Cognitive Reorganization during Pregnancy and the Postpartum Period: An Evolutionary Perspective

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Abstract: Where the non-human animal research investigating reproduction-induced cognitive reorganization has focused on neural plasticity and adaptive advantage in response to the demands associated with pregnancy and parenting, human studies have primarily concentrated on pregnancy-induced memory decline. The current review updates Henry and Rendell’s 2007 meta-analysis, and examines cognitive reorganization as the result of reproductive experience from an adaptationist perspective. Investigations of pregnancy-induced cognitive change in human females may benefit by focusing on areas, such as social cognition, where a cognitive advantage would serve a protective function, and by extending the study duration beyond pregnancy into the postpartum period.

Keywords: pregnancy, cognition, meta-analysis

Introduction

Cognitive re-organization during pregnancy and the postpartum period is complex; researchers studying both human and non-human females have faced challenges in describing the pattern of cognitive changes associated with these distinct reproductive periods. The human literature examining cognitive change in pregnancy is especially equivocal. Despite a relatively narrow focus on pregnancy-induced memory decline, and consistent subjective reports of pregnancy-induced memory impairment, researchers have had a hard time describing actual memory impairment in pregnant women using objective measures. While some studies have reported a pregnancy-induced memory decline on some measures (Brindle, Brown, Brown, Griffith, and Turner, 1991; Keenan, Yaloo, Stress, Fuerst, and Ginsberg, 1998; Sharp, 1993), other studies have found no difference between
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pregnant and non-pregnant women (Crawley, Dennison, and Carter, 2003; Casey, 2000). Further confusing the picture is still other research that shows specific pregnancy-related advantages in certain memory tasks (Anderson and Rutherford, 2010; Christensen, Posyer, Pollit, and Cubis, 1999).

In 2007, Henry and Rendell published a meta-analysis of 14 studies, each of which included pregnant or postpartum women and a control group. Their review suggested that the contradictory results with respect to memory decline in pregnant women may have been caused by the use of different methodologies, the testing of distinct memory processes, and the small sample sizes often employed in examining cognitive change in pregnant women. Other researchers have argued that the assumed pregnancy-related decline in memory performance has been exaggerated, and that subjective reports of a pregnancy-induced impairment result from cultural expectations of a cognitive deficit in pregnancy (Crawley, Grant, and Hinshaw, 2008), as well as the expectations of medical caregivers (Jackson, Schmierer, and Schneider, 1996).

Henry and Rendell (2007) interpreted the results of their large-scale analysis to show three main findings. First, pregnant women show a real, although subtle, cognitive deficit. Second, memory tasks that require more effortful processing are more likely to show a pregnancy-induced impairment. Third, postpartum and pregnant women show similar patterns of cognitive decline. The current review has two main aims. First, we will examine the conclusions drawn by Henry and Rendell (2007) in light of recent human studies and a revised meta-analysis, and contrast the conclusions that may be drawn from the current state of the human literature with what is known about pregnancy and postpartum cognition in the non-human domain. Next, we examine a small but growing literature that suggests that there are pregnancy-induced protective mechanisms designed to safeguard the mother and her fetus. These mechanisms involve physiological responses to nutritional agents, endogenous responses to mitigate stress reactivity in the pregnant and postpartum female, and enhanced social cognition, including facilitated processing of faces and emotions. To date, research on the effects of human pregnancy on cognition have emphasized cognitive costs or deficits. We consider the possibility that apparent deficits in cognition in pregnancy and the postpartum period reflect a trade-off whereby cognitive tasks that are ecologically relevant to their current reproductive phase are facilitated. Moreover, as the demands of pregnancy transitions into the demands of infant care in the postpartum period, there is evidence from the non-human animal literature that enhanced cognition during these periods results in a perpetual cognitive advantage in areas that would promote maternal or fetal fitness.

A review highlighting recent evidence and suggesting new avenues of future research is warranted at this time for several reasons. The different conclusions that have been drawn from the human and non-human literature suggest that researchers investigating pregnancy-induced cognition in women may benefit from adopting a new perspective: that of evolutionary psychology. Decades of research exploring memory decline in pregnancy, without the emergence of a clear picture, suggest that the absence of a functional approach has made it difficult to formulate testable hypotheses that offer insight into human maternal cognition. Researchers may be better served by exploring avenues that serve an adaptive function or offer a survival advantage, rather than assuming cognitive decline as the result
of pregnancy. Much like turning an adaptive lens on the problem of “morning sickness” has led to its re-conceptualization from pathology to an adaptation designed to protect the mother and the fetus (Fessler, 2002; Flaxman and Sherman, 2000; Flaxman and Sherman, 2008; Profet, 1992), we suggest that turning an adaptationist perspective on the question of pregnancy-induced cognitive change may also yield surprising results.

The main aim of this revised meta-analysis was to examine whether Henry and Rendell’s (2007) conclusions are still accurate given that a number of studies have recently investigated cognitive changes in pregnancy, many of which have tested the conclusions drawn by Henry and Rendell (2007) explicitly (Cuttler, Graf, Pawluski, and Galea, 2011; Onyper, Searleman, Thacher, Maine, and Johnson, 2010; Rendell and Henry, 2008).

Materials and Methods

Sample of Studies

In order to revise the meta-analysis that was performed by Henry and Rendell (2007) we followed several of their inclusion criteria, including 1) the studies were written in English, 2) had to include a sample of pregnant and/or postpartum women and a control group, and 3) included participants who were in good health and without complicated pregnancies.

We broadened the inclusion criteria regarding the cognitive measures used in the studies. While Henry and Rendell (2007) examined pregnancy and memory, we also investigated general cognition and processing speed. The sample of memory measures used in the current meta-analysis is also updated. In contrast to the 2007 meta-analysis, we included prospective memory, which is characterized as the memory for future intentions (e.g., remembering a previously scheduled doctor’s appointment) and is in contrast to retrospective memory (the memory for past events). We categorized prospective memory by laboratory and naturalistic prospective memory tasks. For working memory, we did not limit our analysis to studies that reported backwards digit span; several distinct measures of working memory have been used to evaluate working memory including backwards digit span, O-SPAN, and the verbal and non-verbal working memory tasks from the Stanford-Binet, 5th edition (SB5) (Roid, 2003). In order to discriminate between free recall and delayed recall tasks we used the same criteria as Henry and Rendell (2007), with the exception that delayed free recall tasks were those occurring after a delay of 10 minutes, rather than 15 minutes, and we were, again, more liberal in allowing distinct measures of recall to be employed. For processing speed we included studies that used digit symbol-coding, the symbol digit modalities test (SDMT), the letter digit substitution test (LDST), and the speed of comprehension task of the SCOLP (Baddeley, Emslie, and Nimmo-Smith, 1992).

Following Henry and Rendell (2007), we excluded studies that only reported on subjective measures of cognitive functioning during pregnancy in order to facilitate comparisons between objective and subjective measures. We also excluded studies that failed to present adequate statistics for computing an effect size. In the current analysis, we included 13 of the 14 studies originally included in Henry and Rendell’s (2007) meta-analysis. The exception was McDowell and Moriarty (2000), which was excluded due to
implicit long-term memory being excluded (they did not measure any cognitive tasks that were included in the current meta-analysis). An additional eight studies were included in the current revised analysis, bringing the total number of studies used to 21. Appendix A lists studies that were excluded from the current meta-analysis and the reason for their exclusion.

