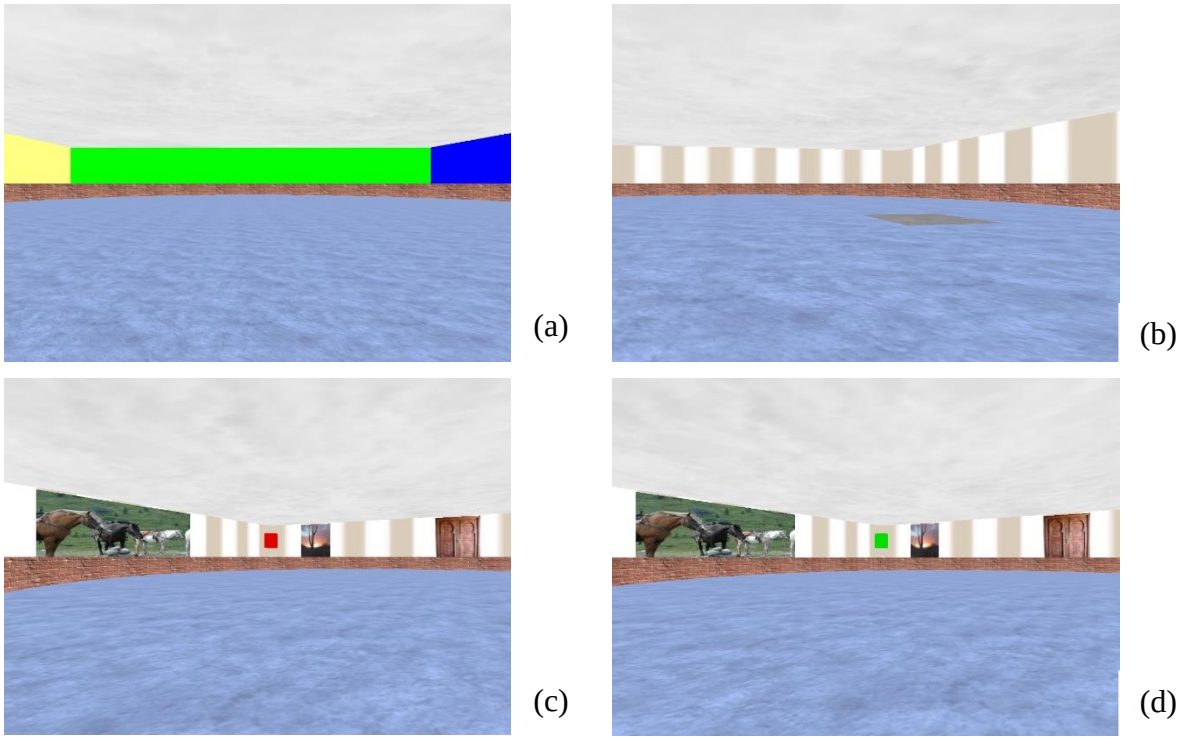

Figure 1. View from within the CG Arena on different trial types. Panel (a): the waiting room. Panel (b): visible-target trial. Panel (c): Standard trial, northwest (NW quadrant). Panel (d): Inter-Trial Strategy Probe trial, NW quadrant.

Table 1
CG Arena Task: Trial Descriptions

Trial	Starting Location	Target Location	Trial Type	Trial Action
1	South	NW	Visible	None
2	West	SW	Visible	None
3	West	SE	Visible	None
4	North	NE	Visible	None
5	South	NW	ST	None
6	NE	NW	ITSP	Swap cue objects
7	East	NW	ST	None
8	SW	NW	ITSP	Swap cue objects
9	West	NW	ST	None
10	NE	NW	ITSP	Swap cue objects
11	North	NW	ST	None
12	SW	NW	ITSP	Swap cue objects
13	East	NW	ST	None
14	NE	NW	ITSP	Swap cue objects
15	North	NW	ST	None
16	SW	NW	ITSP	Swap cue objects
17	South	NW	ST	None
18	NE	NW	ITSP	Swap cue objects
19	West	NW	ST	None
20	SW	NW	ITSP	Swap cue objects
21	South	NW	ST	None
22	NE	NW	ITSP	Swap cue objects
23	East	NW	ST	None
24	SW	NW	ITSP	Swap cue objects
25	Random	N/A	Probe	Swap cue objects

Note. Starting location refers to the quadrant in which the participant started the respective trial. Each starting location is a point close to the arena wall. NW = Northwest; SW = Southwest; SE = Southeast; NE = Northeast; ST = standard trial; ITSP = inter-trial strategy probe.

Post-Arena questionnaires. Participants completed two questionnaires modeled on instruments used by Hussain et al. (2016; see Appendix D). First, a structured questionnaire gathered self-report data on how the participant solved the CG Arena task. Answers to these questions confirmed the strategy categorization made based on task performance. A second questionnaire (Appendix E) gathered information about prior video game experience.

Procedure

After scheduling individual appointments, I met each participant at the agreed-upon time in the Psychology Department and administered consent procedures and the screening questionnaire. Individuals who did not meet the eligibility criteria were dismissed immediately. Those who met the criteria were formally enrolled in the study and assigned to

one of the two menstrual cycle phase groups. Specifically, if the participant reported she was within days 1-7 or days 13-17 of her cycle, she was assigned to the Non-Luteal phase group. If she reported being between day 20 and the end of her cycle, she was assigned to the Luteal phase group.

I strapped the HR sensor to the participant's chest and the BP cuff to her arm, and baseline measurements were recorded. If the participant's BP was above 140/90, I planned to exclude her from participation and encourage her to consult with a medical professional. This situation did not arise, however. The participant then completed the STAI-Trait, STAI-State, and SBSOD questionnaires. Next, the participant was randomly assigned to either experimental condition via an online randomization website (www.randomizer.org).

Those assigned to the Stress condition were administered the PASAT. To increase their experience of socioevaluative threat, they were told that the task tested 'thinking speed' and that most people of their age do well. Those assigned to Non-stress condition were administered the U-PASAT and were told nothing regarding what the test assessed. Immediately post-manipulation, I took another measure of HR and BP, and the participant completed the STAI-State questionnaire. A 10-min rest period followed during which the participant read a magazine. Thereafter, I measured her HR and BP again. Next, the participant completed the CG Arena task, followed by STAI-State, HR, and BP measures, and then the post-Arena questionnaires. Finally, her HR and BP were measured, and she completed the STAI-State questionnaire for the final time. At the conclusion of study procedures, I debriefed the participant and gave her more information on the study.

