

# The Effects of Hormonal Contraception on Auditory Emotional Memory

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**ABSTRACT.** Emotional episodic memory is an important cognitive mechanism that has been extensively studied, however, auditory emotional memory in particular has yet to be thoroughly understood. In addition, sex hormones have been found to affect brain structure and regulate regions of the brain that support higher order cognitive functions. Considering the global usage of oral hormonal contraceptive pills, it is vitally important to investigate the effects of oral contraceptives on executive function, including memory. The aim of the present study was to investigate the extent to which oral contraceptives influence recall for an emotional auditory episodic memory compared to a neutral memory. Participants ( $N = 90$ ; 45 on an oral contraceptive, 45 naturally cycling) performed a free recall task for an emotional and a neutral auditory story, and their recalls were categorized into gist and detail elements and rated for accuracy. Recall accuracy for an emotional or neutral auditory story was not different between women on oral hormonal contraceptives and women who were naturally cycling, however, both groups of women recalled more information regarding the neutral story compared to the emotional story. These findings inform how the use of hormonal contraceptive pills, combined with high emotional valence, may impact the content and accuracy of recalled episodic events.

**Keywords:** emotional memory, auditory memory, neuroendocrinology, hormonal contraceptives, women's health

Episodic memory is a form of long-term memory that allows an individual to remember distinct events from their past personal experiences (Tulving, 1993). It differs from other types of memory due to its autonoetic component, in which individuals essentially relive a prior experience through episodic memory recall, often including sensory components (Tulving, 2005). Episodic memory is essential for many aspects of one's life, including learning, forming identity, and decision-making (Tulving, 2005). Previous research has established that sex hormones have a large impact on various cognitive processes (Boss et al., 2014), including beneficial effects of estradiol on episodic memory (Renz

et al., 2017). Given the widespread usage of hormonal contraception, it is, therefore, pertinent to explore how disruptions to the endocrine system directly impact episodic memory.

## Emotion and Memory

The impact of emotional events on episodic memory recall has been thoroughly studied, especially when looking at varying stimulus types and valence (degree of pleasantness). Previous research has demonstrated that negative emotional events tend to be more richly and accurately remembered compared to neutral events (Cahill & McGaugh, 1995; Dunsmoor et al.,



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2015; Kensinger, 2009). Stimuli with a negative valence are often more easily and accurately recalled than neutral or positive stimuli (Kensinger & Corkin, 2003). Although emotional arousal and stress responses may be a moderator in episodic memory recall (Buchanan & Tranel, 2008), evidence has suggested that the valence of a story alone may still have these enhancing effects (Bowen et al., 2018). Researchers have also found that the hippocampus and amygdala show increased activity when recalling an emotional memory, which coincides with the perception of a more vivid autonoetic reliving of the event and enhanced memory for it (Bowen et al., 2018). Improved memory for events with emotional salience is beneficial, as it aids in decision-making for future events. For example, one may not recall a typical drive to work, however, a drive in which they narrowly avoid an automobile accident would likely form a stronger memory. This may inform them to increase their attention while driving, or to consider alternative routes. Emotions and memory being intertwined serves an evolutionary benefit in increasing chances of survival.

Although there is a large amount of research on emotional memory, more research focusing specifically on auditory emotional memory is needed. The subset of emotional memory relating to auditory stimuli alone is very relevant to our everyday lives, such as through storytelling and relaying information using conversation alone. Previous research regarding auditory memory has typically utilized sounds or single words, whereas recall for narrated stories has been less thoroughly explored. Auditory stories may retain higher ecological validity, as they accurately represent the means in which people transmit information in their day-to-day lives through conversations (Baldassano et al., 2017). As social beings, humans are constantly engaging with others through conversation, and the ability to recall information that was transmitted verbally is pertinent in guiding future decisions. A study examining the effects of gender and age on different domains of episodic memory demonstrated that women may outperform men on auditory episodic memory paradigms, whereas men may perform better on visual episodic memory tasks (Pauls et al., 2013). This reveals potential differences in episodic memory depending on the sensory domain and should be more thoroughly investigated.

### Hormonal Contraceptives and Memory

Although currently over 100 million women worldwide use hormonal oral contraceptives as their preferred method of birth control, the literature surrounding the short and long-term effects of the drug on women's cognitive health is relatively limited (Christin-Maitre, 2013; Cooper et al., 2022). Previous studies have found

that birth control can have widespread effects on areas such as brain structure (gray matter volume; Pletzer et al., 2010), emotion (Lewis et al., 2019), and improved verbal fluency (Griksiene & Ruksenas, 2011) among other cognitive domains (Warren et al., 2014). Given that the endocrine system is an essential component of cognitive function, it is important to evaluate how the pill impacts endocrine structures and hormones.

The oral combination pill is made up of varying levels of synthetic forms of both estrogen and progesterone (Cooper & Mahdy, 2020), and affects sex steroid hormone receptors, mimicking the negative feedback effects of estrogen and progesterone. This reduces the secretion of gonadotropin releasing hormone, which in turn reduces the pituitary gland's production of luteinizing hormone and follicle-stimulating hormone (Taylor et al., 2021). This mechanism prevents pregnancy in two ways: the reduction of follicle-stimulating hormone prevents follicle growth, whereas the reduction of luteinizing hormone prevents ovulation that typically occurs following a luteinizing hormone surge (Rivera et al., 1999). Depending on the specific chemical makeup of the pill, this mechanism leads to constant levels of either progesterone, estrogen, or both in women on a combined hormonal contraceptive (HC), contrasting the large fluctuations in sex hormone levels seen in naturally cycling (NC) women (Fleischman et al., 2010).

