COGNITION IN PREGNANCY AND THE POSTPARTUM PERIOD

COGNITIVE REORGANIZATION AND PROTECTIVE MECHANISMS IN PREGNANCY AND THE POSTPARTUM PERIOD

By

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Abstract

In 2001 Brett and Baxendale reviewed cognitive change in pregnancy and concluded that although "...much has been written in an impressionistic way....at the beginning of the twenty first century considerable gaps in our knowledge remain" (pp. 339). Ten years later a clear picture describing cognitive change in women has still failed to emerge. Recent work investigating pregnancy-induced cognition in women continues to focus on memory deficits, in stark contrast to the cognitive advantage and neural plasticity described in the nonhuman (rat) literature. The following thesis reviews the current literature investigating pregnancy-induced cognitive change, and then reports three empirical studies investigating cognition in pregnant and postpartum women. I hypothesized that, given the high stakes associated with pregnancy and the postpartum period, adaptive mechanisms designed to keep the mother safe exist in the cognitive domain, in much the same way that Nausea and Vomiting in Pregnancy is now believed to buffer the mother and fetus from harm. The results of an updated meta-analysis and a longitudinal study comparing cognitive performance in pregnant and non-pregnant women suggest that there are cognitive costs associated with becoming a mother, in both pregnancy and the postpartum period. Recent research suggests that pregnant women possess an advantage in processing social stimuli: I report that pregnant women show facilitated recognition of faces. Finally, I examined nesting, and developed a questionnaire that tracked women through pregnancy and into the postpartum period, comparing non-pregnant women at similar time points. I report that nesting occurs in women, peaking in the third trimester, and involves space preparation and social

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withdrawal. Reproductive state affects cognition in ways that are distinct, and perhaps specialized, including a deficit in some areas (mathematical reasoning, processing speed), and a cognitive advantage in others (face recognition), some of which may serve a protective function.

Preface

This thesis comprises four manuscript chapters produced in collaboration with my supervisor, Dr. M.D. Rutherford. I was directly responsible for the experimental design, and the collection, analysis, and interpretation of all the data for all the experiments reported, and I was also directly responsible for the ideas put forth in the review chapter. Chapter 2 is a manuscript that has been submitted for publication to the journal *Evolutionary Psychology*. Chapter 3 is a manuscript that has been submitted for publication to *Intelligence*. Chapter 4 is a manuscript that was published in the journal *Evolutionary Psychology*. Chapter 5 is a manuscript that has been invited for revision for publication in the journal *Evolution and human behavior*. I was responsible for the preparation of all 4 manuscripts.

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CHAPTER 1

INTRODUCTION

Pregnancy and the postpartum period entail high stakes; women are uniquely vulnerable as a result of these reproductive states. Physiological and psychological costs associated with pregnancy and the postpartum period include extreme fatigue, increased body mass, and nausea and vomiting in pregnancy (NVP). These physiological costs have been shown to impact movement and foraging rates, as well as predator avoidance, in a number of species (Plaut, 2002; Schwarzkopf & Shine, 1992; Ghalambor, Reznick, and Walker, 2004; Kullberg, Houston, and Metcalfe, 2002; Lee, Witter, Cuthill, and Goldsmith, 1996). Although it is not yet clear how the physiological costs associated with pregnancy influence cognitive performance, reproductive state affects cognition, with pregnant women often reporting a decline in memory, attention, coordination, and even reading abilities. Scientific investigations into cognitive functioning during pregnancy have tended to adopt a relatively narrow focus, examining memory decline. Despite this relatively narrow focus, investigations into pregnancy-induced memory deficits have yielded equivocal results.

The equivocal results may be partially attributable to the fact that researchers have tended to focus on cognitive impairment; an adaptationist perspective predicts that there are protective mechanisms designed to safeguard the mother and her fetus, including protective cognitive mechanisms that would result in cognitive advantages in some areas. The non-human animal (mainly rat) literature suggests that there are physiological and psychological mechanisms that enhance functioning dependent on

reproductive state. The mitigated stress reactivity and enhanced foraging and predator detection skills observed in rats ultimately promote maternal and fetal fitness. Like rats, women show mitigated stress reactivity. Moreover, since we are a socially obligate species, an adaptationist perspective predicts that women will also show evidence of enhanced cognitive functioning in some aspects of social cognition during pregnancy. The current thesis investigates cognitive functioning in pregnancy and the postpartum period, adopting an adaptationist approach, and focusing on cognitive reorganization as the result of reproductive state. Previous research investigating pregnancy-induced cognitive change in women has often failed to consider adaptive and ecological factors; in the chapters that follow I argue that this lack of a functional theoretical perspective has hindered progress into the investigation of maternal cognition.

I investigated three main questions. First, do pregnancy and the postpartum period result in a cognitive decline in general or specific domains? Second, do pregnant women possess cognitive mechanisms that serve a protective function? Past research suggests that pregnant women are hyper-vigilant to threat cues (Pearson, Lightman, & Evans, 2009), and that cues denoting threat and activating survival mechanisms show a memory advantage (Becker et al., 2010; Otgaar, Smeets, & van Bergen, 2010); I investigated whether pregnant women show an advantage in face recognition in certain contexts. Finally, I investigated whether women exhibit "nesting" behaviours, defined as measurable change in attitudes and behaviours related to parturition.

The research studies described in this thesis provide evidence that pregnancy not only results in a cognitive deficit in some areas (recall, quantitative reasoning, processing

speed), but that it also results in a cognitive advantage in other areas (face recognition, emotion processing). Moreover, the results suggest that there are adaptive mechanisms underlying cognitive performance during pregnancy that serve to protect the mother and her fetus. According to this functional perspective, there is an adaptive reallocation of resources whereby limited cognitive resources are shifted to areas that serve a protective function. As a result, there may be a deficit in cognitive tasks that do not serve an adaptive function (such as word stem completion tasks), or may even be a cognitive deficit in processing speed or other cognitive domains that may negatively affect every day functioning, but also importantly results in a cognitive advantage in tasks that would serve an adaptive function, such as social cognition.

1.1 Historical background of research investigating pregnancy-induced cognitive change

Research has shown that not only pregnant women, but a large percentage of adults, across all age groups, report memory impairment. Although self-reports of a memory deficit are correlated with age (Mendes et al., 2008), physical health (Comjis et al., 2002), and affective status (Cargin et al., 2008), attempts to describe the relationship between subjective and objective performance suggest that subjective perception of memory performance does not predict objective performance (Derouesne et al., 1999; Mendes et al., 2008).

That subjective perception does not match objective performance may explain the puzzling observations regarding pregnant women. Women consistently report a

pregnancy-induced memory deficit beginning in either the second or the third trimester of pregnancy (Casey, 2000; Crawley, Grant, & Hinshaw, 2008; Brindle et al., 1991). Researchers investigating the performance of pregnant women on a variety of objective memory tasks have reported cognitive deficits (Rendell & Henry, 2008; Wilson et al., 2011; Glynn, 2010; de Groot, Vurman, Hornstra, & Jolles, 2006; Cuttler, Graf, Pawluski, & Galea, 2011; Brindle, Brown, Brown, Griffith, & Turner, 1991), no difference between pregnant and non-pregnant women, and even a pregnancy-induced advantage (Christensen, Posyer, Pollit, & Cubis, 1999; Anderson & Rutherford, 2010). These ambiguous results have motivated researchers to consider alternative explanations for the consistent self-reports of memory decline made by pregnant women, such as biased sampling (Christensen, Leach, & McKinnon, 2010) and cultural expectations (Crawley et al., 2008). Others have argued that the perceived pregnancy-induced memory impairment is a by-product of the fact that the changes associated with pregnancy make women more attuned to how they are functioning; increased self-awareness results in increased sensitivity to minor changes in cognitive functioning, and lapses in memory or concentration that would have been ignored in the past are awarded monumental importance.