Figure 2 is a diagrammatic depiction of the study procedure.

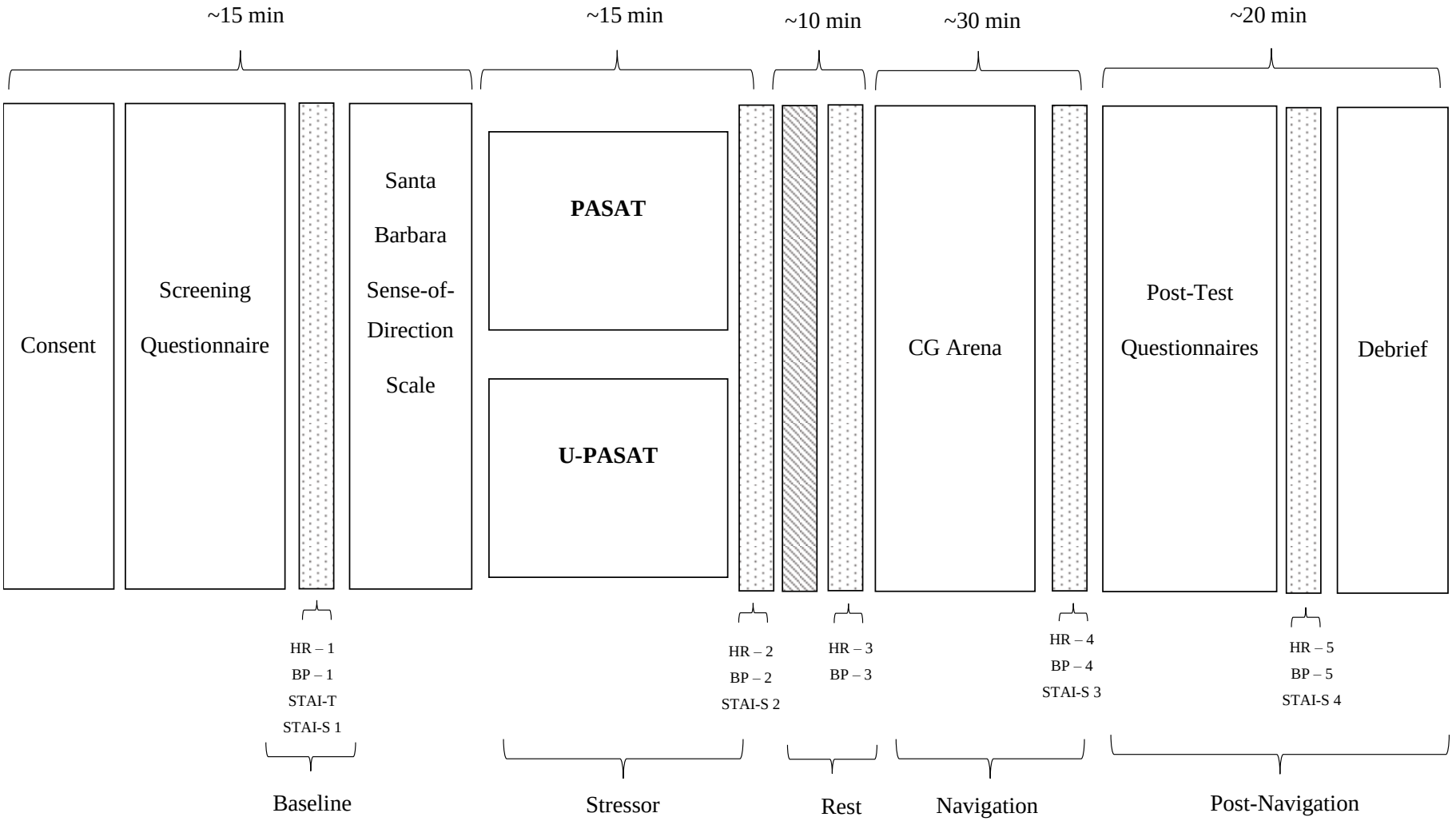

Figure 2. The study procedure. PASAT = Paced Auditory Serial Addition Task; U-PASAT – un-Paced Auditory Serial Addition Task; CG Arena = Computer-Generated Arena; HR= heart rate; BP = blood pressure; STAI = State-Trait Anxiety Inventory (T = trait form, S = state form).

Data Management and Statistical Analyses

I completed all statistical analyses using SPSS (version 25.0), with the threshold for statistical significance set at $\alpha = .05$. Prior to conducting inferential analyses, I generated and examined a complete set of descriptive statistics to ensure that all assumptions underlying those analyses were met. In cases where they were not met, I adjusted the analytic plan (details given at the appropriate places in the Results section).

Sample characteristics. A series of one-way ANOVAs (for continuous variables) and chi-squared tests (for categorical variables) assessed the magnitude of between-group differences with regard to basic sample characteristics (e.g., age, STAI-Trait scores, SBSOD scores, video game experience, average length of menses).

Manipulation check. Four linear mixed models, each including the fixed effects of experimental condition, time, and the interaction between the two, assessed magnitude of changes in physiological and self-reported stress over experimental time for participants in the Stress and Non-Stress conditions (i.e., they investigated the effectiveness of PASAT in inducing stress, and sought to confirm that the U-PASAT did not induce stress). This procedure prevented the listwise deletion of one participant due to missing data for physiological measurements and allowed change over time to be accounted for. A series of independent- and paired-sample *t*-tests followed up the significant results of the mixed models, thus seeking to confirm the precise location of pairwise differences. Finally, because it was ethically important to ensure that Stress-group participants left the laboratory in the same psychological state as when they entered, a series of paired-sample *t*-tests investigated the magnitude of differences between the first (baseline) and last (pre-debrief) measures of physiological and self-reported stress within that group.

Of note here is that, for the purposes of the manipulation-check analyses, the participant's menstrual cycle phase was not relevant and therefore was not included as a factor.