HCs have the potential to affect cognition in a variety of ways, such as by impacting different types of memory (Pletzer & Kerschbaum, 2014), including working memory (Griksiene & Ruksenas, 2011; Herrera et al., 2020) and verbal memory (Mordecai et al., 2008). Yet, few studies have expanded on the effects of HCs on memory for an emotional stimulus using narration alone, a stimulus that is quite relevant to our everyday lives. Previous studies on the effects of hormones on emotional memory have primarily utilized visual stimuli in combination with narration (Nielsen et al., 2011; Presuss et al., 2009) or videos (Wegerer et al., 2014). In Nielsen et al. (2011), NC and participants on oral HCs listened to a recording of either an arousing or a neutral short story while viewing a corresponding slideshow of images. Participants recalled each slide image and associated storyline, then recall accuracy was assessed based on the participants' ability to report gist and detail elements of the stimulus. Gist is the main idea of the story, and when changed or omitted, it alters the entire storyline, whereas details are the smaller, more specific aspects (Cahill & van Stegeren, 2003). The researchers found that there was a difference in memory for emotionally arousing stimuli in women on a combined HC pill compared to NC women. NC women recalled more detail elements of the emotional stimuli compared

to the neutral, but showed no difference for gist recall, whereas HC women recalled more gist elements for the emotional content condition with no difference for detail recall (Nielsen et al., 2011). This may be due to HCs' blunting effects on amygdala reactivity, as explored by Petersen and Cahill (2015). These findings regarding emotional memory, combined with research on the effects of HCs on auditory memory, suggest that the oral contraceptive pill has the capability to impact memory in a variety of domains. This research is important in advising individuals about potential long-term effects of HCs, and should be utilized to make well-informed decisions about using this medication.

Verbal memory in particular has also been shown to be affected by HC use. A study by Mordecai et al. (2008) demonstrated a difference in recall for neutral auditory stimuli (single words administered through the California Verbal Learning Task) for women on an oral contraceptive when compared to NC women. They found that HC women had improved verbal memory during their active pill phase, whereas NC women showed no noticeable differences throughout their menstrual cycle. These findings suggest that exogenous sex hormones, such as the oral contraceptive pill, contribute more to differences in verbal memory than endogenous sex hormones.

### The Present Study

Previous studies have demonstrated numerous effects of hormonal contraception on cognition and memory, yet the drug's impact on auditory emotional memory has not been fully explored. The aim of the present study was to explore how HCs affect recall of the gist and details of an emotional auditory story. We hypothesized that recall accuracy would be higher for the emotional content condition, regardless of birth control status (NC or HC) or recall content (gist or details), analogous to previous work regarding emotional memory. In accordance with the previous studies on visual memory, we hypothesized that the use of hormonal contraception would significantly impact the content of recall for an emotional story, such that: (a) NC women would remember more details of an auditory emotional content story compared to (b) those on hormonal birth control, who would remember more gist elements. We predicted (c) that no significant differences would be found between NC women and women on an HC for gist or detail recall for a neutral story. We did not predict (d) a main effect of contraceptive status on recall accuracy. Lastly, we predicted that (e) participants, regardless of contraceptive status, would recall more information from the emotional story than the neutral story.

To assess these predictions, four 2 (story condition:

emotional or neutral) x 2 (contraceptive status: HC or NC) mixed ANOVAs were used. Specifically, we predicted that there would be a significant interaction effect in all four analyses, such that for prediction (a) NC hit rate (HR) would be significantly greater than HC HR for emotional detail information and that NC false alarm rate (FAR) would be significantly less than HC FAR for emotional detail information. For prediction (b), we predicted that HC HR would be significantly greater than NC HR for emotional gist information, and HC FAR would be significantly less than NC FAR for emotional gist information. We anticipated the interaction effects to be driven by the emotional story, with no significant differences for HR and FAR between HC and NC groups in the neutral gist or neutral detail conditions (c). There was also a predicted main effect (e) of story condition on FAR and HR in all conditions, such that HR for the emotional condition would be significantly greater than the neutral condition, regardless of contraceptive status and gist versus detail information. FAR were predicted to be significantly less for the emotional condition than the neutral condition in all group comparisons.

The findings of this study were anticipated to further elucidate the need to specify a participant's HC usage when including them in a research study regarding emotional content memory, as women may perform differently depending on their respective contraceptive status. Additionally, the results of this study were

TABLE 1

#### Demographics – Ethnicities

Ethnicity	Hormonal Contraceptive	Naturally Cycling	Total
African American	0 0%	1 100%	1 100%
Asian	11 34.4%	21 65.6%	32 100%
Hispanic	3 30.0%	7 70.0%	10 100%
Multiple Ethnicities	5 45.5%	6 54.5%	11 100%
Pacific Islander	1 100%	0 0%	1 100%
European American	25 71.4%	10 28.6%	35 100%
Total	45 50.0%	45 50.0%	90 100%

$\chi^2 = 13.24 \cdot df = 5 \cdot \text{Cramer's } V = 0.38 \cdot \text{Fisher's } p = .01$

Note. Frequency tables include *n* (total number of participants) and % (total *n* = 90).

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expected to increase the understanding of the impacts that this widely utilized medication may have on specific cognitive domains.