Statistical Analysis

Like Henry and Rendell (2007), we prefer to use $r$ as a pooled effect size estimator as it is commonly used, not only as a correlation coefficient, but also as a standardized measure reflecting the strength of the relationship between two variables, along with a random effects model for the same reasons that are listed in their article. In order to perform the meta-analysis, we used the random-effects method recommended by Hedges and Vevea (1998), as it has been shown to better control the Type I error rate compared to a second popular method when the sample size used in the meta-analysis is small (Field, 2001). To make comparisons between this revised meta-analysis and the original meta-analysis easier, we used the same reporting format that was used by Henry and Rendell (2007) in the appendices and tables.

Results

Demographic Characteristics

Table 1 shows the demographic characteristics of the participants in each study. The total sample included in this meta-analysis is 22 studies, consisting of 2,041 participants. One thousand and ninety-nine women comprised the control group (mean age = 29.59 years, $SD = 2.76$), 800 women comprised the pregnant group (mean age = 29.62 years, $SD = 1.75$), and 342 women comprised the postpartum group (mean age = 29.77 years, $SD = 2.02$). Table 1 also portrays education and parity statistics (the percentage of women who have previously given birth at least once) when reported, and notes if the study reported a significant difference between the pregnant and control participants on any of the demographic variables. Seven of 21 studies reported a significant difference on at least one demographic variable of interest (age, education, marital status, household income, parity, and emotional well-being).
| Study                                      | Non-pregnant control group | Pregnant group | Postpartum group |
|-------------------------------------------|----------------------------|----------------|------------------|
|                                           | N  | Age | Education | Parity | N  | Age | Education | Parity | N  | Age | Education | Parity |
| Anderson and Rutherford (2010) / CM       | 39 | 28.8 | -         | -      | 39 | 29.61 | -         | -      |     |      |           |         |
| Anderson and Rutherford (in prep) / LM    | 18 | 29.1 | 4.18      | 33%    | 18 | 31.17 | 4.33      | 61     |     |      |           |         |
| Brindle et al. (1991)                      | 9  | *35  | =         | -      | 32 | 27   | =         | -      |     |      |           |         |
| Casey (2000)                               | 24 | 33.4 | =         | -      | 18 | 28.9 | =         | -      | 22  | 32.5 |           |         |
| Casey et al. (1999) / E                    | 45 | 32.2 | 2.6       | -      | 44 | 28.9 | 2.5       | -      | 22  | 32.5 |           |         |
| Christensen et al. (2000)                 | 542| -    | -         | -      | 76 | -    | -         | -      | 188 | -    |           |         |
| Christensen et al. (1999)                 | 35 | 33.6 | 14.4      | -      | 53 | 32.4 | 14.6      | -      |     |      |           |         |
| Condon et al. (1991)                      | 15 | =    | -         | -      | 38 | 27.3 | -         | -      |     |      |           |         |
| Crawley et al. (2008) / H                 | 25 | 29.1 |           | 100% nulli-parous | 50 | 27.7 |           | 100% primi-gravid |     |      |           |         |
| Crawley et al. (2003)                      | 20 | 31.9 | 13.7      | 55%    | 21 | 27.1 | 14.3      | 50%    |     |      |           |         |
| Cutler et al. (2011)                      | 24 | *NM  | -         | -      | 61 | NM   | -         | -      |     |      |           |         |

Note: = indicates that statistics were not presented, but it was stated in the study that the participants were not significantly different on the variable of interest.

* Upon no information on education was presented, the groups did not differ significantly on the National Adult Reading Test (a measure of premorbid IQ).

† Pregnant participants reported significantly more children than non-pregnant participants.

‡ Pregnant participants reported significantly higher emotional well-being than non-pregnant participants.

§ Non-pregnant participants reported significantly higher education than pregnant participants. (In Crawley et al. (2008), the two groups were not significantly different on verbal intelligence as indexed by the speed and capacity of language-processing test, or SCOLP [Baddeley, Emslie, and Nimmo-Smith, 1992].

¶ Pregnant women reported significantly higher household income than non-pregnant participants.

* Pregnant participants were significantly more likely to be in a committed relationship (married or equivalent) than non-pregnant participants.

NM No statistics were presented, but it was stated that non-pregnant participants were significantly younger than pregnant participants.

* Signifies a significant difference between pregnant and non-pregnant participants.
| Study                               | Non-pregnant control group | Pregnanat group | Postpartum group |
|-------------------------------------|-----------------------------|-----------------|------------------|
|                                     | N  | Age | Education | Parity | N  | Age | Education | Parity | N     | Age | Education | Parity |
| de Groot, Hornstra, Roozendaal, and Jolles (2003) | 57 | 30.5 | 4.4 | 71 | 29.5 | 3.9 | 57 total pregnancies | - | - | - | - |
| de Groot et al. (2006)              | 50 | 30.6 | 4.4 | 30% | 57 | 29.9 | 4.1 | 40% | 100 | 27.3 | 13.9 | Longitudinal study |
| Eidelman et al. (1993)              | 20 | 22   | 13.4 | -   | 20 | 29   | -   | -   | 100 | 27.3 | 13.9 | Longitudinal study |
| Harris (1996)                       | 20 | 29.1 | -    | -   | 20 | 29   | -    | -   |     |     |     | Longitudinal study |
| Henry and Sherwin (2012)            | 21 | 28.8 | 18.4 | -   | 55 | 31.4 | 18.5 | -   |     |     |     | Longitudinal study |
| Janes et al. (1999)                 | 20 | 32.4 | 3.3 | 100% nulliparous | 20 | 30.2 | 2.8 | 100% primigravid or primiparous | 20 | 30.4 | 2.4 |
| Keenan et al. (1998)                | 10 | 34.9 | - | =D | 10 | 32.5 | - | =D |     |     |     | Longitudinal study |
| Ouyser et al. (2010)                | 25 | 29.0 | 16.4 | 76% mothers | 21 | 29.5 | 15.9 | 81% mothers | - | - | - |
| Rendell and Henry (2008)            | 20 | 31.6 | 14.2 | 70% | 20 | 32   | 13.3 | 70% |     |     |     | Longitudinal study |
| Sharp (1993)                        | 19 | 27.3 | 2.5 | -   | 48 | 28.5 | 2.3 | -   |     | - | - | - |
| Wilson et al. (2011)                | 24 | 29.3 | 87.5 | *25% mothers | 46 | 30.8 | 76.9 | 50.6% mothers | - | - | - |
Appendix B portrays the study-level effects for each of the cognitive measures of interest. When a study reported more than one effect for a given cognitive measure, the mean effect size for that study was employed in the meta-analysis.

Meta-Analysis

Table 2 portrays the mean effects (M), along with the upper (upper R) and lower (lower R) 95% confidence intervals, the Fisher transformed variance (tau), the standard error of the mean (SE), the number of studies used in the analysis (K), the total sample size (N), and the homogeneity statistic (Q). A negative sign indicates when pregnant or postpartum women performed worse than control participants.

Working memory. We found a small, albeit significant negative impact of pregnancy on working memory tasks (mean $r = -0.07$), and a slightly larger trend towards impaired working memory in the postpartum period (mean $r = -0.09$).

Recall. We found a small negative effect of pregnancy on free recall tasks (mean $r = -0.14$), and a negligible impact of reproductive status on free recall performance during the postpartum period (mean $r = -0.06$). Delayed free recall showed a moderate negative effect of pregnancy (mean $r = -0.20$) and a small impairment when caring for an infant during the postpartum period (mean $r = -0.10$).

Recognition. We found a significant and positive effect of pregnancy on recognition memory tasks, and the mean effect size was significant in our analysis (mean $r = 0.14$). Unfortunately, to date no studies have investigated recognition in the postpartum period.

Prospective memory. To date, no studies have investigated prospective memory in the postpartum period, therefore our analysis is limited to pregnancy. We found a negligible negative effect of pregnancy for laboratory prospective memory tasks (mean $r = -0.09$), and a significant small to medium effect of pregnancy for naturalistic prospective memory tasks (mean $r = -0.25$).

