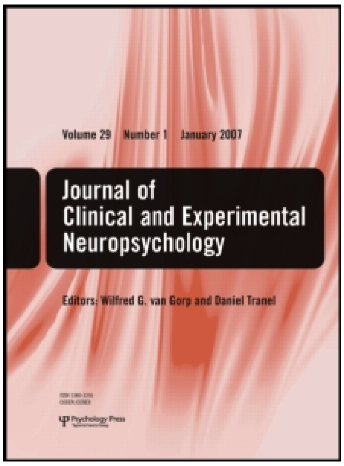

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The effects of pregnancy on memory: Recall is worse but recognition is not

Laura Mickes [a]; John T. Wixted [a]; Alice Shapiro [b]; J. Michael Scarff [c]
[a] University of California, San Diego, La Jolla, CA, USA [b] College of Information Sciences and Technology, Pennsylvania State University, University Park, PA, USA [c] Department of Obstetrics and Gynecology, Sunrise Hospital & Medical Center, Las Vegas, NV, USA

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The effects of pregnancy on memory: Recall is worse but recognition is not

Laura Mickes,[1] John T. Wixted,[1] Alice Shapiro,[2] and J. Michael Scarff[3]

[1]University of California, San Diego, La Jolla, CA, USA
[2]College of Information Sciences and Technology, Pennsylvania State University, University Park, PA, USA
[3]Department of Obstetrics and Gynecology, Sunrise Hospital & Medical Center, Las Vegas, NV, USA

Women who are pregnant frequently complain of memory problems. Past research suggests that pregnancy is associated with a measurable decline when memory is tested using free recall but not when memory is tested using recognition. However, no prior studies on recognition memory tested performance across two time periods (e.g., pregnant vs. postpartum). A repeated measures design has greater power than a between-subject design to detect any difference in recognition memory performance that might exist. We administered a standardized memory test to 37 women during pregnancy and then again during the postpartum period 3 to 12 months later. Our results show that during pregnancy free-recall performance was somewhat worse (in agreement with prior research) than postpartum but that recognition performance was not worse and was, if anything, slightly enhanced. These results weigh against a purely biological explanation of the memory difficulties associated with pregnancy and instead point to a strategic explanation. In particular, the results suggest that when women are pregnant they rely more on item-specific processing (which can enhance recognition) but when they are no longer pregnant they rely more on relational processing (which enhances recall).

Keywords: Pregnancy; Recall; Recognition; Clustering; Strategy.

A common subjective complaint of women who are pregnant concerns the difficulties they have with memory (for reviews, see Brett & Baxendale, 2001, and Henry & Rendell, 2007). In the contemporary study of memory, a distinction is usually drawn between the declarative and procedural memory systems (also referred to as the explicit and implicit memory systems). The declarative memory system involves memories for facts and events that can be consciously recalled or recognized (Cohen & Squire, 1980), and this system is thought to be subserved by several interconnected brain structures of the medial temporal lobes (MTL; Squire, 1986; Squire et al., 1992; Squire & Zola, 1996). The procedural memory system involves learned habits and skills (e.g., riding a bicycle) that do not require conscious recollection, and this system is thought to be subserved by a variety of different brain structures that do not include the MTL. The subjective complaints associated with pregnancy are generally confined to declarative memory.

The most common tests of declarative memory include free recall, cued recall, and recognition (Graf & Schacter, 1985). In a free-recall task, a participant is presented with a list of items (e.g., words on a list) and is later asked to reproduce those items from memory in any order. A cued recall task is similar, except that a stimulus that is in some way associated with the study items is presented at test as an aid to recall. For example, if the to-be-remembered study list included the words

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Address correspondence to Laura Mickes, 9500 Gilman Drive, Department of Psychology, University of California, San Diego, La Jolla, CA 92093-0109, USA (E-mail: lmickes@ucsd.edu).