## Methods

### Subjects

Ninety participants, all biologically female and identifying as women, between the ages of 18 and 33 ( $M = 20.5$ ,  $SD = 2.4$ ) were recruited through the online participant database (SONA) at University of California, Santa Barbara and received a \$5 Amazon gift card for completing the study. Participants completed an online prescreening questionnaire to validate that they were either NC (i.e., not on an HC and for at least three months prior) or on an oral combination pill for at least three months (HC). In total, there were 45 NC participants and 45 participants on a combination oral birth control

pill. Participants were primarily White, Asian, or Multiple Ethnicities (see Table 1). A chi-square test of independence showed that there was a significant association between ethnicity and contraceptive status,  $\chi^2 (5, N = 90) = 13.2$ ,  $V = .38$ ,  $p = .01$ , with disproportionately high representation of Asian participants in the NC group and White participants in the HC group (see Table 1). There was also a significant association between year in school and contraceptive status,  $\chi^2 (4, N = 90) = 9.6$ ,  $V = .33$ ,  $p = .04$ , such that first year participants had a disproportionately high representation in the NC group (see Table 2). Additionally, an independent sample  $t$ -test showed that the number of participants in each contraceptive group (HC and NC) differed significantly by age,  $t(73) = 2.00$ ,  $p < .05$ ,  $d = 0.42$ .

### Measures and Materials

#### Birth Control Eligibility Questionnaire

To determine if a person was eligible to participate in the experiment, participants completed a birth control eligibility questionnaire. To participate in the study, participants for the HC group needed to indicate that they were on an oral HC pill, and had been for at least three months prior, and were asked about the brand and dosage of their oral combination pill. NC participants indicated that they were not on any HC and had not taken one for at least three months prior. They were also asked for information about the first day of their last menstrual cycle and how confident they were that the reported date was correct. All components of this questionnaire, including specific oral contraceptive usage, can be found in Appendix A and Table 3.

#### Positive and Negative Affect Schedule

The Positive and Negative Affect Schedule (PANAS) is a 5-point scale questionnaire that assesses positive and negative affect. It was originally developed to determine state and trait-based affect. It consists of 20 questions regarding how well a participant's current mood matches various emotion words, ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). For the purposes of this study, the state focused scale was used to assess both baseline and any changes in participants' emotional state based on the story narrations. The scale has been shown to have both validity evidence and high reliability (Watson et al., 1988), including through online uses (Díaz-García et al., 2020).

#### Auditory Stimuli

The stimuli for this study consisted of prerecorded narrations of two different stories of a similar length. One story was used as a neutral condition, whereas the other was used with the aim of evoking an emotional

**TABLE 2**

#### Demographics – Year in School

Year in School	Hormonal Contraceptive	Naturally Cycling	Total
First	6 25.0%	18 75.0%	24 100%
Second	10 50.0%	10 50.0%	20 100%
Third	13 61.9%	8 38.1%	21 100%
Fourth	11 68.8%	5 31.2%	16 100%
Fifth	5 55.6%	4 44.4%	9 100%
Total	45 50.0%	45 50.0%	90 100%
$\chi^2 = 9.55 \cdot df = 4 \cdot \text{Cramer's } V = .33 \cdot \text{Fisher's } p = .04$			
Note. Frequency tables include $n$ (total number of participants) and % (total $n = 90$ ).			

**TABLE 3**

#### Birth Control Information

Progestin	$n$
Norgestimate	9
Levonorgestrel	12
Noreth acetate	2
Drospirenone	12
Desogestrel	2
Norgestrel	1
Norethindrone	7
Note. Birth control information, presented as progestin drug name and $n$ (total number of participants).	

response. The neutral story focused on two women completing mundane tasks, such as going to a local mall, browsing stores, having dinner, and returning home. The negative emotional content story included distressing medical situations due to an unfortunate accident. A boy was hit by a car on his way to visit his father at work and was rushed to the hospital where he underwent many medical tests and surgery (see Appendix B for full transcript). The emotional story was based on the emotionally arousing stimuli used in Nielsen et al.'s (2011) study, which was originally adapted from Cahill et al. (1994). Each story was narrated and recorded by the author in a monotonous (limited in variation of tone or pitch) voice to avoid any vocal fluctuations so that participants' recall would only be impacted by the contents of the story.

Because this study was completed remotely, the protocol asked participants to ensure proper administration of the auditory stimuli. Participants underwent a short audio functional test to check that they could properly hear the recordings on their respective devices. Participants noted what device they would be listening with (computer speakers, iPad/tablet/cellphone speakers, headphones, or other), played a short clip of a single tone, and then marked whether they could hear the noise. Just prior to the stimuli, participants had to mark two boxes signifying that their audio was working and that they were "ready and paying attention." When they proceeded to the auditory stimuli, the stimuli only played once and would not allow for repeat.

### **Demographics**

Between the administration of the two stimuli, participants were asked a series of questions regarding their demographics, including age, gender, sex at birth, year in school, and race/ethnicity (see Table 1). This served to not only provide more information regarding their demographics, but also as a small break between listening portions. The aim of this break was to allow time for participants to return to the baseline affective state if it had changed due to the previous stimulus.