Researchers investigating cognitive changes resulting from pregnancy in nonhuman animals (mainly rats) have emphasized how reproductive state can influence neural plasticity and provide a cognitive advantage (MacBeth & Luine, 2010; Kinsley & Lambert, 2008). In nonhuman animals the hormones associated with pregnancy, and the stimulation caused by pup exposure, have been shown to promote maternal behaviour

and enhance the function of the maternal brain. In particular the maternal brain is structurally altered and neuroendocrine changes occur, that result in enhanced cognitive functioning, including facilitated problem solving, spatial memory, and learning.

1.2 A functional perspective investigating cognitive change in pregnant women

A functional consideration of the question of cognitive change in pregnancy suggests two main, and not mutually exclusive, possibilities. First, given the dramatic physiological and psychological challenges associated with pregnancy, it is possible that pregnant women are experiencing a measurable pregnancy-related decline in cognition. Such tangible pregnancy-related deficits may impact everyday cognitive functioning to a greater or lesser degree; there may be a subtle cognitive deficit associated with pregnancy that is nevertheless highly salient to pregnant women. When past research has reported a pregnancy-induced deficit, the authors have often concluded that the deficit was mild, that performance still fell well within the range normal functioning, and that every day cognitive functioning shows no evidence of being impaired (Henry & Rendell, 2007; Oynper et al. 2010; Crawley et al. 2008; Christensen et al. 2010). In contrast, there is also limited evidence to suggest that everyday cognitive functioning is impaired in pregnant women. Past research suggests that there is a decline in processing speed associated with late pregnancy (Oynper et al., 2010; Christensen et al., 2010; Anderson & Rutherford, chapter 3). Processing speed has been found to be of critical importance to cognitive performance, and has also been found to include a memory component. In

chapters 2 and 3, I speculate that it may be this impairment in processing speed that explains the common memory complaints made by pregnant women.

The second possibility suggested by evolutionary theory is that focusing on cognitive deficit is masking the reorganization that occurs as the result of pregnancy and the postpartum period. Maternal cognition is complex; rather than emphasizing cognitive deficit, the cognitive reorganization perspective acknowledges that, as a result of the high stakes involved in pregnancy and the postpartum period, there are protective mechanisms designed to keep the mother and fetus safe. According to this perspective, pregnant women re-distribute limited cognitive resources to areas that serve a protective function, and in so doing may incur a deficit in cognitive tasks that are inessential (such as word stem completion tasks).

1.3 Pregnancy-induced social cognition

In chapter 4 I report the results of a study investigating recognition for social information during pregnancy, and show that pregnant women show enhanced recognition of novel faces, and that this is especially true for same-race male faces. Enhanced social processing serves a protective function; vigilance to social cues may warn the mother of harm, including harm from disease and harm from violence.

Faces and emotions are important means of communication, and offer survivalrelevant information that may be particularly important for pregnant women who are not only vulnerable, but also physiologically taxed. Encoding of negative emotional expressions is facilitated in pregnancy: Pearson et al. (2009) report that pregnant women

showed enhanced processing of emotions communicating threat. Navarette, Fessler, and Eng (2007) reported that women in the first trimester are more ethnocentric than women in the second or third trimester of pregnancy, and they interpret their results as suggesting a disease-avoidance mechanism; the first trimester of pregnancy is an especially vulnerable time. Not only is the mother immunosuppressed as a result of accepting the partially foreign fetus, but the fetus is undergoing organogenesis and is therefore extremely sensitive to teratogens. Therefore, vigilance towards out-group members may help to avoid potentially harmful pathogens, and potentially harmful physical confrontations (Navarette, et al., 2007; Hahn-Holbrook, Holbrook, & Haselton, 2011).

There is a large body of literature showing that reproductive experience, including pregnancy and parenting, results in a cognitive advantage in rats (reviewed in Kinsley & Lambert, 2008; and MacBeth & Luine, 2010). There is an emerging body of research suggesting that pregnancy also results in a cognitive advantage in human females. For example, Christensen, et al. (1999) argued that pregnant women should show a cognitive advantage in areas that are relevant to pregnancy, and reported that pregnant women showed a recognition advantage compared to non-pregnant women when the material was relevant to pregnancy. Human females also show a pregnancy-induced advantage in some aspects of social cognition (Pearson, Lightman, & Evans, 2009; Anderson & Rutherford, chapter 5; Navarette, Fessler, & Eng, 2007).

1.3 Nesting behaviours in human females

Because of the high stakes involved with pregnancy and parturition, not only facilitated cognition in the social domain, but also cognitive and behavioural adaptations specific to parturition, should be expected. Whereas nesting has been studied in many animals, nesting in human females has been the primarily the domain of the popular press, where images of women with overwhelming, and perhaps even compulsive tendencies to clean their houses in preparation for birth are the norm. I aimed to reconceptualize the popular notion of "nesting" in women. As is the case with nonhuman animals, I argue that nesting in women serves a protective function.

As will be described in more detail in chapter 5, the literature investigating birth preparation behaviors in many altricial mammals shows that there are two main suites of nesting behaviors: birth-site preparation and social withdrawal. Whereas females in some species give birth in complete isolation, females in other species seem tolerant of group members. Women benefit from birth attendants. Selection pressures acting on women, including bipedalism, encephalization, and fetal emergence patterns, have made birth attendants a nearly obligate feature of parturition in human females (Trevathan, 1988).

1.4 The current research

The following four chapters investigate cognitive and behavioural reorganization resulting from pregnancy and the postpartum period. Chapter 2 is a review chapter that explores the recent findings regarding pregnancy-induced performance in cognition. I conduct a meta-analysis investigating cognitive performance in pregnancy and the postpartum period and then present evidence to suggest that women share the pregnancy-

induced cognitive advantage reported in nonhuman females, at least in terms of some aspects of social cognition. Chapter 3 investigates cognitive change in pregnancy using longitudinal data, tracking pregnant and non-pregnant women from either pre-conception or the first trimester through to the postpartum period. I demonstrate that pregnancy does not result in a general decline in cognitive functioning, but that there are specific cognitive deficits associated with pregnancy, including impairments in quantitative reasoning, processing speed, naturalistic prospective memory tasks, recall, and working memory, and that the early postpartum period is associated with a decline in IO, especially nonverbal IQ. In chapter 4 I investigate whether there is a pregnancy related advantage in face recognition. I show that pregnant women showed enhanced recognition of novel faces, especially same-race male faces. Unrelated conspecific males present a significant threat of harm to women and children (reviewed in Hahn-Holbrook et al., 2011) and outgroup members have been shown to trigger self-protective mechanisms (Becker et al., 2010). Finally, in chapter 5, I examine "nesting" behaviours in women from a functional perspective. I describe the development of the Nesting Questionnaire and use the longitudinal dataset comparing pregnant and non-pregnant women to show that nesting behaviours peak in the third trimester of pregnancy and fall into two categories, social withdrawal and space preparation. Just as facilitated social processing may serve a protective function for the vulnerable mother and fetus, so too may nesting behaviours serve a protective function for women and their newborns, by ensuring that both the social and physical environment offer a sanctuary for parturition. There is some overlap in the literature reviews in chapters 2 and 3, as both focus on

cognitive change as the result of pregnancy. There is also slight overlap in chapters 2 and chapter 4 in the reviews of social cognition in pregnancy.

CHAPTER 2

COGNITIVE REORGANIZATION DURING PREGNANCY AND THE POSTPARTUM PERIOD: AN EVOLUTIONARY PERSPECTIVE

2.1 Preamble

Human and nonhuman animal researchers have taken vastly different approaches to the question of pregnancy-induced cognition; there is a stark contrast between the focus on memory deficit found in the human literature, and the emphasis on neural plasticity and cognitive advantage found in the nonhuman (rat) literature. In rats, compelling evidence suggests that pregnancy and the postpartum period result in cognitive enhancement (reviewed in MacBeth & Luine, 2010), while in humans, evidence suggests that there is a mild cognitive impairment associated with pregnancy and the postpartum period (Henry & Rendell, 2007).