Processing speed. Six studies contributed to our investigation of the impact of processing speed on pregnancy. Here we found a significant moderate negative effect of pregnancy (mean $r = -0.33$). Three studies contributed to the investigation of processing speed during the postpartum period, and here we found a small, non-significant negative effect of reproductive status (-0.07).

General cognition. For general cognitive functioning we found a significant and small negative effect of pregnancy (mean $r = -0.13$), and a small negative effect during the postpartum period (-0.16).

Subjective memory. Eleven studies contributed to evaluating subjective memory performance in pregnant women. Here we found a significant and moderate negative effect of pregnancy (mean $r = -0.33$). No additional studies have examined subjective memory in the postpartum period, so the mean effect size reported in Table 2 (mean $r = -0.16$) is identical to the effect size reported by Henry and Rendell (2007).
### Table 2. Summary statistics for the meta-analysis, comparing scores of 1) pregnant and non-pregnant women, and 2) postpartum and non-postpartum women

| Summary statistics | M       | Lower R | Upper R | Z   | Tau  | SE  | K   | N  | Q   |
|--------------------|---------|---------|---------|-----|------|-----|-----|----|-----|
| Working Memory     |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.07*   | -.13    | -.00    | 2.06| .00  | .03 | 9   | 1042| 2.34|
| Postpartum         | -.10    | -.20    | .00     | 1.90| .00  | .07 | 6   | 901 | 5.09|
| Free Recall        |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.14**  | -.23    | -.04    | 2.90| .02  | .04 | 15  | 107 | 12.94|
| Postpartum         | -.06    | -.12    | .00     | 1.83| .02  | .00 | 8   | 1149| 6.70|
| Delayed free recall|         |         |         |     |      |     |     |    |     |
| Pregnant           | -.20**  | -.32    | -.07    | 3.08| .02  | .05 | 8   | 1037| 4.42|
| Postpartum         | -.10    | -.21    | .00     | 1.91| .00  | .06 | 5   | 897 | 3.21|
| Recognition        |         |         |         |     |      |     |     |    |     |
| Pregnant           | .14*    | -.00    | .28     | 1.94| .01  | .08 | 5   | 331 | 4.33|
| Postpartum         | -       | -       | -       | -   | -    | -   | -   | -   |     |
| Laboratory         |         |         |         |     |      |     |     |    |     |
| Prospective Memory |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.09    | -.24    | .06     | 1.14| .00  | .01 | 3   | 177 | .02|
| Postpartum         | -       | -       | -       | -   | -    | -   | -   | -   | -   |
| Naturalistic       |         |         |         |     |      |     |     |    |     |
| Prospective Memory |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.25*   | -.46    | -.01    | 2.08| .03  | .13 | 3   | 214 | 2.48|
| Postpartum         | -       | -       | -       | -   | -    | -   | -   | -   | -   |
| Processing speed   |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.33**  | -.53    | -.09    | 2.70| .08  | .09 | 6   | 949 | 4.34|
| Postpartum         | -.07    | -.15    | .02     | 1.54| .00  | .04 | 3   | 752 | 1.94|
| General Cognition  |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.13    | -.27    | .02     | 1.71| .01  | .08 | 5   | 272 | 4.1 |
| Postpartum         | -.16    | -.61    | .38     | .57 | .13  | .27 | 2   | 78  | 1.00|
| Subjective memory  |         |         |         |     |      |     |     |    |     |
| Pregnant           | -.33**  | -.41    | -.24    | 6.89 | .01  | .05 | 11  | 636 | 10.36|
| Postpartum         | -.16    | -.32    | .01     | 1.87 | .01  | .09 | 5   | 221 | 3.8 |

*Note:* □p < .10, *p < .05, **p < .01
Publication Bias. As was the case with the 2007 meta-analysis, the results for all variables which included five or more studies in the current analysis showed no evidence of publication bias; there is no evidence to suspect that “the file drawer problem” (whereby there is a bias in the literature towards results that are significant while non-significant results sit collecting dust in file drawers), is occurring with these data.

Discussion: Revised Meta-Analysis

Is There a Small and Subtle Memory Deficit Associated with Pregnancy?

The first conclusion drawn by Henry and Rendell (2007) is that pregnant women show a subtle memory deficit on some, but not all, memory tasks. The results of our analysis support their conclusion; both free recall and delayed free recall (DFR), as well as working memory and naturalistic prospective memory tasks, show a significant negative effect of pregnancy. Laboratory prospective memory tasks showed a negative effect of pregnancy that failed to reach significance. In contrast, recognition memory showed a small, and significant, pregnancy-induced advantage.

Taken together, this newly revised meta-analysis suggests that there is a pregnancy-induced deficit on some, but not all, memory tasks, with the impact ranging from small to moderate.

Are Pregnancy-Induced Memory Deficits Restricted to Tasks that Require Effortful Processing?

The second conclusion drawn by Henry and Rendell (2007) is that tasks requiring relatively effortful processing or relating to executive functioning are the most likely to show a pregnancy-induced disadvantage. Evidence for this conclusion came from observing that pregnant women seem to have more difficulty with memory tasks such as free recall and delayed free recall (DFR), and showed more difficulty on tasks of working memory, which includes an executive processing component, in contrast to memory tasks that require a storage component only.

We were more liberal in our inclusion of memory tasks that tap working memory, specifically including memory tasks that place higher demands on executive processes (such as verbal working memory, SB5). If the conclusion drawn by Henry and Rendell (2007) is correct, then we should observe increased pregnancy-induced impairment on the working memory task in the revised meta-analysis; this is not what our results revealed. The broader inclusion criteria and the inclusion of more studies resulted in a smaller effect size for working memory (-.07 compared to -.16). Moreover, the pregnancy-induced deficit that is associated with working memory is less than the pregnancy-induced deficit we found in general cognitive processing (-.13), which suggests that working memory tasks are not especially likely to show a pregnancy-induced deficit, but may instead be related to a subtle and overall cognitive impairment related to pregnancy.

Henry and Rendell (2007) argued that prospective memory tasks would be a strong test of the claim that memory processes requiring an executive component are more likely to be impaired during pregnancy. In this meta-analysis we were able to include prospective memory tasks, both those occurring in the laboratory and those occurring in a natural setting (i.e., outside the laboratory). Here we found a significant, medium, pregnancy-
induced impairment in tasks of naturalistic prospective memory, and a small, non-significant effect of laboratory prospective memory tasks. Rendell and Henry (2008) and Cuttler et al. (2011), report that pregnant women performed worse than non-pregnant controls on prospective memory tasks outside of the laboratory setting; the authors argue that the more natural settings, which inherently possess more distractions than laboratory settings, are more sensitive to pregnancy-induced memory impairment.

The results of the current meta-analysis suggest that naturalistic prospective memory tasks are impaired during pregnancy, and it may be that the cognitive effort involved in these tasks is underlying the impairment. However, the inclusion of more difficult working memory tasks along with a decreased pregnancy-induced deficit compared to the 2007 analysis, suggests that alternative explanations may be more fruitful. It may be that the observed impairment is the result of motivational, as opposed to cognitive, factors. The fact that pregnant women are not performing as well as non-pregnant women on naturalistic prospective memory tasks does not necessarily mean that they are failing to remember the task. Instead, they may remember the task and then, being distracted by commitments that occur outside the laboratory setting, assign the task such low priority compared to other pregnancy-related tasks (e.g., preparing a baby room, finishing work or home projects, attending doctors’ appointments, etc.) that low priority tasks are not completed.