Navigation strategies. Following van Gerven et al. (2016), I calculated a single outcome variable that captured the degree to which participants used a spatial (versus a response) strategy when completing the spatial navigation task. To calculate this variable, *Average Spatial%*, I divided the number of ITSP trials on which the participant had used a spatial strategy by the total number of ITSP trials the participant had completed (i.e., Spatial % = [Spatial trials/Total ITSP trials] x 100). Hence, participants with higher values for this variable tended toward more frequent use of a spatial strategy when completing the CG Arena task, whereas those with lower values tended toward more frequent use of a response

strategy. Initial analyses revealed that the data, even after standard attempts at transformation, were not appropriate to be examined using factorial ANOVA. Thus, to investigate whether the independent variables (stress and menstrual cycle phase) had significant main and/or interaction effects on that outcome, I ran a linear mixed-model analysis that included fixed effects of cycle phase, experimental condition, and the interaction between the two.

Results

Power Analysis

I calculated an ideal sample size for this investigation using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007). With type of analysis set at ANOVA (fixed effects, special, main effects and interactions), and statistical parameters set at power (1 - β) = .80, α = .05, and Cohen's f = .40 (a large effect size), .25 (medium), or .15 (small), the software determined that, respectively, a minimum *N* of 73, 179, and 489 participants would be required. Hence, the current *N* of 18 means this study is under-powered, and the following results should be interpreted with caution. However, the purpose of this paper is to describe a pilot study that might give positive feasibility indicators and that might suggest the presence of hypothesized effects. For those purposes, the current *N* is sufficient.

Sample Characteristics

Analyses detected no significant differences on any of the measured sociodemographic, lifestyle, and physiological variables (see Table 2). A similar set of analyses assessed differences across menstrual cycle phase groups (Luteal [n = 7] versus Non-Luteal [n = 11]), and across experimental conditions (Stress [n = 10] versus Non-Stress [n = 8]), separately. These analyses detected one only significant between-group difference: Participants in the Non-Luteal phase had completed more years of education than those in the Luteal phase, $F(1,16) = 7.58$, $p = .014$, $\eta^2 = .32$. (For all other comparisons in this set, $p > .094$.) Overall, these findings imply that the current results were not confounded by between-group differences on any of the measured sociodemographic, lifestyle, and physiological variables.

Table 2

Sample Characteristics: Descriptive statistics and between-group comparisons (*N = 18)*

	Group						
	Stress		Non-Stress				
Measure	Non-Luteal (*n* = 6)	Luteal (*n* = 4)	Non-Luteal (*n* = 5)	Luteal (*n* = 3)	*F* / x^2	*p*	ESE
Age (years)	20.50 (1.76)	20.25 (1.50)	20.60 (.89)	22 (5.20)	.36	.782	.07
Range	19-23	18-21	20-22	19-28			
Education (years)	13.67 (1.21)	12.75 (.50)	14 (.71)	12.67 (.58)	2.40	.111	.34
Range	12-15	12-13	13-15	12-13			
STAI-Trait	35 (7.01)	36.75 (6.90)	34 (6.52)	45 (21.28)	.83	.499	.15
Range	24-44	31-46	23-40	22-64			
SBSOD	4.40 (.98)	4.05 (1.45)	3.80 (1.62)	4.08 (.92)	.20	.896	.04
Range	3.13-5.60	2.50-5.93	1.93-5.67	3.10-4.93			
Sleep					4.33	.632	.35
4-6	2	1	2	2			
7-8	4	3	2	1			
9-10	0	0	1	0			
Exercise					15.72	.401	.54
> 1	1	2	0	3			
1-2	3	1	1	0			
3-4	1	1	1	0			
5-6	0	0	1	0			
7-8	1	0	1	0			
> 8	0	0	1	0			
Alcohol (drinks)					5.75	.119	.57
0-2	6	4	3	3			
3-5	0	0	2	0			
Cigarettes					4.19	.651	.34
0	5	3	4	3			
10-20	0	1	1	0			
20-40	1	0	0	0			
Video Games							
0	3	4	5	3	7.2	.616	.37
3-5	1	0	0	0			
5-10	1	0	0	0			
> 10	1	0	0	0			
Age at first period	13.17 (.98)	13.25 (.50)	13.10 (2.41)	11 (2.65)	1.27	.318	.20
Range	12-14	13-14	10-16	8-13			
Menses duration					11.03	.088	.55
3-5	3	4	2	0			
6-8	3	0	3	2			
> 8	0	0	0	1			

Notes. For continuous variables, means, standard deviations, and ranges are presented; for categorical variables, frequencies with percentages in parentheses. *Sleep* represents average duration per night, in hours, over the last month; *Exercise*, average amount per week, in hours; *Alcohol*, average number of drinks per week; *Cigarettes*, average number smoked per week; *Video Games*, playing experience, in years; *Menses*, average period length, in days. STAI = State-Trait Anxiety Inventory; SBSOD = Santa Barbara Sense of Direction scale; ESE = effect size estimate (η^2 for ANOVAs, and Cramer's *V* for chi-squared tests).

Manipulation Check

Table 3 presents descriptive statistics and results of the mixed-model analyses for HR, BP, and STAI-State data. Figure 3 graphically depicts the time course of these data. Analyses detected significant main effects of (a) experimental condition on HR, (b) experimental condition on STAI-State scores, and (c) time on STAI-State scores. All other main effects, and all two-way interactions, were non-significant.