In 2007 Henry and Rendell conducted a meta-analysis investigating memory performance in pregnant and non-pregnant women. Here, I begin by updating the metaanalysis conducted by Henry and Rendell (2007) in light of recent evidence. Next, I briefly describe recent reviews investigating neural plasticity in nonhuman females, demonstrating that, unlike human females, nonhuman females are thought to possess a cognitive advantage as the result of reproductive experience. Finally, I explore the growing body of research that suggests that the cognitive advantage reported for nonhuman females is shared, at least in some domains, by human females.

Protective physiological mechanisms associated with pregnancy and the postpartum period in rats, for example, have also been found to exist in human females:

pregnant women show evidence of mitigated stress reactivity. In rats, mitigated stress reactivity is thought to promote foraging and hunting behaviors in rats. In women, mitigated stress reactivity is also believed to serve a protective function for the fetus (Glynn, Wadhwa, Dunkel Schetter, Chicz-deMet, & Sandman, 2001); prenatal stress has been shown to negatively impact fetal health outcomes (Beydoun & Saftlas, 2008). Women also experience nausea and vomiting in pregnancy (NVP), which is now believed to serve a protective function, in preventing the mother from ingesting teratogens and other potentially harmful food.

More recent evidence suggests that protective mechanisms are not restricted to physiological processes. Pregnant women appear to have an advantage, in comparison to non-pregnant women, in processing some aspects of social stimuli. In the first trimrester of pregnancy, pregnant women are alert to out-group members (Navarette, Fessler, & Eng, 2007), which may serve a protective function in terms of pathogen-avoidance. Pregnant women have also been found to be more vigilant to facial cues, including increased accuracy of emotional expressions (Pearson, Lightman, & Evans, 2009), and enhanced recognition of novel faces (Anderson & Rutherford, 2010).

In this review chapter, I describe how past research investigating cognitive change in human females has focused on memory tasks that do not hold ecological or evolutionary relevance, and argue that, as a result, a clear picture of cognitive change in human females has failed to emerge, despite decades of research. I suggest a new focus, emphasizing cognitive advantage, as is found in the nonhuman literature. The use of new measures that hold ecological or evolutionary relevance, motivated by evolutionary

theory, may help to describe new, robust findings. A promising starting point is social cognition: results suggest that here, as in the rat literature, pregnant females hold a cognitive advantage.

2.2 Abstract

Although many studies have been conducted on reproduction-induced cognitive reorganization, scientists studying human versus non-human animals have taken vastly different approaches. Where the non-human animal research (mainly conducted on rats) has focused on neural plasticity and stressed adaptive advantage in response to the demands associated with pregnancy, parturition and parenting, the human studies have primarily concentrated on pregnancy-induced memory decline. Furthermore, comparing the reproductive effects on cognition between human and non-human animals has been hampered by many contradictory results. The current review examines the recent literature investigating cognitive reorganization as the result of reproductive experience from an evolutionary adaptationist perspective. New evidence suggests that investigations of pregnancy-induced cognitive change in human females would benefit by broadening the question from memory decline to cognitive reorganization, and by extending the study duration beyond pregnancy into the postpartum period. Moreover, adopting an evolutionary perspective and focusing on areas, such as social cognition, where a cognitive advantage would serve a protective function for the mother and her fetus may also help to describe maternal cognition.

2.3 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 an 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, & Turner, 1991; Sharp, 1993; Keenan, Yaldoo, Stress, Fuerst, & Ginsberg, 1998), other studies have found no difference between pregnant and non-pregnant women (Crawley, Dennison, & Carter, 2003; Casey, 2000). Further confusing the picture is still other research that shows specific pregnancy-related advantages in certain memory tasks (Christensen, Posyer, Pollit, & Cubis, 1999; Anderson & Rutherford, 2010).

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, & Hinshaw, 2008), as well as the expectations of medical caregivers (Jackson, Schmierer, & 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 impairment.

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 metaanalysis, 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 the current reproductive phase are facilitated. Moreover, as the demands of pregnancy transition 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 (Profet, 1992; Fessler, 2002; Flaxman & Sherman, 2000; Flaxman & Sherman, 2008), we suggest that turning an adaptationist perspective on the question of pregnancy-induced cognitive change may also yield surprising results.

2.4 A review of the research since Henry & Rendell (2007):

a revised meta-analysis

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 (Onyper, Searleman, Thacher, Maine, & Johnson, 2010; Cuttler, Graf, Pawluski, & Galea, 2011; Rendell & Henry, 2008).

2.5 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 that the studies 1) 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 on the cognitive measures used. 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. Unlike Henry and Rendell (2007) we did not distinguish between implicit and explicit memory, nor did we include storage memory or implicit long-term memory tasks, as recent studies have not reported new results on comparable measures. Prospective memory, which is characterized as the memory for future intentions, such as remembering a previously scheduled doctor's appointment, is in

contrast to retrospective memory, which is simply the memory for past events, was not included in the 2007 meta-analysis, but it is included here, categorized 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 free recall tasks we used the same criteria as Henry and Rendel (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.

Following Henry and Rendell (2007), we excluded studies that reported on subjective and not objective 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. 13 of the original 14 studies included in Henry and Rendell's (2007) meta-analysis are included in the current analysis. The exception is McDowell and Moriarty (2000), who were excluded after implicit long-term memory was excluded (they did not measure any cognitive tasks that were included in the current meta-analysis). An additional eight studies are 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 reasons for the 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 (see Henry and Rendell, 2007). 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 appendix and tables.

2.6 Results

Demographic characteristics

Table 1 portrays the demographic characteristics of the participants in each study. The total sample included in this meta-analysis is 21 studies, consisting of 1288 participants. 522 women comprised the control group (mean age = 29.59 years, SD = 2.76), 746 women comprised the pregnant group (mean age = 29.62 years, SD = 1.75), and 521 women comprised the postpartum group (mean age = 29.77 years, SD = 2.02). Table 1 also portrays education and parity statistics when reported, and also notes if the study reports a significant difference between the pregnant and control participants on any of the demographic variables. 7 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).

(Table 1 about here)

Appendix A 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). Like Henry and Rendell (2007) we used a negative sign to indicate when pregnant or postpartum women performed worse than control participants.

(Table 2 about here)

Working memory

While Henry and Rendell (2007) only had 4 studies with which to evaluate working memory during pregnancy, we had eight studies, doubling the total sample size used. With the slightly broader criteria of also including working memory tasks that are more demanding than Backwards Digit Span, for example, verbal and performance working memory in the Stanford-Binet, 5th edition (SB5) (Roid, 2003), we reported a similar, although slightly smaller negative effect size, than that reported by Henry and Rendell (2007) (-.11 in the current analysis compared to -.16 in the 2007 analysis). Our results in the postpartum period, although again suggesting a mild impairment, suggest more impairment of working memory in the postpartum period compared to the previous meta-analysis (mean r = -.15 in the current analysis compared to mean r = -.10 in the 2007 analysis.)

Recall

The addition of 30% more studies investigating free recall during pregnancy yielded almost identical results to the original analysis (mean r = -.20 in the current analysis versus mean r = -.21 in the original analysis). Whereas the homogeneity statistic Q was significant in the original analysis (29.2), it is no longer significant in our analysis (10.68). As the homogeneity statistic is a test of the variability between the effect sizes across studies, and whether the effect sizes across studies are homogenous or heterogenous, this difference probably reflects the increased sample size used in the current meta-analysis. The addition of only one more study investigating free recall in the postpartum period did little to change the original results (mean r = -.15 in the current analysis versus mean r = -.14). The addition of new studies did little to change the results

of delayed free recall in both the pregnant (mean r = -.25 in the current analysis versus mean r = -.22) and the postpartum case (mean r = -.18 in the current analysis versus mean r = -.14).