### **Procedures**

The study protocol was reviewed and approved by the University's Institutional Review Board prior to data collection. Due to the COVID-19 pandemic, all research was required to be remote, thus participants completed the experiment through an online Qualtrics survey. They filled out an initial PANAS questionnaire (Watson et al., 1988) to assess their baseline emotional state. They then completed a computer audio functionality test to ensure that they would be able to hear the audio recordings. Next, participants were asked if they were ready to listen

and confirmed that they were free of distractions before proceeding to the story narration task. Participants then listened to a recorded narration of either a story with negative emotional content or neutral content (randomized order for each participant; see Appendix B). Another PANAS was administered to assess any changes in emotional states following the story. They were next instructed to type a summary recalling the story they previously heard. Participants were instructed to take at least two minutes to input their responses and needed to have a minimum of 75 words, otherwise, they would not be permitted to move forward in the study. After the first recall portion, participants were asked a series of demographic questions, and then were instructed to listen to the story narration they had not heard. Upon completion of listening to the second story, participants were tasked with a final PANAS questionnaire to reassess their emotional state. They then were given the same instructions to write a summary of what they recalled from the narrated story. Therefore, this experiment utilized a 2 (within-subjects story condition: emotional and neutral) x 2 (within-subjects recall content: gist and neutral) x 2 (between-subjects contraceptive use: HC or NC) design on free recall for auditory stories.

### **Scoring Free Recall**

The present study categorized participants' responses to ambiguous stimuli into one of two categories: hits (H; correctly identifying a stimulus that was present) or false alarms (FA; identifying a stimulus that was not present). From this, scores can be formulated into rates for each category. The hit rate (HR) is obtained by dividing participants' total hits by the total possible correct categories whereas the false alarm rate (FAR) is the total false alarms divided by the total possible incorrect categories (see equations below):

$$HR = (\text{number of H}) / (\text{number of total possible H})$$

$$FAR = (\text{number of FA}) / (\text{number of total possible FA})$$

A recall was considered more accurate if it had a higher HR and lower FAR. This scoring method was implemented in conjunction with the gist and detail categorization rules used by Nielsen et al. (2011). In the current study, participants' free-recall responses were scored by two independent judges, who qualitatively scored using the categories Correct Gist Information, Correct Detail Information, Incorrect Gist Information, and Incorrect Detail Information. In line with free recall scoring guidelines used by Diamond et al. (2020), an item category for both correct and incorrect information was created if two or more participants mentioned the item. If a portion of the participant's response contained an aspect belonging to a particular category, it was

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marked with a 1, whereas the absence of an aspect was marked with a 0. Disagreements were settled by a third judge. Interrater reliability between the two judges was assessed using Cohen's kappa,  $\kappa = .832$ , which is considered near-perfect agreement (McHugh, 2012).

Both the neutral and emotional content story consisted of 13 Correct Gist categories. The neutral story contained 26 Correct Detail categories, whereas the emotional story contained 31. The neutral story had six Incorrect Gist categories, whereas the emotional story

was determined to have eight. In terms of Incorrect Detail categories, the neutral story contained 19, whereas the emotional content story had 28. Because detail and gist categories have unequal amounts, they were analyzed separately.

## Results

### Recall Accuracy

To assess the effects of story content and birth control status on gist HR, a 2 (birth control status: HC or NC)  $\times$  2 (emotional content condition: neutral or emotional) mixed ANOVA with a within-subjects factor of story content was used. There was a main effect of story content, such that gist HR was higher for the neutral condition ( $M = 0.71$ ,  $SD = 0.17$ ) than for the emotional content condition ( $M = 0.59$ ,  $SD = 0.22$ ),  $F(1, 88) = 31.19$ ,  $p < .001$ ,  $\eta^2 = .09$  (see Table 4 and Figure 1). There was no significant main effect of birth control status on gist HR, indicating that HC women ( $M = 0.64$ ,  $SD = 0.20$ ) and NC women ( $M = 0.66$ ,  $SD = 0.21$ ) did not differ significantly in their recall for gist elements,  $F(1, 88) = 0.13$ ,  $p = .72$ ,  $\eta^2 < .01$ . The interaction effect between birth control status and story content was also not significant,  $F(1, 88) = 0.69$ ,  $p = .41$ ,  $\eta^2 < .01$ . To assess the effects of story content and birth control status on gist FAR, a 2 (birth control status: HC or NC)  $\times$  2 (emotional content condition: neutral or emotional) mixed ANOVA was used. There was a near-significant main effect of story content on gist FAR (Emotional:  $M = 0.04$ ,  $SD = 0.10$ ; Neutral:  $M = 0.07$ ,  $SD = 0.12$ ),  $F(1, 88) = 3.01$ ,  $p = .09$ ,  $\eta^2 = .02$ , and there was no significant main effect of birth control status on gist FAR (HC:  $M = 0.06$ ,  $SD = 0.11$ ; NC:  $M = 0.06$ ,  $SD = 0.11$ ),  $F(1, 88) = 0.11$ ,  $p = .74$ ,  $\eta^2 < .01$ . Additionally, the interaction between birth control status and story content on gist FAR was not significant,  $F(1, 88) = 1.08$ ,  $p = .30$ ,  $\eta^2 < .01$  (see Table 5 and Figure 2).

To assess the effects of story content and birth control status on detail HR, a 2 (birth control status: HC or NC)  $\times$  2 (emotional content condition: neutral or emotional) mixed ANOVA with a within-subjects factor of story content was used. There was a main effect of story content, where detail HR was higher for the neutral condition ( $M = 0.43$ ,  $SD = 0.21$ ) than for the emotional content condition ( $M = 0.35$ ,  $SD = 0.16$ ),  $F(1, 88) = 18.22$ ,  $p < .001$ ,  $\eta^2 = .05$  (see Table 4 and Figure 1). There was not a significant main effect of birth control status on detail HR, indicating that HC women ( $M = 0.38$ ,  $SD = 0.18$ ) and NC women ( $M = 0.40$ ,  $SD = 0.20$ ) did not differ significantly in their recall for detail elements,  $F(1, 88) = 0.37$ ,  $p = .55$ ,  $\eta^2 < .01$ . The interaction effect between birth control status and story content was also not significant,  $F(1, 88) = 0.33$ ,  $p = .57$ ,

**TABLE 4**

#### Hit Rates

	Hormonal Contraceptive		Naturally Cycling		Total	
	Gist	Detail	Gist	Detail	Gist	Detail
Emotional	.57 (.20)	.34 (.15)	.60 (.23)	0.37 (.17)	0.59 (.22)	.35 (.16)
Neutral	.71 (.17)	.43 (.20)	.71 (.18)	0.44 (.23)	0.71 (.17)	.43 (.21)

Note. Descriptive Statistics for hit rates across conditions, given as Mean (Standard Deviation).