Table 3
Physiological and Self-report Data: Descriptive Statistics and Linear Mixed-Model Analyses (N = 18)

	Experimental Condition					
Measure / Measurement	Stress (n = 10)	Non-Stress (n = 8)	Effect	F	df	p
HR						
Baseline	84.10 (5.59)	79.00 (14.83)	EC	6.17	1,31	.019*
Post-Stressor	86.90 (12.22)	72.57 (12.18)[a]	Time	0.22		.646
Post-Rest	79.40 (6.80)	72.57 (13.16)[a]	EC x Time	1.39		.247
Post-Arena	76.60 (6.29)	71.86 (12.95)[a]				
Pre-Debrief	75.10 (5.61)	73.14 (12.75)[a]				
BP: Systolic						
Baseline	118.60 (12.53)	119.25 (7.40)	EC	0.12	1,31	.736
Post-Stressor	114.70 (7.69)	116.29 (9.38)[a]	Time	1.09		.304
Post-Rest	114.80 (7.12)	109.86 (6.15)[a]	EC x Time	.02		.888
Post-Arena	114.50 (9.17)	114.43 (8.14)[a]				
Pre-Debrief	112 (7.02)	113.14 (8.11)[a]				
BP: Diastolic						
Baseline	73.60 (6.31)	72 (7.64)	EC	0.45	1,31	.506
Post-Stressor	71.20 (7.35)	69.71 (4.86)[a]	Time	1.04		.315
Post-Rest	71 (8.30)	70.43 (2.57)[a]	EC x Time	.001		.980
Post-Arena	69.50 (4.40)	72.43 (6.24)[a]				
Pre-Debrief	72 (6.45)	70.14 (7.03)[a]				
STAI-State					1,32	
Baseline	32.00 (12.21)	27.88 (9.48)	EC	4.44		.043*
Post-Stressor	48.90 (12.83)	36.88 (10.20)	Time	11.41		.002**
Post-Arena	30.60 (7.88)	31.88 (12.82)	EC x Time	1.06		.311
Pre-Debrief	27.80 (7.15)	29.25 (12.14)				

Note. Means are presented with standard deviations in parentheses. HR = heart rate (measured in beats per minute [bpm]); BP = blood pressure (measured in mmHG); STAI = State-Trait Anxiety Inventory; EC = experimental condition. [a]n = 7; one dataset lost due to hardware malfunction.
*p < .05. **p < .01. ***p < .005.

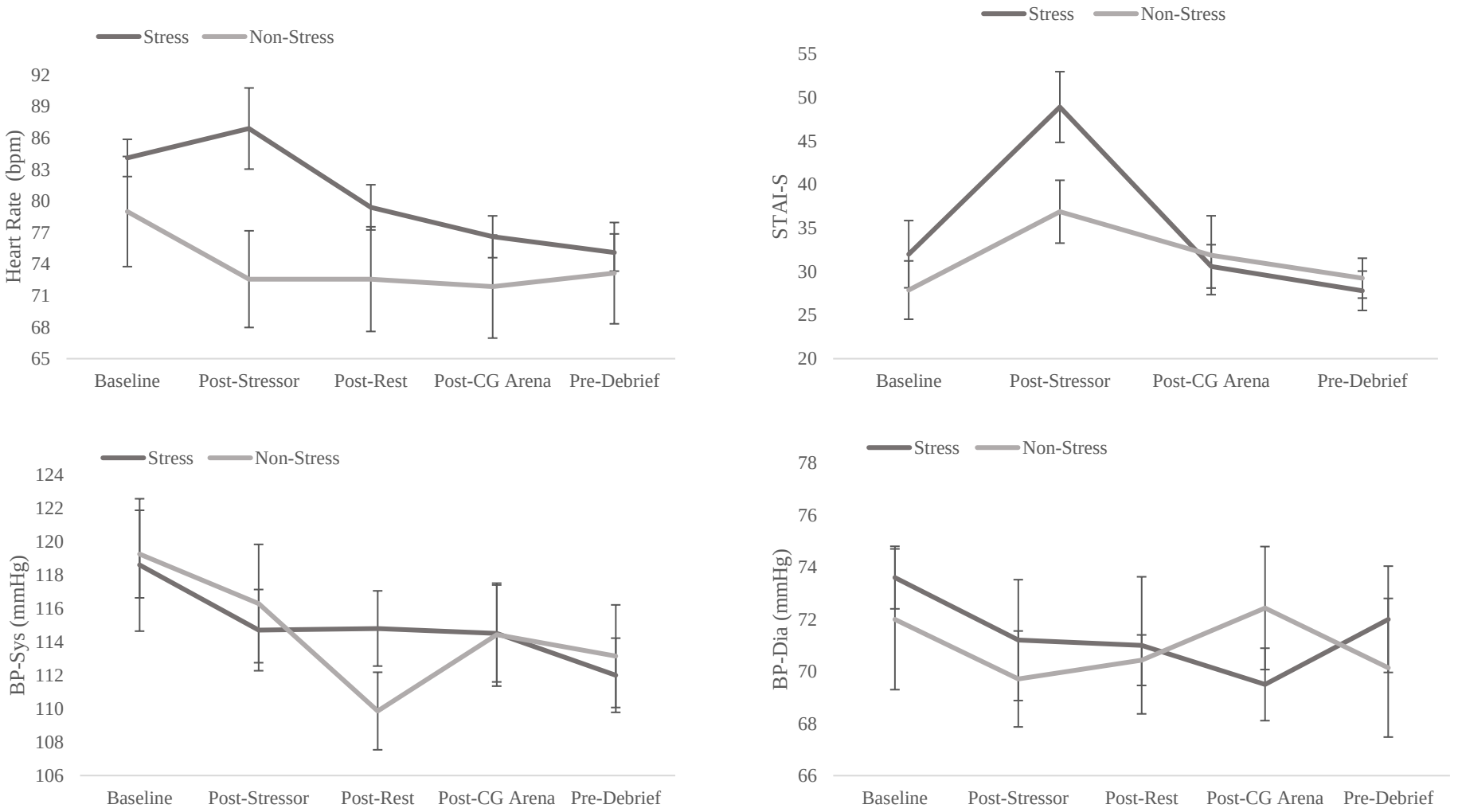

Figure 3. Physiological and self-report measures of stress across the experiment; Stress condition n =10, Non-Stress condition n = 8. Error bars represent the standard error of the mean for each measurement point.

Further regarding the significant main effects of experimental condition, independent-sample *t*-tests compared, for participants in the Stress and Non-Stress conditions, changes in HR, and in STAI-State scores, from baseline to the immediate post-stressor measure. These analyses both detected significant between-condition differences associated with large effect sizes. The order of means suggested that the magnitude of changes in HR and STAI-State scores for participants in the Stress group exceeded those for participants in the Non-Stress group (see Table 4).