Recognition

Henry and Rendell (2007) only had two studies with which to measure recognition memory during pregnancy. We used an additional 3 studies, bringing the total to 5. Like Henry and Rendell (2007) we found that pregnant women performed better than non-pregnant women on recognition memory tasks, and the mean effect size was significant in our analysis (mean r = .14 in the current analysis versus mean r = .09). Unfortunately, to date no studies have investigated recognition in the postpartum period.

Prospective memory

The current study investigated prospective memory tasks that occurred in the laboratory as well as naturalistic prospective memory tasks during pregnancy. We found a very small negative effect of pregnancy for laboratory prospective memory tasks (mean r = -.09), and a significant small to medium effect of pregnancy for naturalistic prospective memory tasks (mean r = -.22).

Processing speed

Five 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 = -.39). Only two studies contributed to the investigation of processing speed during the postpartum period, and here we found a significant, albeit small negative effect of pregnancy (-.20).

General cognition

For general cognitive functioning we found a significant and small effect of pregnancy (mean r = -.13), and a small effect also during the postpartum period (-.16).

Subjective memory

10 studies contributed to evaluating subjective memory performance in pregnant women. Here we found a significant and moderate negative effect of pregnancy (mean r = -.33), which is similar to the negative effect of pregnancy reported by Henry and Rendell (2007) (mean r = -.26). No additional studies had examined subjective memory in the postpartum period, so the mean effect size reported in table 2 is identical to the effect size reported by Henry and Rendell (2007).

Publication Bias

As was the case with the 2007 meta-analysis, the results for all variables which included 5 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.

2.7 Discussion: Revised meta-analysis

1. Is there a small and subtle memory deficit associated with pregnancy?

The first conclusion drawn by Henry & 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 supports the conclusion drawn by Henry and Rendell (2007). Not only is there a pregnancy-induced deficit on some, but not all, memory tasks, our results also suggest that the memory deficit associated with pregnancy is subtle, with effect sizes ranging from -.11 to -.25.

2. 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 required a storage component only (storage memory).

Because there are currently more data available, we were in a better position to evaluate the claim that tasks requiring relatively more effortful processing are more likely to show a pregnancy-induced deficit. 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. Unlike Henry and Rendell (2007) 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), and we were also able to include prospective memory tasks, which Henry and Rendell (2007) argued would be a strong test of the claim that memory processes requiring an executive component are more likely to be impaired during pregnancy.

For working memory, we included not only Backwards Digit Span, but we also included other measures of working memory that require an even more demanding executive processing component. 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. We did not, however, see an increased effect size with regard to working memory tasks. The broader inclusion criteria and the inclusion of more studies resulted in a smaller effect size for working memory. Moreover, the pregnancy-induced deficit that is associated with working memory is very similar to the pregnancy-induced deficit we found in general cognitive processing (-.13), which suggests that the observed deficit in working memory tasks may result from a subtle and overall pregnancy-induced cognitive impairment.

In this meta-analysis we were also able to include prospective memory tasks, both those occurring in the laboratory and those occurring in a natural setting (prospective memory tasks that occur outside the laboratory). Here we found a significant, smallmedium, 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 the laboratory setting, are more sensitive to pregnancy-induced memory impairment.

While the results of the current meta-analysis suggest that naturalistic prospective memory tasks are impaired during pregnancy, it is not clear that it is the cognitive effort involved in these tasks that underlies the observed pregnancy-induced deficit. Especially given that pregnant women show a small and nonsignificant impairment on laboratory prospective memory tasks, and a small-medium significant effect on naturalistic prospective memory tasks, 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. They may instead remember the task, and then, being distracted by commitments that occur outside the laboratory setting, assign the task such low priority compared to the other tasks that occur as the result of pregnancy (preparing the 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 the pregnancy-induced memory deficit and the 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 & Thomson, 1999) - the opposite pattern is observed in pregnant women. Future investigations into how pregnancy influences naturalistic prospective memory, and 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.

Processing speed

Given that several recent studies have recently shown a late pregnancy-induced deficit in processing speed (Christensen, Leach, and MacKinnon, 2010; Oynper et al., 2010; Anderson & Rutherford, in prep; Crawley et al., 2008) we decided to include processing speed as a target variable of interest in the current meta-analysis. We found that processing speed shows 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 found to be correlated with general intelligence (Vernon & 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, & Fein, 2004). Given that the pregnancy-induced deficit in processing speed is the biggest negative effect that we found, and that it maps 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, 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 it is this deficit that is driving the consistent reports of pregnancy-induced cognitive decline made by pregnant women themselves.

3. 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 lack sufficient data with which to accurately evaluate this claim. For example, we are unable to evaluate cognitive performance in recognition and prospective memory during the postpartum period, as no studies met the inclusion criteria. Given the limited evidence available, it seems as though cognitive performance in some areas (working memory, 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 human females: Summary of recent findings

We examined the state of the literature since Henry and Rendell's (2007) metaanalysis, investigating whether their conclusions still hold true today. New evidence suggests that two of their three conclusions may need revision. The results of the updated meta-analysis support Henry and Rendell's (2007) conclusion that pregnant women possess a small and subtle memory deficit in some areas, such as recall and naturalistic prospective memory tasks. Unlike Henry and Rendell (2007) we do not interpret the results of this meta-analysis as suggesting that tasks requiring relatively effortful processing are more likely to be hindered during pregnancy. Although recall tasks were again likely to show a pregnancy-induced deficit, the inclusion of more difficult working memory tasks did not result in a greater pregnancy-induced impairment, and the small negative effect of laboratory prospective memory compared to the large negative effect of naturalistic prospective memory suggests that motivational, as opposed to cognitive, factors may be driving the observed pregnancy-induced performance deficit on prospective memory. Indeed, as will be explained in more detail below, a lack of motivation may be a driving force behind the observed pregnancy-induced deficit on all the cognitive measures. 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, 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 pregnancy and the postpartum period results in a long-lasting cognitive advantage.

2.8 Cognitive reorganization as the result of reproductive state

The animal literature emphasizes that both activities directly related to maternal care, and activities that are not directly related to maternal care, are critical to the survival of the offspring and the 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 neuroanatomic 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. Their work suggests 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 cognitive advantage associated with pregnancy and parenting may be long-lasting in some cognitive domains (Kinsley & Lambert, 2008; MacBeth & Luine, 2010).

We suggest that the narrow focus on memory decline may be responsible for the discrepant conclusions drawn by the human and rat literature, and may be eclipsing potential advantages shared by women. Adopting an evolutionary perspective may yield

important new insights. 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 every day 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 to recognition memory that facilitates cognitive functioning in pregnant women. Of the five studies that contributed to calculating the mean effect size for recognition memory, two took an explicitly evolutionary approach (Anderson & Rutherford, 2010; Christensen et al., 1999), which was not done by any of the other studies investigating cognitive performance in pregnancy. When the effect sizes for only these studies on the tasks that were predicted, based on evolutionary theory, to show a pregnancy-induced advantage are included, the mean effect size moves from .14 to .26. 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, and building hypotheses with the knowledge of these studies may help to further our knowledge of maternal cognitive processes (Pearson, Lightman, & Evans, 2009; Navarette, Fessler, & Eng, 2007; Anderson & Rutherford, 2010). In the next section we show evidence of a pregnancy-induced cognitive advantage in women.