**TABLE 5**

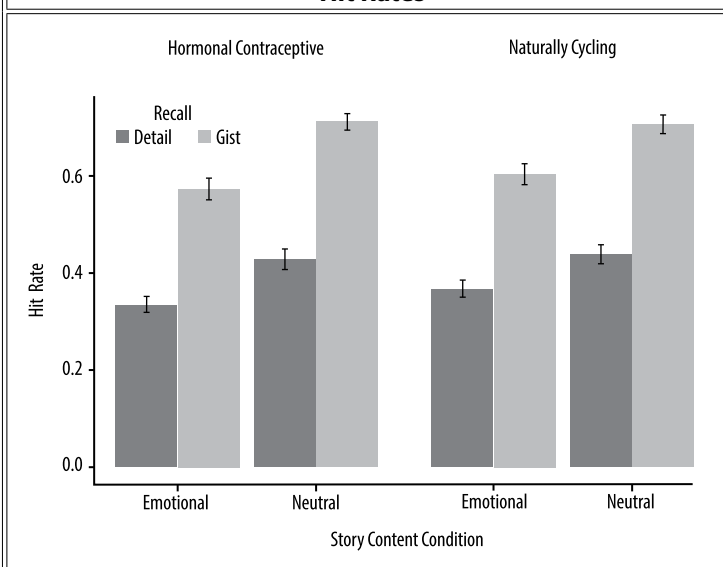
#### False Alarm Rates

	Hormonal Contraceptive		Naturally Cycling		Total	
	Gist	Detail	Gist	Detail	Gist	Detail
Emotional	0.06 (0.11)	0.04 (0.04)	0.03 (0.09)	0.02 (0.03)	0.04 (0.10)	0.03 (0.04)
Neutral	0.07 (0.11)	0.04 (0.05)	0.08 (0.12)	0.04 (0.05)	0.07 (0.12)	0.04 (0.05)

Note. Descriptive Statistics for false alarm rates across conditions, given as Mean (Standard Deviation).

**FIGURE 1**

#### Hit Rates



Note. Mean hit rates for hormonal contraceptive versus naturally cycling women's free recall in the emotional and neutral conditions. Error bars represent standard error.



$\eta^2 < .01$ . Finally, to assess the effects of story content and birth control status on detail FAR, a 2 (birth control status: HC or NC)  $\times$  2 (emotional content condition: neutral or emotional) mixed ANOVA was used. There was no significant main effect of story content on detail FAR (Emotional:  $M = 0.03$ ,  $SD = 0.04$ ; Neutral:  $M = 0.04$ ,  $SD = 0.05$ ),  $F(1, 88) = 2.36$ ,  $p = .13$ ,  $\eta^2 = .01$ , nor was there a significant main effect of birth control status on detail FAR (HC:  $M = 0.04$ ,  $SD = 0.04$ ; NC:  $M = 0.03$ ,  $SD = 0.04$ ),  $F(1, 88) = 1.02$ ,  $p = .32$ ,  $\eta^2 < .01$ . Additionally, the interaction between birth control status and story content on detail FAR was not significant,  $F(1, 88) = 2.75$ ,  $p = .10$ ,  $\eta^2 = .01$ .

### Assessing Current Emotional State

It is important to consider the possibility of current emotional states as a moderator in this experiment. To see if participants were significantly emotionally aroused by our emotional content auditory story, and not emotionally aroused at baseline or by the neutral stimulus, they completed a PANAS at three different time points: (a) before hearing any stimuli, (b) after the first randomized stimulus, and (c) after the final auditory story stimulus. To assess this, a 2 (birth control status: NC or HC)  $\times$  2 (emotional content condition: baseline, postemotional, or postneutral) mixed model ANOVA was used. There was a significant main effect of the story condition (Baseline:  $M = 17.9$ ,  $SD = 6.93$ ; Emotional:  $M = 16.90$ ,  $SD = 7.31$ ; Neutral:  $M = 14.00$ ,  $SD = 5.79$ ) on negative PANAS scores,  $F(1, 176) = 24.79$ ,  $p < .001$ ,  $\eta^2 = .06$ , however participants showed lower negative affect scores following either narration than at baseline (see Table 6). Post hoc analyses with Bonferroni correction were then run to determine which pairwise comparisons within the emotional content condition factor were driving the main effect. Dependent-samples  $t$  tests revealed that this effect was driven by significantly lower scores following the neutral story than at baseline,  $t(88) = 7.45$ ,  $p < .001$ ,  $d = 0.79$ , as well as significantly lower scores following the neutral story than following the emotional story,  $t(88) = 4.58$ ,  $p < .001$ ,  $d = 0.59$ . There was no significant difference between negative PANAS scores following the emotional content story and at baseline,  $t(88) = 1.82$ ,  $p = .22$ ,  $d = 0.19$ . There was no main effect of birth control status on negative arousal, nor was there a significant interaction between birth control group and stimulus administration. This shows that participants, regardless of contraceptive status, were not measurably negatively aroused by either story, however, they might have been significantly calmed by administration of the neutral narration.