Henry and Rendell (2007) also argue that the pattern of memory deficit observed in pregnant women is similar to the pattern of memory deficits seen in normal aging. However, our results show that there are important differences between pregnancy-induced memory deficit and memory deficit seen in normal aging. While aging populations show relatively poor performance on laboratory naturalistic prospective memory tasks compared to younger adults, they show increased performance on naturalistic prospective memory tasks compared to younger adults (Rendell and Thomson, 1999) - the opposite pattern is observed in pregnant women. Future investigations of how pregnancy influences naturalistic prospective memory, as well as exploration of delayed intention in the lives of pregnant women, may help to describe pregnancy-induced cognitive reorganization, and explain the subjective memory impairment often reported by pregnant women.

In terms of recall, our results support those drawn by Henry and Rendell (2007), showing that free recall and delayed free recall (DFR) show a small to moderate negative effect of pregnancy. Free recall tasks place a greater demand on tasks of executive functioning and so this offers limited evidence to support their conclusions.

Processing speed

Given that several recent studies have recently shown a late pregnancy-induced deficit in processing speed (Anderson and Rutherford, in prep; Christensen, Leach, and MacKinnon, 2010; Crawley et al., 2008; Onyper et al., 2010), we decided to include processing speed as a target variable of interest in the current meta-analysis. We found that processing speed showed a significant moderate negative effect of pregnancy, and a small negative effect in the postpartum period. The pregnancy-induced deficit in processing speed is much larger than any of the pregnancy-induced deficits in memory reported herein.

Processing speed has been correlated with general intelligence (Vernon and Weese, 1993; reviewed in Sheppard, 2008), and a pregnancy-induced deficit in processing speed
should not be underestimated. Digit symbol-coding, a common measure of processing speed, is not only or perhaps even primarily a test of processing speed, but also involves a memory component (Joy, Kaplan, and Fein, 2004). Given that the pregnancy-induced deficit in processing speed is the biggest negative effect that we found, and that it mapped very closely to the effect size of subjective memory complaints in both pregnancy and the postpartum period (mean \( r \) processing speed in pregnancy = \(-.39\), mean \( r \) subjective memory in pregnancy = \(-.33\); mean \( r \) processing speed in the postpartum period = \(-.20\); and mean \( r \) subjective memory in the postpartum period = \(-.16\)), and given that processing speed is thought to require a memory component, it is possible that this deficit is driving the consistent reports of pregnancy-induced cognitive decline made by pregnant women themselves.

**Consistent Patterns of Cognitive Performance in Pregnancy and the Postpartum Period**

The final conclusion drawn by Henry and Rendell (2007) is that there are consistent patterns of cognitive performance found in pregnancy and the postpartum period. In spite of an increase in studies included in the current meta-analysis, we still lacked sufficient data with which to accurately evaluate this claim. Given the limited evidence available, it seems as though cognitive performance in some areas (working memory and free recall) is similar during pregnancy and the postpartum period, whereas cognitive performance in other areas (processing speed) shows a distinct pattern dependent on reproductive phase. Self-reports of memory impairment also suggest that cognitive performance has improved in the postpartum period. Future studies investigating cognition in the postpartum period are necessary.

**Pregnancy-Induced Cognitive Change in Women: Summary of Recent Findings**

The results of our updated meta-analysis support Henry and Rendell’s (2007) conclusion that pregnant women possess a small cognitive deficit in some areas, such as recall and naturalistic prospective memory tasks. It is unclear at this point that tasks requiring relatively effortful processing are more likely to be hindered during pregnancy. Executive functioning comprises a wide range of cognitive functions, and it may be that certain tasks of executive functioning are impaired as the result of reproductive state while other tasks are not. Finally, recent studies investigating cognitive change in the postpartum period suggest that while performance on some cognitive tasks may be similar during pregnancy and the postpartum period, other cognitive tasks are differentially impacted by pregnancy and the postpartum period (prospective memory and processing speed); more research is needed in order to determine how these distinct reproductive phases influence cognition.

The current literature emphasizes cognitive decline as the result of reproductive state. Although new evidence suggests that cognition in pregnancy and the postpartum period may be impacted in a distinct, and perhaps specialized fashion, the evidence further suggests that pregnancy results in a mild impairment in general cognitive functioning and in a variety of memory tasks, and in a moderate deficit in processing speed. These conclusions are curious in light of recent reviews of reproduction-induced cognitive change in non-human animals. As shown in the rat literature, the neural plasticity associated with
Cognitive reorganization during pregnancy and the postpartum period may result in long-lasting advantages in some cognitive domains (Kinsley and Lambert, 2008).

Cognitive Reorganization as the Result of Reproductive State

The animal literature emphasizes that activities directly and indirectly related to maternal care are critical to the survival of both offspring and mother. For example, nest defense and nursing are important maternal activities, whereas hunting and moving efficiently to and from the nest are not directly involved in parental care but are nevertheless critical for the safety and survival of the mother and her offspring. A distinctive feature of the non-human animal literature is the assumption of cognitive reorganization rather than of memory decline, underlying these two categories of activities.

Neuroendocrine and neuroanatomical changes observed in the maternal brain are thought to underlie the behavioral and cognitive advantages exhibited by maternal rats, and are markers of neural plasticity. The neural plasticity reported in non-human females has also been found in women. For example, Kim et al. (2010) reported that brain volume showed changes in grey matter in the first few months postpartum, with an increase in areas known to be important for parenting. Swain (2011) cites fMRI evidence showing that there is a biological basis to attachment, and argues that neuroimaging work investigating the parental response to infants suggests neuronal plasticity in humans. Barrett and Fleming (2011) argue that although the brain mechanisms that underlie women’s behavior are more complex than those of rodents, there may be neuroanatomical similarities in the pathways that determine the approach/avoidance behaviors of rats towards pups and the push/pull that women exhibit towards infants. These works suggest that there are parallels between human and non-human animals in cognitive reorganization as the result of reproductive experience, at least in the domain of direct parental activities. More research is needed to ascertain whether there are also parallels in maternal behaviors that are not directly related to parental care.

MacBeth and Luine (2010) reviewed cognitive reorganization and anxiety in both human and non-human animals. Focusing on non-human animals they list several ways in which rats show cognitive enhancement as the result of reproductive state: enhanced spatial skills, foraging, and predator detection. Increased spatial cognition has been reported in pregnancy and in the postpartum period (at least after weaning). Kinsley and Lambert (2006) also report that pregnant and parous rats show enhanced hunting skills compared to virgin females. Evidence further suggests that the impact of reproductive experience on some cognitive tasks, such as long-term memory and some tests of foraging skills, may be long-lasting (Kinsley and Lambert, 2008; MacBeth and Luine, 2010).

In contrast to the human work that has tended to examine cognition during pregnancy, much of the rodent work has emphasized the postpartum period, or has compared nulliparous, primiparous, and multiparous females. The rodent work that has examined cognition during pregnancy has likewise been equivocal, with some studies reporting a cognitive advantage in some tasks (Paris and Frye, 2008; Bodensteiner, Cain, Ray, and Hamula, 2006; MacBeth, Gautreaux, and Luine, 2008) and other studies reporting a cognitive deficit (Galea et al., 2000). Kim, Chung, Kim, and Lee (2012) also reported a negative impact of pregnancy on long-term memory, although the cognitive deficit was
attenuated by the physical exercise of swimming.