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doctor, *engineer*, *mechanic*, and *actor*, the cue *professions* might be provided at test to facilitate the recall of these items. In a recognition task, a participant is presented with items from the study list (e.g., *engineer*) and asked to indicate whether or not each item is old (i.e., from the list) or new (i.e., not from the list). Of these tests, recall is considered to be the most difficult because no retrieval cues are provided, and recognition is considered to be the easiest because the to-be-remembered item itself is presented for a decision (along with items that did not appear on the list).

There is considerable evidence that pregnancy has a negative effect on declarative memory, at least with respect to free recall (Buckwalter et al., 1999; de Groot, Hornstra, Roozendaal, & Jolles, 2003; de Groot, Vuurman, Hornstra, & Jolles, 2006; Keenan, Yaldoo, Stress, Fuerst, & Ginsburg, 1998; Henry & Rendell, 2007; Rana, Lindheimer, Hibbard, & Pliskin, 2006). Keenan et al. (1998), for example, tested recall for paragraphs in 10 pregnant women and 10 control participants four times during each trimester and postpartum. Immediate recall (tested just after reading the paragraph) and delayed recall (tested after a delay of 30 minutes) were both significantly lower in pregnant women during the third trimester relative to control participants. Similarly, de Groot et al. (2006) tested free recall for lists of 15 words at five time points (four times during pregnancy and once 32 weeks after delivery) in 57 pregnant women and 50 controls. Scores for both immediate and 20-minute delayed recall were significantly lower in the pregnant group at all time points than in controls. Buckwalter et al. (1999) tested women during their third trimester and again two months postpartum on a battery of neuropsychological tests, including tests of memory for a list of 16 words over 5 trials. As measured by free recall, their participants performed significantly worse on Trial 5 when pregnant than postpartum, and the authors observed that "In terms of verbal learning characteristics, pregnancy was associated with less effective, more haphazard learning styles" (p. 79).

In a recent review of the literature, Henry and Rendell (2007) argued that although not every study shows the effect to a statistically significant degree, the weight of evidence suggests that the decrement in free recall associated with pregnancy is real. If the effect were hormonal in nature (perhaps because of the effects of hormones on the MTL), then one would expect to find other aspects of declarative memory to be affected as well. However, Henry and Rendell (2007) found no evidence that recognition memory was worse in pregnant women than in nonpregnant controls. From this, they concluded that the memory difficulties associated with pregnancy arise primarily from the effortful processing that is uniquely required for free recall (not from an effect on declarative memory in general). However, they also point out that while previous recognition memory studies have compared the performance of pregnant women with that of controls, no previous studies have compared recognition performance in pregnant women in relation to postpartum. A repeated measures test of that nature has higher power to detect any effect of pregnancy on recognition memory that might exist. To investigate this issue, and to further clarify the nature of the effect of pregnancy on free recall, we administered the California Verbal Learning Test–Second Edition (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000) at two time points: once during pregnancy and once again during the postpartum period approximately 3 to 12 months later. The CVLT-II is a well-known and widely used standardized neuropsychological test that assesses free recall after short- and long-delay intervals, semantic encoding ability via clustering, and recognition memory.

METHOD

Participants and procedure

Approval for human participants was obtained from both the University of California, San Diego institutional review board (IRB) and the Sunrise Hospital & Medical Center IRB in Las Vegas, Nevada. Patients were recruited through author J.M.S.'s obstetrics/gynecology office during routine prenatal and perinatal exams, and they were paid $25 for each of the two visits, during which they completed memory tests (once during pregnancy and once postpartum). A total of 47 patients were recruited, but 10 were lost on follow up, so a total of 37 individuals were included in the study. Table 1 shows that the average age was 28.8 years (SD = 5.68) at Time 1 (during pregnancy) and 29.4 years (SD = 5.68) at Time 2 (postpartum).