To prevent any carry-over emotional arousal effects from one condition to another, demographic

information was collected between recall of the first narration and administration of the second narration. Additionally, the order of stimuli was counterbalanced to further prevent order effects. To further confirm that there was no effect of order of stimulus administration, an independent-sample  $t$ -test was conducted between negative PANAS difference scores (postneutral score subtracted from postemotional score) and order of stimuli. There was no significant difference in these scores for participants who heard the emotional content story first ( $M = 3.77$ ,  $SD = 6.62$ ) and those who heard the neutral story first ( $M = 2.11$ ,  $SD = 5.41$ ),  $t(88) = 1.30$ ,  $p = .20$ .

### Discussion

The current study sought to investigate whether oral hormonal contraception has a significant effect on recall accuracy for a narrated story with emotional content

TABLE 6

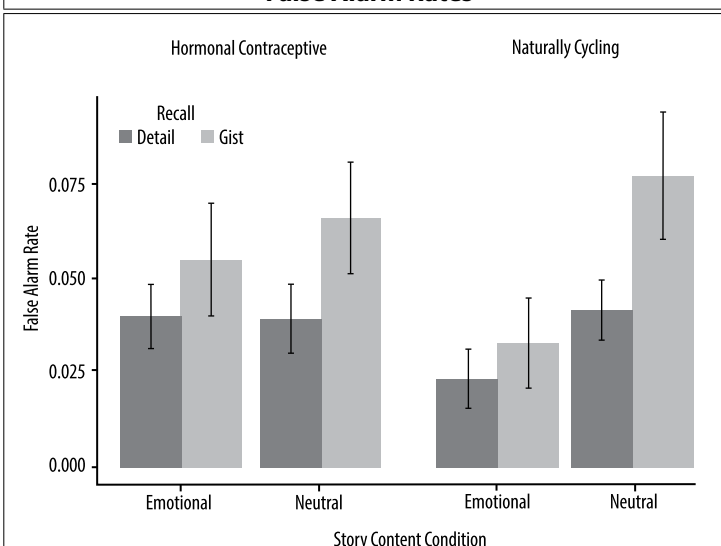
#### Negative PANAS Scores

	Hormonal Contraceptive		Naturally Cycling		Total	
Baseline	17.50	(6.51)	18.40	(7.38)	17.90	(6.93)
Postemotional	17.40	(7.16)	16.40	(7.49)	16.90	(7.30)
Postneutral	13.70	(5.51)	14.30	(6.11)	14.00	(5.79)

Note. Descriptive Statistics for negative PANAS scores, given as Mean (Standard Deviation). Higher scores indicate more negative affect.

FIGURE 2

#### False Alarm Rates



Note. Mean false alarm rates for hormonal contraceptive versus naturally cycling women's free recall in the emotional and neutral conditions. Error bars represent standard error.

compared to a neutral story. Contrary to previous literature, HC and NC women did not differ significantly in their recalls of emotional or neutral episodic events, regardless of gist or detail content. However, all participants, regardless of contraceptive status, recalled more gist information (regardless of story valence) and recalled more information for the neutral story than the emotional story (regardless of gist or detail components).

Given that the story containing emotional content was intended to be negatively arousing, negative affect scores from the PANAS were anticipated to be highest following the emotional stimulus, with lower scores at baseline and following the neutral stimulus. Negative PANAS scores indicated that participants were not significantly aroused by the emotional stimulus. However, inferences can be made on the effects of an auditory story containing emotional content in general. We found one area of significant change in negative PANAS scores following stimulus administration, though it was following the neutral story. Although participants did not appear to be significantly aroused by the emotional story, NC women appear to have been significantly calmed by both stories. This may indicate that all participants had a particularly high level of negative affect at baseline, and neither story significantly elevated that level further.

The lack of significant differences between baseline and post-negative story PANAS scores may indicate that the story did not induce a stress response. This could possibly explain the discrepancy between our findings and others' regarding HCs and emotional memory, as memory for emotional stories often differ depending on whether a cortisol response was evoked (Buchanan & Tranel, 2008). This factor may compound with the HC variable, as birth control can affect the influence of cortisol on memory retrieval for the free recall of words and numbers (Kuhlmann & Wolf, 2005), and therefore HCs might not have had as strong of an effect due to the lack of a cortisol response. However, future research will need to be conducted to directly assess this biological explanation.

The results of this study do not indicate a significant difference in recall for emotional auditory stimuli when comparing women on an HC and NC women, regardless of recall content type. NC women and women on a HC demonstrated similar recall accuracy for both stories, even when considering gist versus detail elements. Regardless of contraceptive use, participants had higher HR for the neutral condition than the emotional content condition, in contrast to prior research.

Analyses did reveal interesting differences in accuracy rates between the emotional content story and neutral story. Contrary to previous studies, participants in this study, regardless of contraceptive status, had

higher HR when recalling a neutral auditory story than for an emotional auditory story. Therefore, the hypothesis that participants' recalls would be more accurate for the emotional content condition was incorrect, because HR was higher for the neutral condition than the emotional content condition. However, FAR was also higher for the neutral condition, indicating that participants might have been more liberal in their recall responses for the neutral story. Both of the hypotheses pertaining to the interaction between birth control status and the emotional content condition were not supported, because there was no significant difference between NC and HC women in the emotional content condition. The hypothesis that NC and HC women would not significantly differ in the neutral condition was supported.