2.9 Protective mechanisms in pregnancy

Perhaps one of the main reasons why the human literature has focused on a pregnancy-induced memory deficit, apart from the subjective accounts of a memory decline made by pregnant women, is the knowledge that pregnancy results in physiological and psychological stress; stress has been shown to negatively impact cognition. Turning again to the non-human animal literature, there is 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: pregnancy and the postpartum period result in decreased neural activation in areas of the brain that are known to underlie stress and anxiety, there exists a specific 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 seems 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 et al. (2004) found that women in later pregnancy perceived major life events as less stressful than women in earlier pregnancy. Women who experienced an acute stressor in the form of a major earthquake in late pregnancy reported the event as less stressful than women who experienced the earthquake in early pregnancy (Glynn et al., 2001).

Attenuated stress reactivity is thought to serve a protective function: maternal stress during pregnancy may negatively impact fetal development at a time when the fetus is vulnerable to perturbations. Stress and anxiety have been shown to have a negative impact on birth outcomes (Rondo et al. 2003; Dole et al. 2003), including increasing birth complications and the chance of a premature birth (reviewed in de Weerth & Buitelaar, 2005). Maternal stress during pregnancy has also been shown to negatively impact postnatal infant development (Davis & Sandman, 2010; Huizink et al. 2003; Brouwers, van Baar, & Popp, 2001; Bergman et al. 2007). A dampened stress response would promote maternal and especially fetal health.

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 (Profet, 1992; Fessler, 2002; Flaxman & Sherman, 2000; Flaxman & Sherman, 2008).

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, and how pregnant women process social information is also dependent on 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 the ingroup 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 et al. (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 is dependent on 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, and 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 that 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 & 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 and instead 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 previously, 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. While 8 of 17 non-pregnant women were involved in a virtual collision on at least one trial, only 1 of 13 pregnant women was involved in a virtual collision. Although Crawley et al. (2008) suggest that the results of this study be interpreted with caution 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.

2.10 General Discussion

Evidence from studies investigating the impact of reproductive experience on non-human and human animals suggests that many females possess species-typical protective mechanisms during pregnancy. 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, and effectively identifying sources of disease, and establishing alliances. Moreover, there is also 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.

Researchers investigating compromised cognitive function as the result of pregnancy, especially in the laboratory setting, have had a difficult time describing cognitive reorganization due to reproductive state. The results of the current metaanalysis suggest that pregnancy does result in a small, but significant impairment in some memory measures, including recall and naturalistic prospective memory. Future research could also investigate alternatives to actual cognitive impairment in order to explain the observed performance deficits. Motivational factors have not been awarded much attention, and it is possible that pregnant women are lacking the motivation necessary in order to perform well on cognitive tasks. Moreover, 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 & Rodin, 1992; Monk et al., 2001). It may be that decreased stress reactivity, which serves a protective function, is also resulting in decreased performance on some cognitive measures. However, it is also true that pregnant women are able to perform equally well or better than nonpregnant women on some cognitive tasks, and that even tasks that show a pregnancyinduced impairment may be buffered by protective mechanisms during pregnancy in order that pregnant women may avoid threat.

Compelling evidence suggests that at least some processing speed tasks are impaired during late pregnancy, coinciding with the timing of self-reported memory

impairments. However, consistent with the adaptationist approach being espoused here, 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 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 in pregnancy despite the general pregnancyinduced impairment in processing speed. This limited evidence also suggests that pregnancy may result in enhanced processing of not only threatening social stimuli, but even non-social threatening stimuli.

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, & 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, it is in some

aspects of social cognition, namely threat detection, that the cognitive advantages being reported so frequently in the rat literature are also observed in human females.

In order to describe maternal cognition not only negative but also positive aspects of cognitive functioning as the result of reproductive experience need to be explored. 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, like has been found in non-human animals, cognitive reorganization as the result of reproductive experience lasts in perpetuity.

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2.12 Tables

Table	1.	De	emogr	aphic	chara	cteris	tics fo	or eac	h of tl	ne studie	s used in	the	e me	eta-analysis
Cuttler et al. (2011)	al. (2008)	Crawley et	Crawley et al. (2003)	Condon et al. (1991)	Christensen et al. (1999)	Christensen et al. (2000)	Casey et al. $(1999)/^{E}$	Casey (2000)	Brindle et al. (1991)	Anderson & Rutherford (in prep)/ ^{I,M}	Anderson & Rutherford (2010)/ ^{C,M}	Study		Table 1. Den
24		25	20	15	35	542	45	26	9	18	38	Z	Nor	nogra
NM		29.1	31.9	II	33.6	I	32.2	33.4	5£	29.1	28.8	Age	1-pregnar	tphic cha
I		$^{\rm H}$	13.7		14.4	I	2.6	II	II	4.18		Education	it control gro	racteristics fo
ı	nulliparous	100%	55%	1	1	1	I		I	33%	I	Parity	dn	r each of the
61		50	21	38	53	76	44	44	32	18	37	Z		studies us
NM		27.7	27.1	27.3	32.4	I	28.9	28.9	27	31.17	29.61	Age	H	ed in the
ı		$^{\rm H}$	14.3	1	14.6	1	2.5	II	II	4.33		Education	regnant grou	meta-analys
·	primigravid	100%	50%	I	1	I	I	I	I	61	1	Parity	dr	<u>r</u> .
		•	Longitudinal study	Longitudinal study	1	188	22 32.5 -	Longitudinal study	1	Longitudinal		N Age Educati	Postpartum gr	
		ı			1	, I	I		I		I	on Parity	dno	

Wilson (2011)/ [^]	Sharp et (1993)	Rendell Henry (2007)	Onyper (2010)	Keenan (1998)	(1999)	Janes et	Henry & Sherwin (2011)	Harris (1996)	Eidelma al. (199)	De Groc al. (200	De Groc al. (200)
et al	al.	&	et al	et al		al.	- 6		3) 3)	5) 5)	3)
. 24	19	20	.25	. 10		20	21	20	20	50	57
29.3	27.3	31.6	29.0	34.9		32.4	28.8	29.1	22	30.6	30.5
87.5	2.5	14.2	16.4	I		3.3	18.4	I	13.4	4.4	4.4
*25% mother		70%	76% mothers	d =	nulliparous	100%	ı	I	I	30%	*71 total pregnancies
's 46	48	20	21	10		20	55	20		57	71
30.8	28.5	32	29.5	32.5		30.2	31.4	29	1	29.9	29.5
76.9	2.3	13.3	15.9	I		2.8	18.5	1	I	4.1	3.9
50.6% mothers		70%	81% mothers	II.	primigravid c primiparous	100%	ı	I	I	40%	57 total pregnancies
•		Longitudinal		Longitudinal study	or	20 30.4 2.4	Longitudinal study	Longitudinal study	100 27.3 13.9	Longitudinal study	

= 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.

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

/^C Pregnant participants reported having significantly more children than non-pregnant participants.

)/^E Pregnant participants reported significantly higher emotional well-being than nonpregnant participants.

/^H Non-pregnant participants reported significantly higher education than pregnant participants. (In the Crawley et al. 2008 study the two groups were not significantly different on verbal intelligence as indexed by the speed and capacity of language-processing test (SCOLP)).

/^I Pregnant women reported significantly higher household income than non-pregnant participants.

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

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

* signifies a significant difference between pregnant and non-pregnant participants.

			1	Summar	y stati.	stics			
	М	Lower R	Upper R	Z	Tau	SE	Κ	Ν	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	1621	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	-	-	-	-	-	-	-	-	-
Lab.Prospective									
Memory									
Pregnant	09	24	.06	1.14	.00	.01	3	177	.02
Postpartum	-	-	-	-	-	-	-	-	-
Nat. 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

Table 2. Summary statistics for the meta-analysis, comparing 1) pregnant and non-pregnant women, and 2) postpartum and non-postpartum women.