TABLE 1
Mean age and education by trimester

	Trimester		
	First	*Second*	*Third*
n	15	18	14
Age (years)	31.47 (5.38)	29.28 (4.56)	28.14 (6.54)
Education (years)	14.40 (2.50)	14.08 (2.53)	14.27 (3.32)

Note. Standard deviations in parentheses.

The average years of education were 14.4 (*SD* = 2.65). The patients were divided into three groups according to the trimester in which the first test was taken, with 15 patients initially tested during the first trimester (mean age = 31.5 years; *SD* = 5.4), 18 initially tested during the second trimester (mean age = 29.3 years; *SD* = 4.6), and 14 initially tested during the third trimester (mean age = 28.1 years; *SD* = 6.5). A trained assistant administered a standardized memory test, the CVLT-II, to each patient. During the postpartum period approximately 3 to 12 months later (range 3.4–12.6 months), 37 participants returned and completed the alternate version of the CVLT-II.

Measures

Participants were administered the CVLT-II (Delis et al., 2000) using standard procedures. Alternate forms were used postpartum to minimize contamination of the second test by the first. Woods, Delis, Scott, Kramer, and Holdnack (2006) tested for evidence of practice effects when the standard form was administered first, and the alternate form was administered 1 month later. Compared to when the standard test was administered on both occasions, they found that the use of the alternate form on the second test greatly reduced practice effects.

The CVLT-II is a standardized test of verbal learning and memory abilities. When the test is administered, participants first hear a list of 16 items (List A), with each item belonging to one of four semantic categories (i.e., vegetables). Immediately after hearing the list, they are asked to freely recall as many items from the list as they can remember in any order. This procedure was repeated on five consecutive trials, with the same list read and tested each time. Next, a second list of 16 items (List B) is presented to participants who then recall as many of these items as possible. The second list is composed of items from two of the categories from List A and two new categories. Immediately after recall of List B, short-delay free and cued recall of List A items is elicited. In the cued-recall test, the name of the semantic category is presented as an aid to recall (e.g., “name all of the items from List A that are vegetables”).

Following a 20-minute rest period, three additional delayed memory measures were obtained (free recall, cued recall, and recognition of List A items). In delayed free recall, participants again recalled as many items from List A as possible. In delayed cued recall, recall of List A items was elicited after four taxonomic prompts were given. Finally, delayed recognition was tested by presenting participants with a list of items that were or were not on List A and having them report “yes” if they heard the item on List A or “no” if they did not remember hearing the item on List A. The dependent measure used to assess recognition performance was d', a standard bias-free measure derived from signal detection theory. Scores on this measure range from 0 to approximately 4.0, with 4.0 reflecting perfect performance.

Semantic clustering is a measure of the degree to which semantically similar items are recalled together during free recall. If semantically similar items on the list are encoded in relational fashion during list presentation (i.e., if participants take note of the fact that some items are semantically related to other items on the list), recall is generally enhanced, and items are recalled in clustered fashion (Stricker, Brown, Wixted, Baldo, & Delis, 2002). For calculating clustering scores, the clustering scores on each trial were summed and then divided by the number of trials containing more than two responses (Delis et al., 2000).

RESULTS

Standard scores for all subtests of the CVLT-II fell well within the normal range according to gender- and age-appropriate norms (Delis et al., 2000), and this was true both during pregnancy and postpartum. Thus, any effect of pregnancy on memory likely reflects a change from the patient’s normal level of functioning but does not usually reflect a clinically significant degree of impairment.

We first analyzed memory performance across the three trimesters of pregnancy. That is, a between-subjects analysis of variance (ANOVA) was performed on all scales of the CVLT-II, with trimester serving as the grouping variable. Because no significant differences were found for any measure (replicating Sharp, Brindle, Brown, & Turner, 1993), the three trimester groups were combined for further analysis. Because all 37 of these participants were tested twice, once while pregnant (Time 1) and once again 3 to 12 months later during the postpartum period (Time 2), a repeated measures ANOVA was performed on all scales of the CVLT-II to determine whether or not memory performance was impaired during pregnancy relative to postpartum.