Although the findings of the current study did not match the hypothesized results, a few important implications can be drawn. The finding that participants had significantly higher HR for neutral content recall than for emotional content conflicts with some of the previous literature, including the findings of Nielsen and colleagues (2011). One important distinction between the current study and previous research regarding emotional memory lies in the current study's analysis of participants' criterion as it pertains to recalling an emotional versus a neutral story. Previous studies have found a difference between groups in recall for gist and detail elements of a story (Nielsen, 2011), though they did not account for FAR. This could be a crucial distinction in whether a difference actually occurs for the memory itself, or if the difference lies in a participant's criterion for reporting a memory. Furthermore, a memory cannot necessarily be considered more accurate from correct responses alone, as the amount of incorrect information recalled must also be considered.

One limitation of this study would be its remote administration due to the COVID-19 pandemic. Participants completed the study remotely on their own personal devices in an environment that could not be controlled completely, and thus participants might not have paid full attention to the audio recordings. Another limitation may lie in the auditory stimuli themselves. To control for the effects of tonality on emotional arousal, both the neutral and emotional stimuli were recorded with a very neutral, nonfluctuating tone. However, perhaps a large aspect of what is necessary to be aroused by auditory stimuli alone is within the delivery of the story itself. Removing vocal inflections from the auditory story may be directly removing an important component of emotional storytelling and could potentially explain the lack of significance in negative arousal scores following the emotional stimulus. Although the neutral story was created to mimic an everyday scene, individual



participants' personal preferences and experiences might have led to a positive interpretation of the story as opposed to neutral. Nevertheless, the neutral story evoked less of a negative response than the emotional content story, as was intended. Additionally, the use of pre-existing groups (i.e., not assigning participants to the HC or NC condition) does introduce potential confounding variables. Although various demographic information was collected, we did not control for demographic differences that might have impacted performance on the task, such as age, religiosity, and education. Given that there was an unequal distribution of age, year in school, and ethnicities into HC and NC groups (see Tables 1 and 2), it is possible that any of these may have factored into the experimental results. However, the contribution of demographic variables into recall accuracy is beyond the scope of this experiment.

Future iterations of the study should incorporate various changes to the design. First, in-person administration of the experiment would allow for better control of the participants' environment, which would, in turn, lead to fewer confounds. Second, allowing for natural vocal intonations in the recorded narrative may allow for larger emotional arousal by the emotional content story, as previous research has demonstrated limbic activation (in particular the amygdala) associated with emotional responses to changes in affective prosody (Brück et al., 2011). A control group that reads the stories as opposed to listening to them would also allow for further conclusions on the direct effects of an auditory component, and assessments of auditory processing abilities would aid in clarifying whether all participants were adequately absorbing the auditory material. Finally, validating the level of valence and arousal for the auditory stimuli is an important step for future iterations of the current study. Using a separate sample of participants to assess their momentary affective state at baseline and also poststimulus would be valuable in guaranteeing that the stimuli properly arouse participants as intended. A longer delay between story administrations may also have resulted in PANAS scores that more closely resembled the anticipated results.

Information was collected regarding HC participants' specific birth control pills, including brand, dosage, and approximately how long they had been on their current form of birth control (see Table 2). For NC participants, data collection included menstrual health information including the first day of their last menstrual period and their confidence that the reported date is accurate. These questions were meant to approximate which phase of menstruation they may be in at the time of the study. Due to large individual variabilities in menstrual cycles, we were not able to

draw definitive conclusions on the cycle stage based on these self-reports. However, previous research demonstrating the impact of the menstrual cycle stage on memory has indicated that this might have been an important factor to consider, and future research should incorporate a reliable measure of cycle stage. The current study focused primarily on negative PANAS scores, because the emotional stimulus was intended to be negatively arousing. However, future analyses should include positive PANAS scores to see if there were any changes in momentary positive affect following either the emotional or the neutral stimulus. Finally, a deeper look into the contributions of the correct and incorrect categories may elucidate whether there was a difference between the number of categories that HC and NC women contributed. The current analyses created categories if the element reported was mentioned by two or more participants; however, this was not broken down into HC and NC participants. Perhaps there would have been a significant difference between groups that would be clarified by further analyses. Last, due to time constraints, there was not a significant time delay between the administration of the story and free recall, as well as between the stories themselves. Some evidence has suggested that the effects emotions have on memory are most apparent for memories for events following a significant delay (Yonelinas & Ritchey, 2015), and therefore more significant effects might be observed with a longer duration between study elements.

The present study's findings reveal a potential difference in HCs' impacts on emotional memory that is domain-specific. While previous research has demonstrated differences in recall for emotional stories with a visual component, the current study's findings allude to an alternative effect when stimuli are exclusively auditory. These results add to the knowledge base of an incredibly complex relationship between hormonal contraception and cognition. However complicated, this area of research is paramount in understanding the short and long-term effects of a drug utilized by hundreds of millions of women worldwide.

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The authors thank Courtney Durdle for her indispensable help on this project and Dr. Michael Miller for his guidance. Additionally, the authors would like to acknowledge two undergraduate research assistants in the Miller Memory Lab, Ziyuan Chen and Natasha Pansare, for qualitatively coding the participant responses. Special thanks to Dr. Tyler Santander for his help with the analysis of this project. Finally, the authors thank their peers, mentors, friends, and family for their constant support throughout this project.

Materials and data for this study can be accessed at <https://osf.io/k7h8c/>. The authors have no known conflict of interest to disclose. Research was sponsored by the U.S. Army Research Office and accomplished under cooperative agreement W911NF-19-2-0026 for the Institute for Collaborative Biotechnologies.