•p < .10, * p < .05, **p < .01

2.13 Appendices

Appendix A. List of studies that were not included in 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 et al. (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.
Jarrahi-Zadeh et al.	Did not include a pregnant/postpartum control group; did not report data
(1969)	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 & 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 & Redman	Did not report data on an objective measure
$\frac{(1991)}{\text{Dereases at al} (2004)}$	Did not include a presenent/negtportum control group
$\frac{\text{Parsons et al. (2004)}}{\text{Parsons et al. (2004)}}$	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 & Patek (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 pregnant/postpartum control group
Swain et al. (1997)	Data reported was collapsed across cognitive domains (memory,
	attention, psychomotor)
Vanstone & Watson (2005)	Did not include a pregnant/postpartum control group

		Pr	egnant	t/nostn	artum	(PP) g	roun				Mer	norv N	Teasure				
Study	CN	PN	1stA	2 ^{ndA}	3rdA	1-3 ^A	4-6 ^A	~6 ^A	Exec.	FR	DFR	Rec.	Lab. Pros	Nat. Pros	Subj.	Proc. Speed	Ger Cog
Anderson & Rutherford (2010)	239	39	10	44	46	I	I	ı	ı	ı	ı	.31	ı	ı	I		04
Anderson & Rutherford	218	18	0	100		ı	ı	I	42	ı	I	ı	ľ	'	'	26	25
(in prep)	18 ^{b, RT}	18 ^b	0	100		ı	·	ı	.08	ı	I	ı	ı	'	ı	ı	ı
	18 ^{b, RT}	18 ^b	0	100		I	ı	I	25	•	I	'	ı	ı	ı	ı	1
	18 ^{b, RT}	18 ^b	0	0	0	100	T	I	I	I	I	T	I	I	ı	ı	4)
	12 ^{b, RT}	10 ^b	0	0	0	61	I	I	29	I	I	I	I	I	I	14	ı
	12 ^{b, RT}	10 ^b	0	0	0	61	I	ı	58	I	I	I	I	I	I	I	I
	12 ^{b, RT}	10 ^b	0	0	0	61	I	ı	14	I	I	I	I	I	I	I	I
Brindle et	9	4	4	0	0	0	ı	ı	ı	44	ı	.79	ı	ı	ı	ı	ı.
al. (1991)	96	S	S	0	0	ı	ı	ı	ı	13	ı	.62	ı	ı	ı	ı	ı
	96	6	0	6	0	ı	ı	ı	ı	66	ı	.30	ı	ı	ı	ı	·
	9b	S	0	0	100	ı	ı	1	ı	.17	ı	08	ı	ı	ı		ı
	96	5	0	0	100	1		1	ı	71	ı	.31	1	ı	ı	ı	ı
	96	7	0	0	100	'	'	'	'	57	'	22	'	'	'	ı	'

Appendix B. Effect sizes for each dependent variable for all the studies included in the metaanalysis.

et al. (19	Christens				et al. (20	Christens		(1999)	Casey et											(2000)	Casey	
99) <u>35 b</u>	sen 35	542 ^b , rt	542 ^{b,}	RT	10) <u>542 b</u> ,	sen 542	45 ^b	45 ^b	al. 45	24 ^{b, R}	24	96										
d 53 p	53	112	76		46	30	22	22	22	T 18 ^b	г 18 ^ь	г 18 ^ь	г 18 ^ь	Г 18 ^b	г 18 ^р	Г 18 ^b	18	32 ^b				
0	0	0	0	psed	Colla	Colla	•	18	9	ı	·	·	·	·	·	0	0	0	0	100	100	Colla
40	40	ı	1		2	upsed	1	45	9	1	·	ı	·	ı	ı	0	0	100	100	0	0	psed
0	0	ı	ı			'	•	36	82	1	1	1	1	1		100	100	0	0	0	0	
·	ı	ı	I		·	•				0	0	0	0	100	100	'	•	•	•	'	'	
I		Z	Z			ı	Ζ	ı	ı	0	0	100	100	0	0	'	ı	ı	ı	'		•
I		ı	ı		•		•		'	100	100	0	0	0	0		•		•			
ı		.05	14		12	.04	21	18	13	04	.23	.08	.01	.07	.04	06	.04	.08	.00	.00	.14	
ı	·	.08	13		01	.04	.07	.15	.31	ı	•	•	•	•	•	•	•	•	•	•	•	ı
ı	•	.08	.11		04	.02	ı	•	I	ı	•	•	•	•	•	•	•	•	•	•		ı
0	0.09	ı			ı	·	ı	·	I	I	ı	·	·	ı	·	·	ı	ı	ı	·		ı
,	ı	ı			•	'	·	'	ı	·	•	•						•			•	ı
•	I	ı			ı	ı	ı	·	12°													ı
ı	I	ı			ı	I	37	17	31	I	.00	·	.00	·	.00		.00	ı	.00		.00	40°
•	ı	02	06		05	05	I	I	I	I	·	·	·	·	·		ı	I	ı			I
1	I	ı			'	I	I	I	1	0.11	0.09	0.2	0.19	0.06	0.06	0.22	0.04	0.01	0.24	0.2	0.16	I

	35 ^b	53 ^b	0	40	0	•	ı	'	•	•	'	-0.14		ı	'	ı	ı	1
	35 ^b	53	0	0	60	I	ı	ı	'	ı	I	0.36	I		ı		'	I
	35 ^b	53 ^b	0	0	60	I		ı	ı		ı	0.18	I	'	I	I	ı	
	35 ^b	53 ^b	0	0	60	ı	ı	ı	ı	ı	I	0	I	ı	I	ı	'	
Condon et	15	38	0	0	100	ı	ı	ı	ı	33		'	'	'	1	'	ı	1
al. (1991)	15 ^{b, RT}	38 ^b	I	I	I	100	0	0	'	25	ı	•		ı		'	ı	I
Crawley et	20	21	Colla	ıpsed	I	1	•	•	ı	16		•	'	'	54	'	ı	
al. (2003)	18 ^{b, R}	г 18 ^b	Colla	-		1	·	ı		00	'	'	'		.00	ı	ı	
	1 / 1 / 1		psed				1			3								
	16 ^{b, K}	16 ^b	C	'	'	•	z	•	•	23	'	ı	ı	ı	.20	ı	ı	
	14 b, R	Г 15 ^b	0	•	•	•	z	•	•	.17	1	ı	ı	ı	05	·	I	
Crawley et	25	50	0	100	0	•	•	•	•	15	04	ı	I	I	05	72	ı	
al. (2008)	25 b	50 ^ь	0	100	0	•	•	•	•	•	'	ı	ı	ı	62	ı	I	
	25 ^b	50	0	0	100	1	•	•	•	34	25	ı	ı	1	41	67	I	
	25 ^b	<u>ө 05</u>	0	0	100	•	•	•	•	•	'	ı	ı	ı	62	•	I	
Cuttler et al	.24	61	20	40	40	•	•	•	12	08	1	.13	01	23	33	I	I	
(2011)	^d 05	9.4 p	20	40	40	1	1	•	'	035	ı	ı	15	04	48	I	I	
	<u> 4</u> 05	57 b	20	40	40	1	ı	ı	ı	136	I	I	I	20	34	'	ı	
de Groot et al. (2003)	57	71	100	0	0	ı	ı	ı		25	26		'		'	13	ı	1
de Groot et	50 ^b	d 75	0	100	0	I	ı	ı	ı	18	16	ı		•	·		ı	
al. (2006)	<u> 60 р</u>	57 b	0	0	100	•	1	1	1	15	08	I	I	ı	ı	I	ı	
	50 ^ь	57 b	1	1	I	0	0	100	ı	23	19	1		1	•	1	•	•
																		1

	Onyper et al. (2010)			al. (1998)	Keenan et	(1999)	Janes et al				(2012)	Sherwin	Henry &		(1996)	Harris et a		al. (1993)	Eidelman
25 ^b	25	10 ^{b,]}	10 ^{b, 1}	10 ^b ,	10	20 ^b	. 20	21 b,	21 °,	21 ^b ,	21 b,	21 ^b ,	21	20 ^b ,	20 ^b ,	al. 20	20 ^b	20 ^b	et 20
21 ^b	21	RT 10 ^b	RT 10 ^b	RT 10 ^b	10	20	20	RT 55 b	KI 55 0	RT 55 b	RT 55 b	RT 55 b	55	RT 20 ^b	^{RT} 20	20	35	36	29
0	0	ı	0	0	100	I	2	I		'	0	0	0	'	ı	0	ı	1	·
100	100	I	0	100	0	ı	8	I		'	0	0	0	•	I	0	ı	ı	ı
		I	100	0	0	ı	10	I	•	'	100	100	100	•	I	100	ı	'	'
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CN sample of control participants; PN Sample of pregnant or postpartum participants. Cognitive 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.