Table 2 shows the raw scores for the participants at Time 1 and Time 2 for each measure of interest within the CVLT-II. In general, the results show lower free-recall scores, and that effect is summarized in Figure 1. For both the short- and long-delay free-recall measures, performance was

TABLE 2
California Verbal Learning Test results for participants at time of pregnancy and approximately six months to one year postpartum

Measure	*Time 1*	*Time 2*
Trial 1	8.32 (2.48)	7.89 (1.95)
Trial 5	13.95 (1.79)	14.35 (1.38)
Trials 1–5	59.89 (8.66)	60.95 (7.33)
Trial B	7.68 (2.29)	7.89 (2.38)
Short-delay free recall*	12.70 (2.76)	13.57 (1.92)
Short-delay cued recall	13.51 (2.23)	14.03 (1.94)
Long-delay free recall*	13.16 (2.44)	13.84 (1.91)
Long-delay cued recall	14.03 (2.02)	14.19 (1.70)
Clustering*	2.32 (2.37)	3.80 (2.53)
Primacy	0.28 (0.04)	0.28 (0.03)
Middle	0.47 (0.05)	0.46 (0.05)
Recency	0.26 (0.04)	0.26 (0.04)
Recognition (d')*	3.70 (0.44)	3.55 (0.55)

Note. Time 1 = at time of pregnancy. Time 2 = approximately six months to one year postpartum.
*$p \leq .05$ (significant difference).

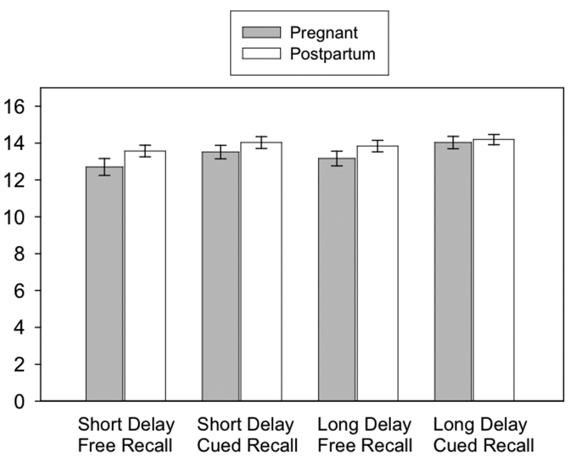

Figure 1. Mean (standard error) number correct on cued- and free-recall measures during pregnancy and postpartum.

significantly worse when participants were pregnant, $F(1, 36) = 5.41$, $p = .03$, Cohen's $d = 0.38$; $F(1, 36) = 4.47$, $p = .04$, $d = 0.35$, respectively. According to approximate guidelines offered by Cohen (1988), effect sizes can be classified as being small, medium, or large when Cohen's d equals 0.20, 0.50, or 0.80, respectively. Thus, the effect sizes that we observed for free recall fall in the small to medium range. This result was not surprising, and it confirms much prior research suggesting that pregnancy has a modest detrimental effect on free recall. Cued recall scores were numerically worse during pregnancy, but the difference between the two tests was small and not significant.

Table 2 also shows that clustering scores were significantly reduced during pregnancy relative to

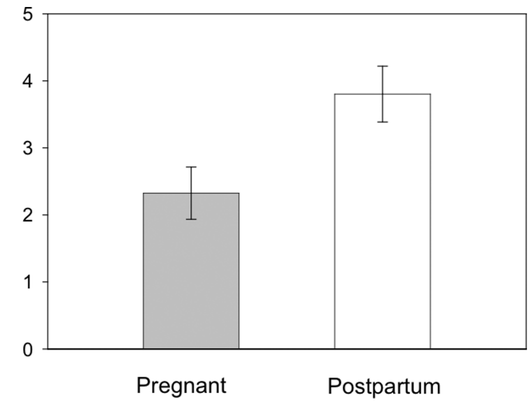

Figure 2. Mean semantic clustering scores for participants when pregnant and postpartum.

postpartum, $F(1, 36) = 16.07$, $p < .001$, $d = 0.66$, a result that is highlighted in Figure 2. That is, semantically similar items were less likely to be recalled together when the memory test was taken during pregnancy. This result suggests that, when pregnant, women are less likely to take into consideration the semantic relationships among the list items.