Although more research is needed in order to fully describe cognitive changes during pregnancy in humans and rodents, the rodent work has tended to focus on cognitive reorganization as opposed to memory deficit. We suggest that the narrow focus on memory decline may be eclipsing potential advantages shared by women. Adopting an evolutionary perspective may yield important new insights. An adaptationist approach accepts that the costs associated with pregnancy may result in a cognitive deficit in some areas, but also recognizes that the potential benefits associated with pregnancy may also result in an advantage in other cognitive domains. A criticism that may be directed at much of the current research investigating cognition in pregnancy and the postpartum period is that the tasks employed are often abstracted verbal tasks that are devoid of ecological validity and relevance to everyday life. Although naturalistic prospective memory tasks occur outside the laboratory, this does not necessarily suggest that they are ecologically valid. As such, pregnant women who are vulnerable and physiologically taxed may not be motivated to perform. If researchers were to employ tasks that tapped a survival function, or were relevant to pregnancy or infant-care, the observed pregnancy-induced deficit may disappear, or may even be overturned into a cognitive advantage; evidence for this claim is the pregnancy-induced advantage observed in recognition memory.

The current meta-analysis suggests that recognition memory is facilitated during pregnancy. This positive result of pregnancy is curious given that the other memory measures showed a small to medium negative impact of pregnancy. It may be that there is something specific about recognition memory that facilitates cognitive functioning in pregnant women. Two of the five studies that contributed to calculating the mean effect size for recognition memory took an explicitly evolutionary approach (Anderson and Rutherford, 2010; Christensen et al., 1999). When the effect sizes for only these studies are included, the mean effect size increases from .14 to .26, suggesting a moderate cognitive advantage. This limited evidence suggests that adopting an evolutionary perspective may help to pinpoint domains where pregnant women show a cognitive advantage.

There is a growing body of research describing pregnancy-induced advantages in social cognition. Generating hypotheses informed by these studies may help to further our understanding of maternal cognitive processes (Anderson and Rutherford, 2010; Navarette, Fessler, and Eng, 2007; Pearson, Lightman, and Evans, 2009). In the next section we show evidence of a pregnancy-induced cognitive advantage in women.

Protective Mechanisms in Pregnancy

Pregnancy results in physiological and psychological stress. The relationship between stress and cognitive performance is complex (reviewed in Roozendaal, 2002), with stress having been shown to negatively impact some aspects of memory functioning while facilitating other cognitive tasks. For example, chronic stress has been shown to facilitate spatial learning and memory (Bowman, Zrull, and Luine, 2001). Moreover, recent evidence suggests that maternal experience may provide a buffer to the negative effect of stress on learning (Maeng and Shors, 2012). Although the impact of stress on cognitive functioning during pregnancy and the postpartum period has yet to be fully described, there is evidence showing that stress can result in negative consequences for the mother and the fetus.
Further evidence suggests that there are protective mechanisms mitigating the stress response in both rats and women.

Maternal stress during pregnancy has been shown to have an adverse effect on the fetus and post-natal infant. Stress and anxiety negatively impact birth outcomes (Dole et al., 2003; Rondo et al., 2003), including increasing birth complications and the likelihood of premature birth (reviewed in de Weerth and Buitelaar, 2005). Maternal stress during pregnancy has also been shown to negatively impact postnatal infant development (Bergman, Sarkar, O’Connor, Modi, and Glover, 2007; Brouwers, van Baar, and Popp, 2001; Davis and Sandman, 2010; Huizink, Robles de Medina, Mulder, Visser, and Buitelaar, 2003). A dampened stress response would therefore promote maternal and, especially, fetal health.

Although the impact of stress on cognitive functioning during pregnancy has not yet been fully described, the non-human animal literature shows evidence to suggest that there are mechanisms designed to attenuate stress and anxiety in females with reproductive experience. MacBeth and Luine (2010) describe several lines of evidence showing that stress reactivity is specifically mitigated during pregnancy and the postpartum period: both reproductive states result in decreased neural activation in areas of the brain that are known to underlie stress and anxiety. Specifically, there is a mitigating effect of the hypothalamic-pituitary-adrenal (HPA) axis on hormonal stress effects during pregnancy, pup-exposure postpartum decreases anxiety in new mothers, and even synaptic connectivity in areas underlying stress seem to be transformed as the result of pregnancy and the postpartum period.

The attenuated stress response reported in rats has also been found in human females. de Weerth and Buitelaar (2005) reviewed stress reactivity and concluded that the stress response is dampened in pregnancy; blood pressure, heart rate, and cortisol reactivity to a variety of stressors are mitigated during pregnancy. Glynn, Dunkel Schetter, Wadhwa, and Sandman (2004) found that women in later pregnancy perceived major life events as less stressful than women in earlier pregnancy. For example, women who experienced a major earthquake in late pregnancy reported the event as less stressful than women who experienced the earthquake in early pregnancy (Glynn, Wadhwa, Dunkel Schetter, Chicz-DeMet, and Sandman, 2001).

Attenuated stress responses and anxiety during pregnancy are not the only protective mechanisms associated with pregnancy in women. Morning sickness, now known as Nausea and Vomiting in Pregnancy (NVP), was long considered an unpleasant symptom resulting from pregnancy, but is now believed to protect the fetus from teratogens and other nutritional agents that may cause harm, and is also thought to protect the mother who is immunosuppressed during early pregnancy (Fessler, 2002; Flaxman and Sherman, 2000; Flaxman and Sherman, 2008; Profet, 1992).

Mitigated stress reactivity during pregnancy, along with NVP, show that there are protective physiological mechanisms designed to keep the mother and fetus safe. A promising line of research suggests that there are also protective mechanisms in response to social stimuli: pregnant and non-pregnant women process social stimuli in a distinctive fashion. Furthermore, the way in which pregnant women process social information is different, depending on the trimester of pregnancy. For example, Navarette et al. (2007)
showed that pregnant women display increased ethnocentrism and in-group bias in the 1st trimester of pregnancy. They interpreted their results as reflecting a disease-avoidance mechanism, arguing that during periods of vulnerability (such as pregnancy) a preference for in-group and decreased tolerance towards out-group members would decrease the exposure to pathogens and limit the risk of disease. This study was one of the first to show that pregnant women process social information in a distinctive fashion that may serve a protective function. A small but growing body of research examining the effect of reproductive status on face and emotion processing suggests that certain aspects of social cognition are enhanced in pregnant females.

Social Cognition in Pregnancy: Face and Emotion Processing

Both menstrual cycle studies and pregnancy studies suggest that reproductive status influences face and emotion processing. Pearson and Lewis (2005) reported that fear recognition varies with the menstrual cycle. They found that women are best able to recognize fear during the pre-ovulatory phase when estrogen levels are high. They emphasize the importance of fear recognition in social competence. Conway et al. (2007) reported that when progesterone levels are relatively high (as in pregnancy) women rate other peoples’ fear and disgust as more intense than when progesterone levels are relatively low. Derntl, Kryspin-Exner, Ferbach, Moser, and Habel, (2008) reported that progesterone is correlated with accuracy in emotion identification in naturally cycling women; when progesterone levels are high women show a response bias in identifying negative emotions as anger or disgust. Like Conway et al. (2007), they interpreted the observed response bias as a protective mechanism to socially threatening stimuli during pregnancy. Evidently, there are specialized face processing mechanisms designed to identify physical threat (fear) and disease threat (disgust), and the way in which women process threat depends on their menstrual cycle phase.