CHAPTER 3

WOMEN SHOW SPECIFIC COGNITIVE DEFICITS ACROSS PREGNANCY, AND GENERAL COGNITIVE DECLINE POSTPARTUM

3.1 Preamble

As described in chapter 2, pregnancy-induced cognitive reorganization in women is not yet fully understood. While there is evidence that pregnancy may result in compromised memory functioning, there is also evidence to suggest that pregnancy may result in a cognitive advantage, at least in some aspects of social cognition. In chapter 2, I urged researchers investigating pregnancy-induced cognitive change in women to investigate pregnancy-induced cognitive advantage, and base investigations in evolutionary theory. Before attention is turned to cognitive advantage, however, understanding pregnancy-induced patterns of cognitive performance in general and specific domains may be warranted. The fundamental aim of the study in this chapter is to describe cognitive performance in pregnancy and the early postpartum period. In an attempt to describe how reproductive state impacts cognition several issues associated with past research were addressed. First, research investigating pregnancy-induced cognitive decline has examined a wide variety of distinct memory processes, and employed a wide variety use of distinct measures, with equivocal results. Moreover, the interpretation of the equivocal results is challenging: do the equivocal results suggest that pregnant women have a distinctive failure in this type of verbal paragraph recall and not this other type of verbal memory recall, for example, or do the equivocal results show that pregnancy does not predict performance differences on this task? In order to test

cognitive performance patterns associated with pregnancy in general and specific cognitive domains, I used standardized IQ tests. The use of standardized IQ tasks presents several advantages. IQ tests are comprised of different tasks belonging to either the nonverbal (performance) or verbal domain. Hence, performance differences between pregnant and non-pregnant participants may either be observed in general, or in specific domains. Further, scoring of standardized IQ tasks also controls for age, a factor that could be confounding the results of previous studies (for example, digit span backwards has been tested quite frequently with equivocal results). Finally, should pregnancy predict performance on any of the IQ tasks, the results should also be a simple matter for replication. Hence, although standardized IQ tasks are not ideal for investigating cognitive change in pregnancy, as they hold little ecological validity and are not based on evolutionary theory, they are optimally suited for investigating pregnancy-induced cognitive performance in a variety of domains.

A second issue associated with past research is that few studies investigating cognitive change in human females have adopted a longitudinal approach, and even fewer have reported a pre-conception baseline. While it is true that a longitudinal approach to cognitive change in pregnancy holds disadvantages as well as advantages, given the relatively small samples that are typical of research investigating pregnancy cognition, a lack of studies that have examined within-subject changes over time makes it difficult to determine whether reported differences between pregnant and non-pregnant women are due to pregnancy, or other factors. A paucity of studies employing a repeatedmeasures design also makes it difficult to describe how cognitive performance changes

over time as the result of pregnancy. Pre-conception data is even more useful, as performance patterns comparing the same woman before and after she has become pregnant would demonstrate when pregnancy impacts cognitive functioning. As practice effects are always a concern with longitudinal data, a non-pregnant control group shows what sort of performance increases could be expected as the result of repeated testing, making it more appropriate to interpret observed performance differences in the pregnant group as pregnancy-induced.

Here, I report longitudinal data tracking women from either pre-conception or the first trimester of pregnancy through to the early postpartum period, testing non-pregnant women at similar time intervals. The results show distinct cognitive performance associated with reproductive state. Non-pregnant women showed a general trend towards performance increases over time (indicative of practice effects). Like non-pregnant women, pregnant women showed a slight increase in general cognitive functioning throughout pregnancy. However, they also showed a performance deficit in some areas, including processing speed, compared to non-pregnant women. In the early postpartum period the changes in cognitive functioning were the most pronounced: while processing speed had nearly returned to pre-conception/first trimester levels by the first two months postpartum, women in the early postpartum period showed a general drop in IQ, especially nonverbal IQ, and tasks requiring abstract reasoning, compared to women in the non-postpartum group. I conclude that while pregnancy is a time of cognitive reorganization, and that the pregnancy-induced deficit in processing speed should not be underestimated, the results suggest that it is in the early postpartum period when women

are caring for new infants that cognitive reorganization associated with motherhood is the most intense. I further speculate that it may be the early preoccupation with their newborn that is causing the compromised performance, as opposed to an actual drop in cognitive functioning.

3.2 Abstract

Previous research investigating cognitive change during pregnancy has not determined whether there is a decline in general, or specific, cognitive functioning as the result of pregnancy. Here, we present longitudinal data comparing pregnant and nonpregnant women through the early postpartum period. We report a significant decline in functioning, especially in nonverbal subtasks, during the early postpartum period. In contrast, our results suggest that pregnancy does not result in a general decline in cognitive functioning, but that a specific subset of cognitive processes, including mathematical reasoning and processing speed, may be impaired during pregnancy. Furthermore, we report that cognitive performance in pregnancy and the postpartum period are distinct.

3.3 Introduction

The claim that pregnancy negatively impacts cognitive functioning is widely accepted, with accounts of pregnancy-induced cognitive deficits, or 'Baby Brain', commonplace in the popular press. It is perhaps not surprising that this notion has such appeal. Pregnant women consistently report a host of cognitive deficits including lapses in memory, concentration, coordination, and attention (Stark, 2000; Crawley, Grant, & Hinshaw, 2008). Given the cognitive deficits reported by pregnant women, along with the physiological and psychological challenges associated with pregnancy, a pregnancy-induced deficit in cognitive functioning seems evident. However, attempting to characterize pregnancy-related deficits through objective measures has proven to be challenging, with researchers often reporting equivocal results.

The search for a pregnancy-induced memory deficit has been complicated by the fact that memory is not singular; instead, it is comprised of several distinct processes. Moreover, these distinct processes may be measured in a variety of ways, many of which have been used by researchers investigating cognition in pregnancy. For example, Sharp (1993) reported that pregnant women showed a deficit compared to non-pregnant women in an implicit and explicit verbal recall task, but found no deficit in verbal or picture recognition. Janes, Casey, Huntsdale, and Angus (1999) reported no difference between pregnant and non-pregnant women on any of their implicit or explicit measures; they did report a pregnancy-related deficit on working memory (Digit Span – Backwards). The null findings reported by Janes et al. (1999) on their implicit memory word-stem measure are in contrast to the pregnancy-related deficit reported by Brindle, Brown, Brown,

Griffith and Turner (1991), while their pregnancy-induced deficit in working memory (Digit Span – Backwards) is in contrast to the null results reported on the same task by Onyper, Searleman, Thacher, Maine, and Johnson (2010). Hence, even when researchers used the same, standardized measure, they sometimes failed to find consistent results. Given that pregnancy studies generally employ small samples, and that pregnancyinduced memory effects appear to be small (Henry & Rendell, 2007), these ambiguous results are perhaps to be expected.