Finally, as shown in Table 2 and as highlighted in Figure 3, we also found that the patients performed somewhat better on the recognition task when they were pregnant than postpartum, $F(1, 36) = 16.07$, $p = .0502$, $d = 0.33$. Overall recognition performance (d') was very good (and was close to ceiling) at both time points in that the hit rate (proportion of items correctly identified as having appeared on the list) was high, and the false-alarm rate (proportion of items incorrectly identified as having appeared on the list) was low. At pregnancy and postpartum the hit rates were .98 and .97, and false-alarm rates were .05 and .08, respectively. Of the 37 women tested, 10 achieved perfect recognition scores on both testing occasions.

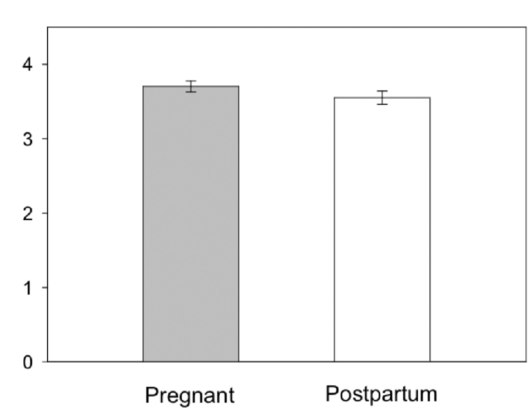

Figure 3. Mean d' recognition scores during pregnancy and postpartum.

If those women are removed from the analysis, the recognition scores during pregnancy still significantly exceed those obtained 3 to 12 months later during the postpartum period, $t(26) = 2.06$, $p < .05$, $d = 0.40$.

The distribution of d' difference scores (pregnant minus nonpregnant) was somewhat skewed but did not deviate significantly from normality ($p = .13$, according to the Lilliefors Test). Also, no clear outliers were identified. The Tukey outlier detection method (Tukey, 1977) identifies potential outliers using the interquartile range (IQR) as a metric, which is defined as the difference between the 75th percentile score and the 25th percentile score. Scores that fall more than 1.5 IQRs above the 75th percentile (or more than 1.5 IQRs below the 25th percentile) are flagged as possible outliers, whereas scores that fall more than 3 IQRs above the 75th percentile (or more than 3 IQRs below the 25th percentile) are flagged as "far" outliers. Using this method, only one score fell into the possible outlier range, and it did so just barely (falling 1.6 IQRs above the 75th percentile). No scores fell into the far outlier range. Thus, the results of the Tukey test would not seem to clearly justify excluding any scores as outliers. Still, if the possible outlier is excluded, the effect on recognition is still evident but is no longer significant, $t(25) = 1.74$, $p = .09$. On balance, these results clearly suggest that recognition memory is not worse during pregnancy than during the postpartum period, and they raise the possibility (but do not unambiguously establish) that recognition may even be better during pregnancy.

The time between the initial memory test (administered during pregnancy) and the subsequent memory test (administered during the postpartum period) was variable across patients and ranged from 3.4 to 12.6 months (mean = 7.9 months). Despite this relatively wide range, no clear relationship between intertest interval and change in memory performance was identified. More specifically, the correlation between the change in performance (pregnant minus not pregnant) and intertest interval was less than .05 for short-delay recall, long-delay recall, and clustering. For the recognition test, the correlation was higher (.33), but it was still not significant. Thus, the differences in memory performance that we observed appear to be attributable to pregnancy status per se rather than to the time between tests.