Studies investigating the processing of social information in pregnant participants have found similar results to studies investigating the way that naturally cycling women process social information. Pearson, Lightman, and Evans (2009) reported that pregnant women show facilitated encoding of emotions denoting threat (anger, fear, disgust) and sadness, and suggest that there may be a cognitive bias towards threatening stimuli in late pregnancy. They also argue that vigilance towards emotional cues will result in a survival advantage. Because anxious individuals have also been found to show enhanced encoding of emotional expressions, they tested whether relatively high anxiety is a possible mechanism for enhanced encoding of emotional stimuli during pregnancy. They found no support for this hypothesis, which should be expected given the mitigated stress reactivity and anxiety shown to be associated with pregnancy. Pearson et al. (2009) speculate that the attenuated stress and anxiety response associated with pregnancy allows pregnant women to benefit from facilitated emotion encoding without the cost associated with increased anxiety. Anderson and Rutherford (2010) also examined whether pregnant women may show facilitated processing of social stimuli. They found that pregnant women showed increased recognition of novel faces, and that this effect was especially pronounced for same-race male faces. Like Pearson et al. (2009), they argue that facilitated processing of faces serves a protective function, and that because male conspecifics posed a significant
threat throughout the ancestral past, cognitive mechanisms designed to keep the vulnerable mother and fetus safe may be expected.

As suggested by the research examining social cognition during the menstrual cycle and the pregnancy literature, reproductive status and reproductive experience alters the way women encode threatening social information. Like rats, who show enhanced spatial learning, foraging, and predator detection abilities while pregnant; human females may also possess cognitive processes that are species-typical and present an advantage during pregnancy.

One mechanism thought to underlie enhanced social cognition is increased vigilance (Anderson and Rutherford, 2010; Pearson et al., 2009). Interestingly, there is limited evidence that this increased vigilance may aid pregnant women even in evolutionarily novel situations. Using a simulated driving task, Crawley et al. (2008) investigated whether driving ability shows a pregnancy-induced deficit. Instead, they found that pregnant women navigate with increased vigilance, which serves a protective function. Approximately 20% of the pregnant women in the study reported driving more carefully since becoming pregnant. In contrast, in comparison to a year ago, over 50% of the non-pregnant women reported driving more quickly, more frequently, and more impatiently, and none of the non-pregnant women reported increased caution. Driving performance (number of collisions) also seems to be affected by pregnancy. Eight of 17 non-pregnant women were involved in a virtual collision on at least one trial, but only 1 of 13 pregnant women was involved in a virtual collision. Although Crawley et al. (2008) suggest that the results of this study should be interpreted cautiously due to small sample size and a lack of controls on previous experience and driving competence, these results seem to suggest that pregnant women adopt a more vigilant driving style than their non-pregnant counterparts.

General Discussion

Evidence from studies investigating the impact of reproductive experience on non-human and human animals suggests that females possess species-typical protective mechanisms during pregnancy. Just like rats, women also exhibit an attenuated stress response in late pregnancy. Whereas rats show protective mechanisms designed to facilitate efficient foraging, hunting, and nest protection, women show protective mechanisms designed to facilitate some aspects of social cognition. Enhanced social cognition in human pregnancy may serve multiple roles including efficiently identifying physical threats of violence from conspecifics, affectively identifying sources of disease, and establishing alliances. Moreover, there is evidence suggesting that increased vigilance may serve to protect pregnant women and their fetuses even in domains that are evolutionarily novel such as driving a car.

The results of the current meta-analysis suggest that pregnancy does result in a small, but significant impairment in some memory measures, including recall and naturalistic prospective memory. The finding that pregnancy results in a genuine cognitive impairment is supported by decades of women consistently reporting pregnancy-induced deficits. However, motivational factors have not been awarded much attention, and it is possible that pregnant women are lacking the motivation necessary to perform well on cognitive
tasks. Future research could investigate alternatives to actual cognitive impairment in order to explain the observed performance deficits. Alternatively, as described above, pregnancy and the early postpartum period result in decreased stress reactivity. A certain degree of stress is required for optimal performance, and pregnant women have shown attenuated physiological stress responses to cognitive testing (Matthews and Rodin, 1992; Monk et al., 2001). It may be that decreased stress reactivity, which serves a protective function, also results in decreased performance on some cognitive measures. However, it is also true that pregnant women are able to perform equally well as, or better than, non-pregnant women on some cognitive tasks, and that even tasks that show a pregnancy-induced impairment may be buffered by protective mechanisms during pregnancy to help avoid threats.

It may also be the case that the observed cognitive deficit serves an adaptive function. The fertility and parental care hypothesis describes the relatively poor female performance on some spatial tasks as serving an adaptive function by decreasing distances traveled from the nest and thereby increasing female reproductive success (Jones, Braithwaite, and Healy, 2003; Sherry and Hampson, 1997). Support for this hypothesis has been found in rats (Galea et al., 2000) and voles (Sheridan and Tamarin, 1988). Galea et al. (2000) found that rats in the third trimester of pregnancy, but not in the first and second trimester, performed worse than non-pregnant rats on a task of spatial working memory. They suggest a similar advantage for the observed deficit; staying close to the nest in the third trimester of pregnancy would mitigate the threat of predation, and conserve energy for parturition. As has been suggested by Darnaudery et al. (2007), who found a cognitive deficit in postpartum rats on a task of spatial learning, a cognitive deficit in the postpartum period may facilitate pup-directed behaviors; enhancing pup-directed behaviors may promote maternal care and bonding.

A genuine impairment as the result of pregnancy does not undermine the cognitive reorganization view espoused here. Although the costs associated with pregnancy evidently result in a cognitive disadvantage in some areas, which is somewhat expected given the myriad of costs associated with pregnancy, there is also evidence that areas that serve a protective function for the mother and her fetus are buffered and even facilitated as the result of pregnancy. An emerging body of research suggests that investigating threat-detection from an evolutionary perspective may yield the most intriguing insights into maternal cognition. In comparison to human males, human females show an advantage in processing social stimuli, including emotions, and this advantage is thought to occur as the result of the female’s role of primary caregiver (Hampson, van Anders, and Mullin, 2006). Evidently, women who are pregnant show an even greater proficiency in processing potentially harmful social stimuli in comparison to non-pregnant females. Hence, in some aspects of social cognition (namely, threat detection), the cognitive advantages being reported in the rat literature are also observed in human females.

Self-reports suggest that memory impairments are more likely to occur in the latter half of pregnancy. Likewise, objective measures show decreased performance on some processing speed tasks in the later stages of pregnancy. However, consistent with the adaptationist approach we advocate, it is possible that there are protective mechanisms affecting processing speed; limited evidence suggests that pregnancy does not impair the processing speed of threatening information. Anderson and Rutherford (2009) reported no
A difference in reaction time between pregnant and non-pregnant women in a snakes in the grass pop-out task, and further found that pregnant women were more accurate than non-pregnant women at detecting threatening stimuli (spiders) amongst nonthreatening stimuli (flowers and butterflies). Future research could further investigate processing speed during pregnancy and the postpartum period, determine whether there is a relationship between the observed deficit in processing speed and self-reports of cognitive impairment during pregnancy, and investigate the possibility that there are protective mechanisms facilitating the speed of threat-detection during pregnancy despite the general pregnancy-induced impairment in processing speed. This limited evidence also suggests that pregnancy may result in enhanced processing of threatening social stimuli as well as non-social threatening stimuli.

In order to describe maternal cognition, researchers should explore the positive aspects of cognitive functioning as they result from reproductive experience, not just the negative aspects. Future research could examine more precisely when cognitive reorganization occurs, describe the cognitive profiles in pregnancy and the postpartum period, investigate whether cognitive advantages directly linked to infant care occur in women, and explore whether cognitive reorganization resulting from reproductive experience lasts in perpetuity, as has been found in non-human animals. In fact, given that humans are unique in the close contact they share with their offspring, as well as their offspring’s offspring, we may expect that future research will show that cognitive reorganization and its associated advantages in women are more pervasive and dramatic than those observed in rats.