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**APPENDIX A****Eligibility Questionnaire**

1. Are you currently on any form of hormonal contraceptive?
  - No
  - Yes, I am on an oral contraceptive/birth control pill
  - Yes, I am on another form of contraceptive other than the pill (if they select this option they are deemed ineligible for the current study)

If they answer "No" to question 1:

2. Have you been on any type of hormonal contraceptive in the past 3 months?
  - Yes (if they select this option they are deemed ineligible for the current study)
  - No
  - Unsure (if they select this option they are deemed ineligible for the current study)

If they answer "Yes" to question 1:

3. Have you been on this same type of hormonal contraceptive for at least 3 months?
  - No, I have been on this hormonal contraceptive for less than 3 months (if they select this option they are deemed ineligible for the current study)
  - Yes, I have been on this hormonal contraceptive for 3 months or more

Hormonal contraceptive pathway:

If they answer "Yes" to question 3:

4. How long have you been on this same type of hormonal contraceptive in months? (Please give your best guess) \_\_\_\_\_
5. Is your oral contraceptive a combined (estrogen and progestin) or progestin-only pill?
  - Combined pill (estrogen and progestin)
  - Progestin-only pill (minipill)
  - Unsure (All selected options remain eligible to continue, this is just to collect further data)
6. What type of oral contraceptive are you on? Please specify the brand and dosage if possible. \_\_\_\_\_

No hormonal contraceptive pathway:

If they answer "No" to question 2:

3. When was the first date of your last menstrual period? (Please look at a calendar if you need) \_\_\_\_\_
4. On a scale of 1 to 10, how confident are you that you gave an accurate estimate of the first date of your last menstrual period?  
(Slider function from 1–10 displayed here for them to toggle)

**APPENDIX B****Story Scripts****Arousal Version**

Robin and her son, Teddy, are leaving their New York apartment on a cold December morning. She is taking him to visit his father's workplace, which is a 20-minute walk from their home. The father is a laboratory technician at Victory Memorial Hospital. They look both ways before crossing Broadway, a busy street. While crossing the road, Teddy is struck by a white Mercedes, which critically injures him. A man at a nearby bus stop calls 911 for an ambulance. At the hospital, the staff prepare the emergency room, to which Teddy is rushed. An image from a brain scan machine shows severe bleeding in the left side of Teddy's brain. All morning long, Dr. Smith's surgical team struggled to save Teddy's life. Specialized surgeons were able to stop the bleeding in his brain, though he did sustain blindness in his right eye. After the surgery, while the father stayed with Teddy, the mother left to phone her other child, Samantha's, preschool. Feeling distraught, she phones the preschool to tell them she will pick up Samantha as soon as possible. Heading to pick up her child, she hails a taxi at the number nine bus stop.

**Neutral Version**

Two women decide to go to the mall after they get off work on Sunday afternoon. Susan picked up Kate in her red BMW at 4:00. They headed to Westfield mall in Placerville. Once they got to the mall, they headed straight for Dottie's clothing store for a big sale. At the store they tried on lots of different sweaters, but neither of them bought anything. After that, they decided to go to the mall's candy shop because Kate had a gift certificate for \$10.00. They looked around the shop for a while and tried different samples. They each decided on buying an assortment of chocolate and split a pound of saltwater taffy. Next, they decided to get some dinner at a local diner located down the street from the mall. Once there, Kate ordered a bacon cheeseburger and fries, and Susan ordered a garden salad. While enjoying their meals they talked about work. After they finished, Susan dropped Kate off at her house before heading home herself.

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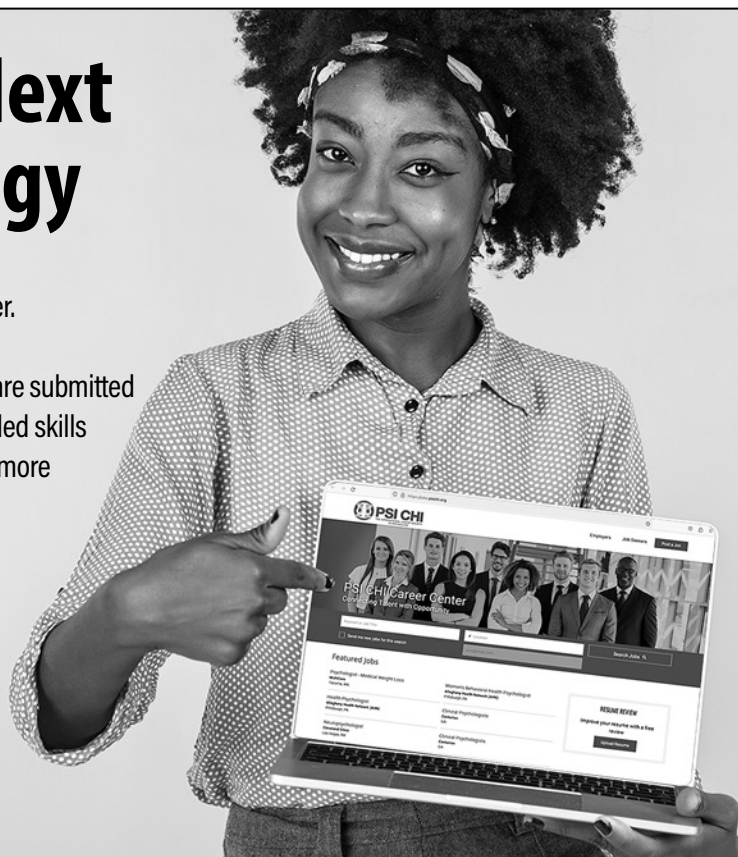


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