GENERAL DISCUSSION

The results of our inquiry into the effects of pregnancy on declarative memory were consistent with other investigations in that free recall was found to be worse during pregnancy than during the postpartum period (i.e., Buckwalter et al., 1999; Keenan et al., 1998). However, we also found that recognition memory was, if anything, slightly enhanced. Thus, the adverse effect of pregnancy on declarative memory is not pervasive but instead applies to free recall and, perhaps, cued recall.

Prior studies comparing the recognition performance of pregnant women to that of control participants have reported no apparent deficit on this task, unlike with free recall (Brindle, Brown, Brown, Griffith, & Turner, 1991; Sharp et al., 1993). Indeed, Brindle et al. (1991) found that, in most cases, pregnant women exhibited better recognition performance than that of controls (similar to our findings), but the effect did not reach statistical significance. In a follow-up study, Sharp et al. (1993) found that the recognition performance of pregnant women was approximately the same as (or, in some cases, slightly but nonsignificantly worse than) that of controls. However, the power to detect a difference is often higher in within-subjects designs (such as the one we used) than in a between-subjects design, such as that used by Brindle et al. (1991) and Sharp et al. (1993). At a minimum, our findings would seem to establish that the failure of previous studies to detect a recognition impairment associated with pregnancy was not simply the failure to detect a small effect. Using a more powerful within-subjects design, our results clearly show that recognition memory is not impaired by pregnancy, and they raise the possibility that recognition is actually enhanced.

The fact that the negative effect of pregnancy on declarative memory does not generalize to all tests weighs against a purely biological explanation and points instead to a strategic explanation. Because declarative memory is subserved by the structures of the MTL, it is sometimes supposed that hormonal changes that occur during pregnancy (i.e., increases in levels of estradiol, progesterone, oxytocin, and cortisol) negatively affect brain areas that govern the encoding and retrieval of memories. This hypothesis is made all the more plausible by the fact that hormonal changes have been shown to induce synaptic changes in the MTL, specifically in hippocampal dendritic density (e.g., Wallace, Luine, Arellanos, & Frankfurt, 2006; Woolley & McEwen, 1994). However, prevailing theories agree that the hippocampus subserves both recall and recognition (Squire, Wixted, & Clark, 2007), so an explanation along these lines would anticipate at least some degree of impairment on both tests. Instead, we found that pregnancy has opposite effects on recall and recognition.

If the effect of pregnancy on memory is not biological, then it is presumably strategic in nature. Based on their review of the literature, Henry and Rendell (2007) concluded that pregnant women are disinclined to engage in the effortful processing required to perform well on a free-recall task. This explanation makes sense in light of the fatigue that often accompanies pregnancy, but it offers no ready explanation as to why recognition performance might be enhanced. If pregnant women are less likely to engage in effortful processing, then recognition should be negatively affected as well (albeit to a lesser degree than the more demanding free-recall task).

One clue as to what might be responsible for the observed pattern of results comes from an analysis of the free-recall clustering scores (shown in Figure 2). During pregnancy, our participants were much less likely to show evidence of semantic clustering (i.e., recalling semantically similar words together) in their free-recall protocols than postpartum. This finding suggests that the use of an organizational strategy to master the list is less likely to occur when pregnant, which is partially consistent with Buckwalter et al.'s (1999) suggestion that pregnancy is associated with a less effective learning style.

Some caution is warranted before attributing the recall effect to semantic clustering because Woods et al. (2006) showed that semantic clustering was one of the few variables that exhibited practice effects when the standard version of the CVLT-II was followed 1 month later by the alternate version. However, the interval between the two tests in our study was substantially longer than 1 month (nearly 8 months, on average), which would presumably reduce any practice effect. In addition, the effect size in our study was larger than it was in Woods et al. (2006) despite the longer intertest interval ($d = 0.66$ vs. 0.48, respectively). Thus, while the higher degree of semantic clustering postpartum may, to some degree, reflect a practice effect, the size of the effect and the fact that it was evident over such a long intertest interval suggest that it is also related to pregnancy status.