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## Appendix A. List of studies that were excluded from the current meta-analysis, and the reason for the exclusion

| Study (year) | Reason for exclusion |
|--------------|----------------------|
| Buckwalter et al. (1999) | Did not include a pregnant/postpartum control group |
| de Groot, Adam, and Hornstra (2003) | Did not include a target variable of interest |
| de Groot et al. (2004) | The relevant analyses were included in the meta-analysis in the de Groot et al. (2003) and (2006) studies. |
| Glynn, L.M. (2010) | Could not compute effect size with the data as presented. |
| Jarrahi-Zadeh et al. (1969) | Did not include a pregnant/postpartum control group; did not report data on an objective measure |
| Kane et al. (1968) | Did not include a pregnant/postpartum control group; did not report data on an objective measure |
| Lurie et al. (2005) | Did not include a pregnant/postpartum control group |
| McDowell and Moriarty (2000) | Did not include a target variable of interest |
| Mickes et al. (2008) | Did not include a pregnant/postpartum control group |
| Morris et al. (1998) | Did not report data on an objective measure |
| Parsons and Redman (1991) | Did not report data on an objective measure |
| Parsons et al. (2004) | Did not include a pregnant/postpartum control group |
| Poser et al. (1986) | Did not include a pregnant/postpartum control group |
| Rana et al. (2006) | Did not include a pregnant/postpartum control group |
| Schneider (1989) | Did not include a pregnant/postpartum control group |
| Silber et al. (1990) | Could not compute effect size as data was presented in the form of graphs |
| Shetty and Pathak (2002) | Data reported was collapsed into a global measure of memory |
| Stark (2000) | Did not include a pregnant/postpartum control group |
| Stark (2006) | Did not include a non-pregnant control group |
| Swain et al. (1997) | Data reported was collapsed across cognitive domains (memory, attention, psychomotor) |
| Vanston and Watson (2005) | Did not include a pregnant/postpartum control group |
## Appendix B. Effect sizes for each dependent variable for all the studies included in the meta-analysis.

| Study                  | Pregnant/postpartum (PP) group | Memory Measure | Proc. Spd. | Gen. Cog |
|------------------------|--------------------------------|----------------|------------|----------|
| Anderson and Rutherford (2010) | 39 39 10 44 46 - - - - .31 - - |                | -0.04     |
| Anderson and Rutherford (in prep) | 18 18 0 100 - - -.42 - - |                | -0.25 -0.25 |
|                         | 18b, RT 18b 0 100 - - .08 - - |                | - -        |
|                         | 18b, RT 18b 0 100 - - -.25 - - |                | - -        |
|                         | 12b, RT 12b 0 0 0 61 - - -.29 - - |                | -0.14      |
| Brindle et al. (1991)  | 9 4 4 0 0 0 - - -.44 - .79 |                | - -        |
|                         | 9b 5 5 0 0 - - - - - -13 - .62 |                | - -        |
|                         | 9b 6 0 6 0 - - - - - -66 - .30 |                | - -        |
|                         | 9b 5 0 100 - - - - - -17 - -.08 |                | - -        |
|                         | 9b 5 0 100 - - - - - -71 - .31 |                | - -        |
|                         | 9b 7 0 0 100 - - - - - -57 - -.22 |                | - -        |
|                         | 9b 32b Collapsed - - - - - - - - -.40c |                | - -        |

### Note:
- **CN** sample of control participants; **PN** Sample of pregnant or postpartum participants.
- **Memory tasks**: Exec. Working Memory tasks, FR Free recall tasks, DFR Delayed free recall tasks, Recog. Recognition tasks
- **Lab. Pros** Laboratory prospective memory tasks, **Nat. Pros** Naturalistic Prospective memory tasks, **Subj.** Subjective memory tasks
- **Proc. Spd.** Processing speed, **Gen. Cog** General cognitive performance
- ^A Indicates the percentage of the pregnant/postpartum sample that falls into that category.
- ^B Indicates whether the results of these participants have been listed in the table previously.
- ^C Indicates that effect size was calculated using Cramer’s Phi.
- ^RT Indicates a longitudinal design.
- ^M Indicates that the average number of participants is in the category indicated.
- ^N Indicates that the exact time in the postpartum period was not stated: new mothers fall into one of two categories: Those with children less than 12 months old and those with children more than 12 months old.
### Cognitive reorganization during pregnancy and the postpartum period