Table 4
Changes in Heart Rate and STAI-State Scores from Baseline to Post-stressor (N = 18)

	Experimental Condition				
	Stress	Non-Stress			
Variable	(*n* = 10)	(*n* = 8)	*t*	*p*	ESE
ΔHR	2.80 (11.08)	-5.57 (5.13)[a]	-2.09	.028*	0.91
ΔSTAI-State	16.90 (9.31)	9.00 (9.13)	-1.80	.045*	0.86

Note. Means are presented with standard deviations in parentheses. HR = heart rate (measured in beats per minute [bpm]); STAI = State-Trait Anxiety Inventory; ESE = effect size estimate (Cohen's *d*). [a]*n* = 7; one dataset lost due to hardware malfunction.
*$p < .05$. All *p*-values reported are one-tailed.

Paired-samples *t*-tests examined the same data, but this time compared changes in HR and STAI-State scores from baseline to the immediate post-stressor measure within each of the Stress and Non-Stress groups separately (see Table 3 for the relevant descriptive statistics). For participants assigned to the Stress condition, these analyses detected (a) a non-significant increase in HR, $t(9) = -0.80$, $p = .223$, Cohen's $d = 0.29$, and (b) a significant increase in STAI-State scores, $t(9) = 5.74$, $p < .001$, $d = 1.35$. For participants assigned to the Non-Stress condition, these analyses detected (a) a significant decrease in HR, $t(6) = 2.96$, $p = .013$, $d = 0.37$, and (b) a significant increase in STAI-State scores, $t(7) = 2.79$, $p = .014$, $d = .91$.

Finally, four separate paired-sample *t*-tests compared baseline HR, BP, and STAI-State values to those at the pre-debrief measurement point. Analyses detected only two significant between-measure differences: At pre-debrief, participants' HR and systolic BP readings were significantly lower than at baseline.

Table 5
Changes in Stress Measures from Baseline to Pre-Debrief Measurement: Stress-group participants (N=10)

	Measurement Point				
Variable	Baseline	Pre-Debrief	*t*	*p*	ESE
HR	84.10 (5.59)	75.10 (5.61)	5.73	$p < .001$***	-1.61
BP					
Systolic	118.60 (12.53)	112 (7.02)	2.04	.036*	-.65
Diastolic	73.60 (6.31)	72 (6.45)	.88	.427	-.16
STAI-State	32.00 (12.21)	27.80 (7.15)	0.92	.384	-0.42

Note. Means are presented, with standard deviations in parentheses. HR = heart rate (measured in beats per minute [bpm]); BP = blood pressure (measured in mmHG); STAI = State-Trait Anxiety Inventory; ESE = effect size estimate (Cohen's *d*).
*$p < .05$. **$p < .01$. ***$p < .005$. All *p*-values reported are one-tailed.

Interim summary. Taken together, these results suggest that exposure to the PASAT was associated with mild increases in HR levels and substantial increases in STAI-State scores. In contrast, exposure to the U-PASAT was associated with substantial decreases in HR levels and relatively minor increases in STAI-State scores. Hence, at both physiological and subjective levels, participants in the two experimental conditions were distinguishable from one another at the immediate post-manipulation measurement point. However, within the Stress group, both physiological and self-report measures of stress were not significantly increased over baseline when the participants left the laboratory, indicating no chronic effects of the experimental manipulation.

Effects of Cycle Phase and Stress on Navigation Strategy

Table 6 presents the cell means and standard deviations for the primary outcome variable, Average Spatial%. Analyses of these data detected a significant main effect of Experimental Condition, $F(1,14) = 11.10$, $p = .005$. As Figure 4 shows, participants in the Stress condition tended toward using a response strategy much more frequently than did those in the Non-Stress condition.

The analysis did not detect a significant main effect of Cycle Phase, $F(1,14) = 1.82$, $p = .198$. As Figure 5 shows, participants in both the Luteal and Non-Luteal groups showed a preference for using a spatial strategy, although that preference was slightly more marked in the former than in the latter.

Finally, the analysis did not detect a significant Experimental Condition x Cycle Phase effect, $F(1, 14) = 0.093$, $p = .765$. As the data shown in Table 6 and Figure 6 show, however, those in the Non-Stress group tended toward a much stronger spatial strategy

preference. Moreover, only participants in the Non-Luteal phase and the Stress condition showed a preference for a response strategy over a spatial strategy (i.e., Average Spatial% < 50).

Table 6

Navigation Strategy Across Experimental Groups: Descriptive statistics (N=18)

	Experimental Condition	
Cycle Phase Group	Stress (*n* = 10)	Non-Stress (*n* = 8)
Non-Luteal (*n* = 11)	46.25 (31.45)	81.00 (13.06)
Luteal (*n* = 7)	58.25 (26.70)	100.00 (0.00)

Note. Mean percentages are presented, with standard deviations in parentheses.

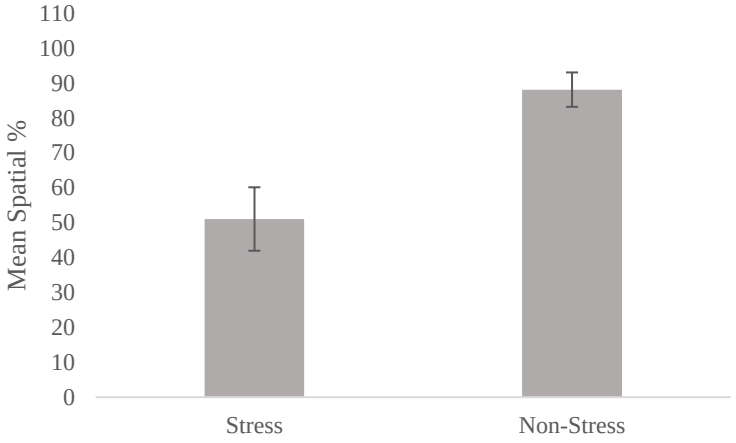

Figure 4. Effect of experimental condition on navigational strategy. Participants in the Stress condition tended to use a response strategy more frequently than did those in the Non-Stress condition, who tended strongly toward using a spatial strategy (*M* = 52.25±7.60 versus *M* = 90.50±8.61). Error bars represent the standard error of each respective group mean.