Previous work has clearly established that semantic organization at encoding (later reflected by semantic clustering at retrieval) facilitates recall. Thus, the fact that semantic clustering was greater during the postpartum period provides a natural explanation for why both short-delay and long-delay recall scores were higher during that period. What remains to be explained is why the failure to use an organizational strategy at encoding during pregnancy might facilitate recognition. Einstein and Hunt (1980) drew an important distinction between item-specific and relational processing that may help to shed light on this issue. Item-specific processing refers to a focus on the individual items of a list, whereas relational processing refers to a focus on the semantic interrelationships between the list items. Generally speaking, relational processing enhances free recall (and semantic clustering), whereas item-specific processing enhances recognition. As Hunt and Einstein (1981) observed:

> Relational processing, under the control of orienting tasks or related list structure, produced higher levels of clustering while individual-item processing, induced by orienting tasks or unrelated list structure, produced highest recognition performance in Experiment 1. (p. 511)

Engelkamp, Biegelmann, and McDaniel (1998) manipulated item-specific versus relational processing during list learning either by having participants rate the pleasantness of items on a 7-point scale (item-specific processing) or by having them name the semantic category to which the items belonged (relational processing). They found that for lists with 4 items per category (similar to that of the CVLT-II), item-specific processing enhanced recognition but impaired recall relative to relational processing. That is, the effect of item-specific processing on memory mirrors the effect of pregnancy on memory.

The fact that, in our study, pregnancy was associated with reduced free recall (characterized by reduced semantic clustering) and possibly enhanced recognition suggests that learning was not simply more haphazard. Instead, learning during pregnancy was apparently of a different kind, with the focus being on individual items (item-specific processing) instead of on the relationships between them (relational processing). The obvious next question concerns why that would be. Because this result was unexpected, our study was not designed to answer that question, but it is possible to offer speculations based on related research concerned with the effect of mood on item and relational processing. In particular, Storbeck and Clore (2005) noted that mood can sometimes enhance and sometimes impair memory (cf. Bless et al., 1996). They tested the idea that a happy mood induces relational processing, whereas a negative mood encourages item-specific processing. Music was used to manipulate mood, and participants were asked to memorize a list of words using the Dees–Roediger–McDermott

(DRM) paradigm (Roediger & McDermott, 1995). In the DRM paradigm, the words on a study list are all highly related to a single word that is not actually presented on the list. For example, the list might include the words *bed*, *pillow*, *rest*, *awake*, and *dream*, all of which are related to the word *sleep* (which did not appear on the list). The non-presented associate (*sleep*, in this case) is called the critical lure. After studying a list like this, participants are very likely to mistakenly declare that the critical lure appeared on the list. Storbeck and Clore (2005) showed that this effect is quite pronounced when a happy mood is induced but is much less pronounced when a negative mood is induced. They concluded from this that negative mood states induce item-specific processing (such that the relationship between the list items and the critical lure becomes less apparent), whereas happy mood states induce relational processing. When the relationship between the list items becomes salient (as it would when relational processing is used), participants fall prey to the highly related critical lure and mistakenly believe that it appeared on the list.

A similar state of affairs may apply to pregnant women. Several studies have reported that women were more depressed during pregnancy than in the 6 months following childbirth (e.g., Evans, Heron, Francomb, Oke, & Golding, 2001; Hayes, Muller, & Bradley, 2001). Conceivably, the observed effects on memory are secondary to that. That is, a more depressed mood during pregnancy may induce item-specific processing, which, in turn, would be expected to impair free recall, reduce semantic clustering, and facilitate recognition. This interpretation is speculative because we did not measure depression, either during pregnancy or postpartum, but it does make sense out of what is otherwise a rather puzzling set of results.

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