| Study            | Pregnant/postpartum (PP) group | Memory Measure | Proc. Spd. | Gen. Cog |
|------------------|--------------------------------|----------------|------------|----------|
| Casey (2000)     |                                |                |            |          |
|                  | CN 24                          | PN 18          | 1stA 100   | 2ndA 0   | 3rdA 0   | 1-3A - | 4-6A - | >6A - | Exec. 14 | FR - | DFR - | Rec. - | Lab. Pros - | Nat. Pros - | Subj. 0.00 | Proc. Spd. 0.16 | Gen. Cog 0.2 |
|                  | 24b, RT                         | 18b            | 100 0      | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | .00     | -     | -     | -     | -     | -     | -     | -     | -     | 0.24 |
|                  | 24b, RT                         | 18b            | 0 100      | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | .08     | -     | -     | -     | -     | -     | -     | -     | -     | 0.01 |
|                  | 24b, RT                         | 18b            | 0 0 100    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | .04     | -     | -     | -     | -     | -     | -     | -     | -     | 0.04 |
|                  | 24b, RT                         | 18b            | 0 0 100    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | -0.06   | -     | -     | -     | -     | -     | -     | -     | -     | 0.22 |
|                  | 24b, RT                         | 18b            | 100 0 0    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | 0.04    | -     | -     | -     | -     | -     | -     | -     | -     | 0.06 |
|                  | 24b, RT                         | 18b            | 100 0 0    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | 0.07    | -     | -     | -     | -     | -     | -     | -     | -     | 0.06 |
|                  | 24b, RT                         | 18b            | 0 0 100    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | 0.08    | -     | -     | -     | -     | -     | -     | -     | -     | 0.19 |
|                  | 24b, RT                         | 18b            | 0 0 100    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | 0.23    | -     | -     | -     | -     | -     | -     | -     | -     | 0.2   |
|                  | 24b, RT                         | 18b            | 0 0 100    | 0 0      | 0 0      | 100 0  | 0 0    | 100 0 | 0.04    | -     | -     | -     | -     | -     | -     | -     | -     | 0.09 |
| Casey et al.     |                                |                |            |          |          |          |        |        |        |        |        |        |        |        |        |        |          |
| (1999)           | 45                             | 22             | 9 9 82     | - -      | - -      | -13    | .31    | -12c  | -31    | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 45b                            | 22             | 18 45 36   | - -      | - -      | -18    | .15    | -17   | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 45b                            | 22             | - - -      | - -      | M -      | -21    | .07    | -37   | -     | -     | -     | -     | -     | -     | -     | -     | -    |
| Christensen et   |                                |                |            |          |          |          |        |        |        |        |        |        |        |        |        |        |          |
| al. (2010)       | 542                            | 30             | Collapsed  | - -      | - -      | .04    | .04    | .02   | -0.05  | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 542, RT                        | 46             | Collapsed  | - -      | - -      | -12    | -.01   | -.04  | -0.05  | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 542, RT                        | 76             | 0 - -      | - -      | N -      | -14    | -.13   | -.11  | -0.06  | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 542, RT                        | 112            | 0 - -      | - -      | N -      | .05    | .08    | .08   | -.02   | -     | -     | -     | -     | -     | -     | -     | -     | -    |
| Christensen et   |                                |                |            |          |          |          |        |        |        |        |        |        |        |        |        |        |          |
| al. (1999)       | 35                             | 53             | 0 40 0    | - -      | - -      | -      | -0.09  | -     | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 35b                            | 53             | 0 40 0    | - -      | - -      | 0      | -      | -     | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 35b                            | 53             | 0 40 0    | - -      | - -      | -      | -0.14  | -     | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 35b                            | 53             | 0 0 60    | - -      | - -      | .36    | -      | -     | -     | -     | -     | -     | -     | -     | -     | -     | -    |
|                  | 35b                            | 53             | 0 0 60    | - -      | - -      | 0.18   | -      | -     | -     | -     | -     | -     | -     | -     | -     | -     | -    |
| Study                        | Pregnant/postpartum (PP) group | Memory Measure |
|-----------------------------|-------------------------------|----------------|
|                             | CN   | PN | 1s | 2nd | 3rd | 1-3 | 4-6 | >6 | Exec | FR  | DFR | Rec | Lab | Nat | Subj | Proc. Spd | Gen. Cog |
| Condon et al. (1991)        | 15   | 38 | 0  | 0   | 100 | -   | -   | -  | -.33 | -   | -   | -   | -   | -   | -   | -        |          |
|                             | 15b, RT | 38b | - | - | 100 | 0   | 0   | -  | -.25 | -   | -   | -   | -   | -   | -   | -        |          |
| Crawley et al. (2003)       | 20   | 21 | Collapsed | - | - | - | - | -.16 | - | - | -.54 | - | - | - | - | - | - |
|                             | 18b, RT | 18b | Collapsed | - | - | N | - | -.00 | - | - | .00 | - | - | - | - | - | - |
|                             | 16b, RT | 16b | 0 | - | - | N | - | -.23 | - | - | .20 | - | - | - | - | - | - |
|                             | 14b, RT | 15b | 0 | - | - | N | - | .17 | - | - | -.05 | - | - | - | - | - | - |
| Crawley et al. (2008)       | 25   | 50 | 0 | 100 | 0 | - | - | - | -.15 | -.04 | - | -.05 | -.72 | - | - | - |
|                             | 25b  | 50b | 0 | 100 | 0 | - | - | - | - | - | - | -.62 | - | - | - | - | - |
|                             | 25b  | 50b | 0 | 100 | 0 | - | - | - | -.34 | -.25 | - | -.41 | -.67 | - | - | - |
|                             | 25b  | 50b | 0 | 100 | 0 | - | - | - | - | - | - | -.62 | - | - | - | - | - |
| Cuttler et al. (2011)       | 24   | 61 | 20 | 40 | 40 | - | - | - | -.12 | -.08 | .13 | -.01 | -.23 | -.33 | - | - |
|                             | 50b  | 57b | 20 | 40 | 40 | - | - | - | -.035 | - | -.15 | -.04 | -.48 | - | - |
|                             | 50b  | 57b | 20 | 40 | 40 | - | - | - | -.136 | - | -.20 | -.34 | - | - | - |
| de Groot, Hornstra, Roosendaal, and Jolles (2003) | 57   | 71 | 100 | 0 | 0 | - | - | - | -.25 | -.26 | - | - | -.13 | - | - | - |
| de Groot et al. (2006)      | 50b  | 57b | 0 | 100 | 0 | - | - | - | -.18 | -.16 | - | - | - | - | - | - |
|                             | 50b  | 57b | 0 | 100 | 0 | - | - | - | -.15 | -.08 | - | - | - | - | - | - |
|                             | 50b  | 57b | 0 | 100 | 0 | - | - | - | -.23 | -.19 | - | - | - | - | - | - |
| Eidelman et al. (1993)      | 20   | 29 | - | - | 100 | 0 | 0 | - | -.30 | - | - | - | - | - | - | - |
|                             | 20b  | 36 | - | - | 100 | 0 | 0 | - | -.12 | - | - | - | - | - | - | - |
|                             | 20b  | 35 | - | - | 100 | 0 | 0 | - | -.06 | - | - | - | - | - | - | - |
| Harris et al. (1996)        | 20   | 20 | 0 | 0 | 100 | - | - | - | -.18 | - | - | - | -.16 | - | - | - |
|                             | 20b, RT | 20 | - | - | 100 | 0 | 0 | - | -.22 | - | - | - | -.26 | - | - | - |
|                             | 20b, RT | 20 | - | - | 100 | 0 | 0 | - | -.10 | - | - | - | -.21 | - | - | - |
| Study                        | Pregnant/postpartum (PP) group | Memory Measure |
|-----------------------------|--------------------------------|----------------|
|                             | CN   | PN  | 1st | 2nd | 3rd | 4th | 6th | Exec. | FR | DFR | Rec. | Lab. Pros | Nat. Pros | Subj. | Proc. Spd. | Gen. Cog |
| Henry and Sherwin (2012)    | 21   | 55  | 0    | 0   | 100 | -   | -   | - .12 | - .22 | - .16 | -    | -        | -        | - .4  | -         | -        |
|                             | 21b, RT | 55b | 0    | 0   | 100 | -   | -   | - .06 | - .13 | - .06 | -    | -        | -        | -     | -         | -        |
|                             | 21b, RT | 55b | 0    | 0   | 100 | -   | -   | - .27 | - .26 | -    | -    | -        | -        | -     | - .21     | -        |
| Jomes et al. (1999)         | 20   | 20  | 2    | 8   | 10  | -   | -   | - .36 | - .41 | -    | -    | -        | -        | - .13 | -         | -        |
|                             | 20b  | 20  | -    | -   | M   | -   | -   | - .35 | - .11 | -    | -    | -        | -        | - .14 | -         | -        |
| Keenan et al. (1998)        | 10   | 10  | 100  | 0   | 0   | -   | -   | - .13 | -    | -    | -    | -        | -        | -     | - .13     | -        |
|                             | 10b, RT | 10b | 0    | 100 | 0   | -   | -   | -    | - .13 | -    | -    | -        | -        | -     | - .13     | -        |
|                             | 10b, RT | 10b | 0    | 0   | 100 | -   | -   | -    | - .46 | -    | -    | -        | -        | -     | - .46     | -        |
|                             | 10b, RT | 10b | -    | -   | Not stated | -   | -   | -    | - .36 | -    | -    | -        | -        | -     | - .36     | -        |
| Oynner et al. (2010)        | 25   | 21  | 0    | 100 | -   | -   | -   | - .12 | - .05 | -    | -    | - .09    | - .5     | - .37 | - .29     | -        |
|                             | 25b  | 21b | 0    | 100 | -   | -   | -   | - .01 | -    | -    | -    | -        | -        | -     | - .16     | -        |
| Rendell and Henry (2008)    | 20   | 20  | 0    | 0   | 100 | -   | -   | - .14 | - .10 | - .38 | - .15 | - .11    | - .52    | -     | -         | -        |
| Sharp (1993)                | 19   | 48  | 25   | 27  | 48  | -   | -   | -    | - .34 | -    | -    | -        | -        | - .48 | -         | -        |
| Wilson et al. (2011)        | 24   | 46  | 100  | 0   | 0   | -   | -   | -    | - .48 | - .33 | -    | - .35    | - .21    | -     | -         | -        |
|                             | 24b  | 46b | 100  | 0   | 0   | -   | -   | -    | - .36 | - .46 | -    | - .40    | -        | -     | -         | -        |
|                             | 24b  | 46b | 100  | 0   | 0   | -   | -   | -    | - .17 | -    | -    | -        | -        | -     | -         | -        |
|                             | 24b  | 46b | 0    | 0   | 100 | -   | -   | -    | - .43 | - .49 | -    | - .559   | - .04    | -     | -         | -        |
|                             | 24b  | 46b | 0    | 0   | 100 | -   | -   | -    | - .40 | - .29 | -    | - .22    | -        | -     | -         | -        |
|                             | 24b  | 46b | 0    | 0   | 100 | -   | -   | -    | - .31 | -    | -    | -        | -        | -     | -         | -        |