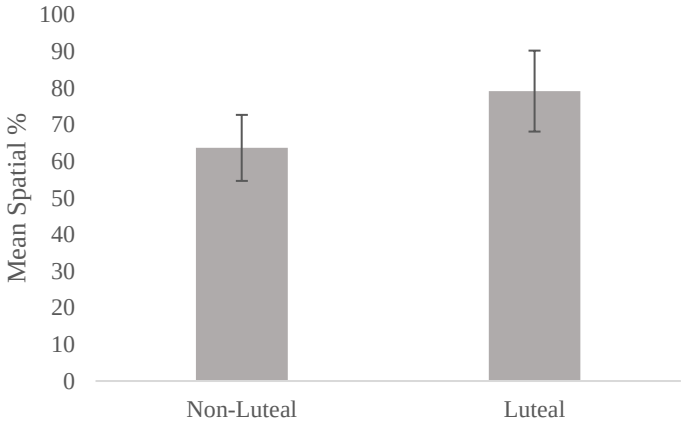

Figure 5. Effect of menstrual cycle phase on navigational strategy. Participants in the Luteal phase tended to use a spatial strategy slightly more frequently than did those in the Non-Luteal phase, although both preferred spatial over response strategies (*M* = 79.13±9.00 versus *M* = 63.63±7.13). Error bars represent the standard error of each respective group mean.

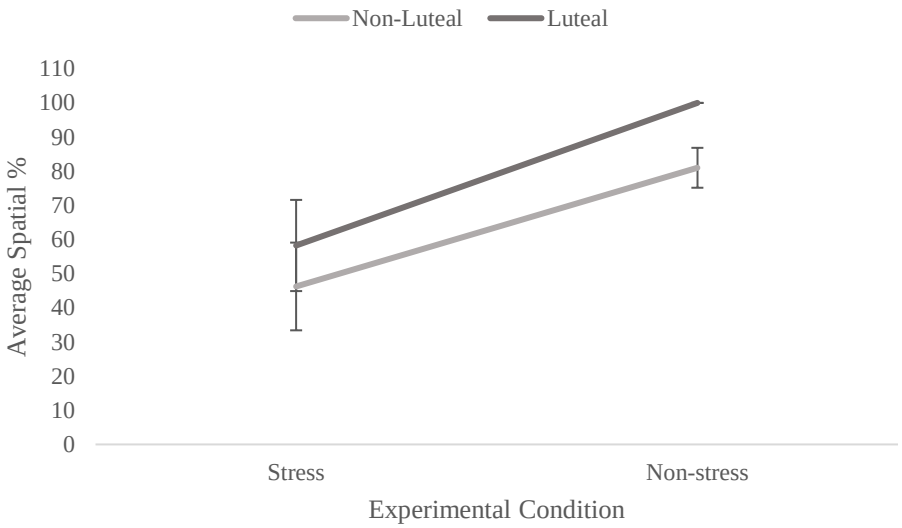

Figure 6. Interaction effect (Cycle Phase x Experimental Condition) on navigational strategy. Only participants in the Non-Luteal phase and the Stress condition showed a preference for a response strategy over a spatial strategy (i.e., Average Spatial% < 50; descriptive statistics reported in Table 5). Error bars represent standard error of means for each group.

Discussion

This pilot study aimed to investigate effects of acute psychosocial stress and menstrual cycle phase on navigational strategy use. Below, I discuss results for my three hypotheses and explore how these findings relate to previous literature. The paper concludes with the consideration of limitations and recommendations for future research.

Menstrual Cycle Phase and Navigational Strategy use

Hypothesis 1 stated that menstrual cycle phase will have a significant main effect on navigational strategy use: Participants in the Non-Luteal phase will prefer using a response strategy, whereas those in the Luteal phase will tend to use a spatial strategy. Although this hypothesis was not confirmed, the observed direction of means was in the predicted direction. Hence, the results of this pilot study are promising, and one might speculate that a full investigation, powered by a large enough sample size, would confirm the hypothesis. Following prior studies, a sample size of 90 would be ideal.

The current results' pattern is consistent with that reported in at least two recent studies. Scheuringer and Pletzer (2017) found that participants in the Luteal phase performed better on a computerized 2D-matrix navigation task when using a spatial strategy compared to those in the early follicular phase, who favoured a response strategy. Hussain et al. (2016) found that women in early follicular and ovulatory phases preferred using response strategies

when solving a VR navigation task, while those in the Luteal phase tended towards using a spatial strategy. Both of those results, as well as those reported here, support the inference that the use of spatial (rather than response) navigational strategies is not associated with fluctuating levels of estrogen (given the opposite levels across the early follicular and ovulatory phases), but are instead associated with high levels of progesterone (i.e. in the Luteal phase). As Hussain et al. (2016) note, one neurobiological mechanism that fleshes out this account is that higher progesterone levels promote hippocampal use (the brain structure central to spatial strategies), while depressing the use of the caudate nucleus (the brain structure central to response strategies).

Stress and Preference for Navigational Strategy

Stress induction manipulation check. This pilot study's results suggest that the PASAT and U-PASAT manipulations had notably different effects on objective and subjective stress measures. For instance, both heart rate (HR) and STAI-State values increased from baseline to post-manipulation in the PASAT condition, whereas in the U-PASAT condition, HR values decreased over the same period.

Closer inspection of the data suggests that the PASAT did not induce physiological stress beyond very mild levels. The analyses detected no significant differences in HR and blood pressure (BP) from baseline to the immediate post-stressor measurement point within the Stress group. In contrast, the manipulation appears to have been more successful at inducing psychological stress: The analyses detected a significant increase in STAI-State scores from baseline to immediate post-stressor. Furthermore, the U-PASAT appears to have been an adequate control task, given its calming effect on HR, the lack of significant BP differences from baseline to immediate post-stressor, and the relatively small increase in STAI-State scores across that time span. This increase could be due to the mathematical nature of the task, as some participants in the Non-Stress group noted in their debriefing session that they struggled with mathematics.

Several previous studies have used the PASAT as a stress induction method. Those studies have consistently found that the PASAT significantly increases both physiological and self-reported levels of stress (Mathias et al., 2004; Tanosoto et al., 2015; van Gerven et al., 2016). Although the current findings are consistent with previous studies with regard to subjective stress levels, the current preparation did not produce significant increases in physiological stress measures. It is likely, however, that this lack of consistency is due to differences in sample size. Additionally, and in contrast to the above-mentioned studies, the current sample consisted of women only. This difference is relevant because prior research,

focusing on sex differences in HPA-axis reactions to psychosocial stressors, has shown that men have consistently larger cortisol responses than women (Kudielka & Kirschbaum, 2005). Nevertheless, the significant PASAT-induced increase in subjective stress, observed using relatively few participants, is a promising indicator for similar future studies.

Stress and strategy selection. Hypothesis 2 stated that laboratory-induced will have a significant main effect on navigational strategy use: Participants exposed to stress, but not those in the control condition, will tend to use a response rather than a spatial strategy. This hypothesis was confirmed.

These findings are consistent with those from some previous studies. For instance, Thomas et al. (2010) found that, in females of a similar age range to those studied here but with no menstrual cycle data captured, exposure to acute psychosocial stress impaired allocentric spatial navigation but not landmark-based egocentric navigation. Similarly, Smith, Burgess, Brewin, and King (2015) found that participants (male and female) diagnosed with posttraumatic stress disorder performed significantly more poorly than healthy controls on a VR navigation task that required allocentric spatial processing. One reason that stress might impair map-based spatial strategies is that the physiological stress response has direct consequences for hippocampal function (Alderson & Novack, 2002; Kemeny, 2003; McEwen & Sapolsky, 1995). These consequences are due, in part, to the hippocampus containing many glucocorticoid receptors, and thus being implicated in ending stress responses via glucocorticoid-mediated negative feedback of the HPA axis (Gjerstad, Lightman, & Spiga, 2018).

The current findings stand in contrast to those of van Gerven et al. (2016), however. Those authors found that stress biased participants toward using allocentric spatial strategies rather than egocentric response strategies when completing a VR navigation task. Given that this pilot study was a systematic replication of van Gerven et al. (2016), with an identical design and similar VR paradigm, these contrasting results are particularly interesting. One possible reason for the between-study difference in findings is that I excluded participants who reported using oral contraceptives, whereas van Gerven and colleagues did not. Because ingestion of such medication alters natural estrogen and progesterone levels, thus affecting the neural action of these hormones, it is possible that strategy use of their participants was confounded. Moreover, van Gerven and colleagues included participants currently taking mood-stabilizing medication, whereas the current study excluded such individuals. The PASAT may not have been effective in inducing stress for participants taking such medication, and thus they may have preferred using allocentric spatial strategies.

Unfortunately, van Gerven et al. (2016) did not analyze the effects of these factors on their outcomes, nor did they control for them within their analysis. Without information from such analytic approaches, it is impossible to say whether, and to what degree, their results may have been confounded. This pilot study is free of those confounds, and the larger study building on this one will remain so in our laboratory's attempts to accurately represent the real-life effects of stress on female spatial navigation.

Menstrual Cycle Phase and Stress on Navigational Strategy use

Hypothesis 3 stated that laboratory-induced acute psychosocial stress and menstrual cycle phase will have a significant interaction effect on navigational strategy use, with this specific prediction: Participants in the Luteal phase who are exposed to the stressor will tend to use a response strategy, whereas those who are in that phase but not exposed will tend to use a spatial strategy. Although this hypothesis was not confirmed (i.e., analyses detected non-significant interaction effects), inspection of the descriptive statistics suggested that the direction of the effect was in the predicted direction. Stress-group participants who were in the Luteal phase did show a greater preference toward using a response strategy than did their phase counterparts in the Non-Stress group. It should be noted, however, that there was a ceiling effect present: All Non-stress participants used a spatial strategy on 100% of their trials. Nevertheless, the results are promising and suggest that a larger-scale investigation of this novel question may find a significant interaction of the predicted kind.

Of interest, naturally, are the neurobiological mechanisms that might drive the interaction effect under consideration. One such mechanism might arise from the fact that levels of estrogen are relatively low during the luteal phase. There is evidence that estrogren, specifically estradiol, modulates the physiological effect of stress on women, such that it depresses cortisol responses to stressful encounters and thereby protects the hippocampus from the deactivational effects of stress (Foy, Baudry, Foy, & Thompson, 2008). Hence, women who experience stress during the luteal phase may have to rely on extra-hippocampal mechanisms (and, consequently, response strategies) to solve spatial navigational problems.

Limitations and Directions for Future Research

This study has some limitations that should be addressed by future research. First, being a pilot study, it is by definition small and statistically underpowered to detect the effects under consideration. Although a sample size of 18 was adequate for the present purposes, prior research suggests that a full-scale study exploring the questions at hand should aim to recruit at least 90 participants. Within that larger group of participants should be adequate numbers of women in each of the three relevant menstrual cycle phases (early

follicular, ovulatory, and luteal). Collapsing the two former groups into one Non-Luteal group, as was done here, is not ideal given the differing estrogen levels across the early follicular and ovulatory phases. Additionally, future research should aim to have equal sample sizes across experimental conditions. A limitation of this study is the uneven spread across stress conditions. This was due to the online randomizer assigning participants based on a sample size of 24 participants (n = 8 per cycle phase group). Thus, future research should use more flexible methods for random assignment, in which an overall sample size need not be specified.

Finally, results of the current manipulation-check analyses were mixed. Although PASAT exposure appeared to induce increases in subjective stress, it did not provoke significant physiological elevations. One might attribute this mixed pattern of data to the small sample size, or to the fact that my sample consisted of females only—women appear to respond more to social rejection challenges compared to achievement challenges such as those presented by the PASAT (Stroud, Salovey, & Epel, 2002). Certainly, previous studies, as mentioned above, suggest that the PASAT is an effective laboratory-based stress induction tool. Nonetheless, future research might consider using a stress-induction method that includes physical, mental, and socioevaluative components, such as the Maastricht Acute Stress Test (MAST; Smeets et al., 2012) or the Fear Factor Stress Test (du Plooy, Thomas, Henry, Human, & Jacobs, 2014). Additionally, larger-scale investigations should collect measures of cortisol and salivary alpha-amylase to assess the effects of both arms of the physiological stress response (that centered on the sympathetic nervous system, which was measured here via HR and BP, and that centered on the HPA axis, which is typically measured via cortisol).

Summary and Conclusion

This pilot study adds to the growing body literature on the effects of stress and of the menstrual cycle on cognition. My specific aim was to investigate effects of menstrual cycle phase and stress, and their possible interaction, on female navigational strategy use. Results detected consistent differences in navigational strategy use across the luteal and non-luteal phases of the menstrual cycle, with those in the latter preferring a response strategy and those in the former preferring a spatial strategy. Furthermore, analyses detected a significant main effect of stress on navigational strategy use, with those exposed to the stressor showing less preference for the allocentric spatial strategy. These results support the notion that cortisol-induced impairment of hippocampal function impairs female spatial navigation. Finally, while the interaction effect in this pilot study was non-significant, the direction of the effect

was as predicted, and thus these results are promising. Although the lack of statistical significance may be attributed to the small sample size, the data patterns do encourage larger-scale exploration of this research question.

In conclusion, this pilot study provided useful insight into the effects and possible interaction of menstrual cycle phase and acute psychosocial stress on spatial navigation in women. As previous research only focuses on main effects of menstrual cycle and of stress on navigational strategy use, this original pilot study adds real-life value to the current literature on the topic: Hormones do not act independently of each other in natural settings, as they might in controlled clinical settings. This pilot study has great significance as exploratory research on a novel topic and drives researchers to navigate themselves towards future explorations.

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Appendix A – Screening Questionnaire

Instructions: Please circle your answer from the given choices or write it in the space provided.

Basic Demographic Information

How old are you? _____

Is this your first undergraduate degree? | Yes | | No |

Which education year have you most recently completed?

Matric / Grade 12	1st Year	2nd Year	3rd Year

Other (please specify): _____

Sleep and Exercise

On average, how many hours do you sleep per night?

Less than 4 hours	4-6 hours	7-8 hours	9-10 hours	11+ hours

How many hours did you sleep last night?

_____

On average, how many hours do you exercise per week?

Less than 1 hour	1-2 hours	3-4 hours	5-6 hours	7-8 hours

Other (please specify): _____

Did you exercise in the last 24 hours? If so, for how long?

_____

Alcohol, Smoking & Other Substances

On average, how many alcoholic drinks do you consume per week?

0-2	3-5	6-8	9-11	12-14	More than 14

Did you drink alcohol in the last 24 hours? If so, how many drinks?

_____

Do you smoke cigarettes? Yes No

On average, how many do you smoke per week?

Less than 10	10-20	20-40	40- 60	60-80	80-100

Other (please specify): _____

How many have you smoked within the last 24 hours?

_____

Do you have a history of substance addiction? Yes No

Are you currently addicted to any substance (other than nicotine)? Yes No

Psychological & Neurological Factors

Are you currently experiencing any psychological disorder (such as depression or anxiety)?

Yes No

Are you currently on any mood/anxiety stabilizing medications? Yes No

Do you have a history of neurological illness (e.g., epilepsy, traumatic brain injury)?

Yes No

Birth Control, Pregnancy and Breastfeeding

Are you currently using any hormonal birth control methods? (i.e. the pill, the implant, injections, IUD, contraceptive patch, vaginal ring) Yes No

If no, but have used previously, when did you stop using said birth control method(s)?

_____

Have you used any emergency contraceptive medication within the last 3 months? (e.g., Plan B) Yes No

Have you been pregnant within the last two years (i.e., since January 2016)? Yes No

Are you currently breastfeeding? Yes No

Menstrual Cycle (the most NB section! Please take your time and answer as accurately as possible)

At what age did you have your first period? _____

On average, how many days is your menstrual cycle (from the day of menses onset to the day prior to next menses onset)?

Less than 20 days	20-24 days	25-34 days	More than 34 days

On average, how long do your periods last (from day of menses onset to day bleeding stops)?

Less than 3 days	3-5 days	6-8 days	More than 8 days

On what date did your second most recent period start? _____

On what date did your most recent period start? _____

On what day of your cycle are you on today? _____

Do you have any hormonal disorders (e.g., endometriosis or polycystic ovarian syndrome)?

Yes	No

Appendix B - SBSOD

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences.

After each statement, you should circle a number to indicate your level of agreement with the statement.

Circle "1" if you strongly agree that the statement applies to you. Circle "7" if you strongly disagree, or some number in-between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.

strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.

strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.

strongly agree 1 2 3 4 5 6 7 strongly disagree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).

strongly agree 1 2 3 4 5 6 7 strongly disagree

6. I very easily get lost in a new city.

strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

8. I have trouble understanding directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.

strongly agree 1 2 3 4 5 6 7 strongly disagree

10. I don't remember routes very well while riding as a passenger in a car.

strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don't enjoy giving directions.

strongly agree 1 2 3 4 5 6 7 strongly disagree

12. It's not important to me to know where I am.

strongly agree 1 2 3 4 5 6 7 strongly disagree

13. I usually let someone else do the navigational planning for long trips.

strongly agree 1 2 3 4 5 6 7 strongly disagree

14. I can usually remember a new route after I have travelled it only once.

strongly agree 1 2 3 4 5 6 7 strongly disagree

15. I don't have a very good "mental map" of my environment.

strongly agree 1 2 3 4 5 6 7 strongly disagree

Appendix C – STAI

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

STAIP-AD Test Form Y
www.mindgarden.com

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Appendix D – Post Arena Questionnaire

Instructions: Please circle your answer from the given choices or write it in the space provided.

Did you know where the target was? Yes No

If yes, where was the target?

_____

_____

How did you find the target?

_____

_____

_____

_____

Did you use any environmental cues to help you find the target? Yes No

If yes, which cues?

_____

_____

_____

Did you follow the same general direction in each trial? Yes No

If yes, in which direction did you go?

_____

Did you follow the same path to reach the target in each trial? Yes No

If so, please describe the path you took.

_____

_____

_____

_____

_____

Appendix E – Video Game Experience Questionnaire

Instructions: Please circle your answer from the given choices or write it in the space provided.

1) Have you ever played video games? Yes | No

2) Do you currently play video games? Yes | No

If you answered 'Yes' to question (2), please answer the following questions.

3) How long have you been playing video games?

1-6 months	6-12 months	1-2 years	3-5 years	5-10 years	More than 10 years

4) How often do you currently play video games?

Daily	Weekly	Once a month	Once in 6 months	Once a year	Less than once a year

5) How good do you feel you are at playing video games?

Very good	Good	Not very skilled	No skill