The search for pregnancy-induced cognitive change in human females may also be hindered by the lack of a functional perspective. An advantage that the nonhuman literature holds over the human literature is that it tends to adopt an evolutionary approach to the question of pregnancy-related cognitive change, which may help to motivate research design. Rodent studies have shown that pregnancy and the postpartum period result in extensive cognitive reorganization (reviewed in MacBeth & Luine, 2010; and in Kinsley & Lambert, 2006), and that there are cognitive advantages associated with pregnancy and the postpartum period in female rats. For example, spatial cognition is enhanced in pregnant rats and may promote pup survival by facilitating foraging and predator-defense behaviors (MacBeth & Luine, 2010). The pregnancy and postpartum induced cognitive advantage often reported in rodent studies is in contrast to the focus on cognitive decline found in the human literature.

Further complicating investigations into pregnancy-induced cognitive change is the fact that cognitive and physical challenges vary across pregnancy. The first trimester, for example, is a critical time for fetal development, whereas the third trimester is

associated with a stark increase in body mass for both the mother and the fetus. It is possible that cognitive priorities could change across the first, second, and third trimesters. Subjective accounts of cognitive change in pregnancy suggest that deficits are likely to arise in the second or third trimester of pregnancy (Crawley, Carter, & Dennison, 2003; Casey, 2000; Crawley et al., 2008; Brindle et al., 1991). However, the majority of studies investigating cognition in pregnancy have compared pregnant and non-pregnant women at only one time point. A cross-sectional approach to pregnancy-induced cognitive change that has occurred in the third trimester, for example, may be masked by performance of women in the first trimester.

Given that the majority of studies investigating pregnancy-induced cognitive change in human females have used relatively small samples, longitudinal studies offer important insight into pregnancy-induced cognitive change; longitudinal studies may be more accurate than cross-sectional studies in attributing cognitive performance differences to pregnancy, as opposed to other factors. Some existing longitudinal studies suggest that late pregnancy is more likely to show a cognitive disadvantage than early pregnancy (Keenan, Yaldoo, Stress, Fuerst, & Ginsberg,1998; de Groot, Adam & Hornstra, 2003). In contrast, Crawley et al. (2003) reported no differences between pregnant and non-pregnant women on any of their objective measures at any time point in pregnancy or the postpartum period.

Practice effects are typical of repeated testing and pose a challenge for the interpretation of longitudinal data. If non-pregnant and pregnant women are shown to

improve at similar rates, then no effect of pregnancy can be claimed. However, if pregnant and non-pregnant women show a different pattern of results over time, pregnancy may explain the performance differences. Studies that have failed to include a non-pregnant control group (see Mickes, Wixted, Shapiro, & Scarff, 2008; Stark, 2000) make it difficult to interpret whether reported results are due to pregnancy effects or other factors. Along with the use of a non-pregnant control group, employing a pre-conception baseline would also be useful in determining the impact of pregnancy on cognition. Casey (2000) is one of the few who included a pre-conception group. He found no effect of pregnancy on any of his objective measures, at any point in pregnancy and into the postpartum period.

Henry and Rendell (2007) conducted a meta-analysis that made use of fourteen studies that included a non-pregnant control group. They were able to investigate the results on several distinct tasks and their analysis helps to describe cognitive change in pregnancy. They concluded that there is a real, although limited, cognitive deficit associated with pregnancy. They also concluded that while pregnancy does not negatively affect all aspects of memory and cognition (hence the contradictory results), tasks that require effortful or executive processing, such as free recall and Digit Span – Backwards, are more likely to show a pregnancy-induced disadvantage. Executive cognitive processes require more effort, and according to Henry and Rendell (2007), working memory tasks place demands on executive cognitive processes, such as "... strategic, self-initiated retrieval, monitoring, and information updating" (p. 799). Executive processing in relation to working memory has also been defined as tasks that

require both a processing and a storage component, such as is the case in Digit Span – Backwards and Arithmetic (WAIS-III). Digit span – Backwards requires a processing component in that participants need to recite, from memory, a string of words in reverse order from which they were presented; Arithmetic (WAIS-III) requires that the participant respond to mathematical questions, from memory, without the use of pen and paper, hence requiring a processing component (solving math problems) in addition to a memory component (remembering the key facts of the question in order to answer correctly). These tasks are in contrast to Digit Span- Forwards (WAIS-III) which includes a storage component only. The final conclusion that Henry and Rendell (2007) gleaned from their analysis is that cognitive performance is similar during pregnancy and the postpartum period.

Three research teams recently tested Henry and Rendell's (2007) conclusion that areas of effortful processing are most likely to be hindered by pregnancy. Cuttler, Graf, Pawluski, and Galea (2011) reported that while pregnant women performed on par with non-pregnant women on a variety of memory tasks, naturalistic prospective memory tasks that required the most effort showed a pregnancy-related decline. They interpreted their results as supporting the conclusions drawn by Henry and Rendell. Rendell and Henry (2008) also reported that naturalistic prospective memory tasks are impaired during pregnancy, arguing that this supports the conclusion that tasks requiring more effort are more likely to be hindered during pregnancy. In contrast, Oynper et al. (2010) examined executive functioning, a broad range of memory tasks, and the relationship between mood, physiological symptoms, and cognitive functioning in pregnant and non-

pregnant women. They found no evidence of impaired executive functioning in their pregnant participants, nor did they report a general decline in cognitive ability as the result of pregnancy. They did find that pregnant women performed worse than non-pregnant women on Digit Symbol-Coding, a speed of processing task.

Alternative explanations for the consistent subjective reports of pregnancyinduced cognitive decline in light of the ambiguous results when testing objective memory processes include biased sampling and hyper-sensitivity to cognitive change. Christensen, Leach, and MacKinnon (2010) argue that biased sampling helps to explain the equivocal findings, and suggest that emotional or other unexplored factors may explain the fact that pregnant women often report a cognitive deficit. Crawley et al. (2003) argue that while minor variations in cognitive functioning are highly salient to pregnant women who have become hypersensitive to how their bodies and minds are functioning, they do not reflect substantial change in cognitive performance, thus explaining the consistent self-reports, and inconsistent objective accounts, of a pregnancy-induced cognitive decline.

Current study

To our knowledge, no studies have yet run a full-scale IQ test comparing pregnant and non-pregnant women in a longitudinal study spanning pregnancy and the postpartum period. Here, we used standardized IQ tests in order to measure changes in memory, executive processing, and general cognitive processes in pregnancy and the postpartum period. We also sought to analyze whether tasks requiring executive processing (Arithmetic, Working Memory) were more likely to show a pregnancy-induced

disadvantage. Based on past research, we did not predict a general pregnancy-induced decline in cognitive performance, as past research has shown that while specific pregnancy-induced deficits may be detected (free recall, processing speed) no general decline as the result of pregnancy has yet been reported (Onyper et al., 2010; Anderson & Rutherford, 2010; Wilson et al., 2011; Casey, 2000). However, it is possible that difficulties in focusing attention during the third trimester (Stark, 2000) may yield a cognitive disadvantage in late pregnancy.

3.4 Methods

This study was part of a larger project examining cognitive change in pregnancy conducted at McMaster University. The IQ tests were run approximately 60 minutes into sessions that lasted, on average, 2.5 hours; participants spent the first 60 minutes completing a variety of tasks, including a nesting questionnaire, two tasks of social cognition, and an object pop-out task. Participants were permitted to take a break during the IQ testing sessions, at a break between tasks, if they so desired. Test sessions occurred either at McMaster University, or in the participants' homes, based on participant preference. All testing sessions occurred in a quiet place, away from the distraction of the telephone, television, and family members.

Participants

In total 19 pregnant and 19 non-pregnant women completed four testing sessions. We obtained partial session data for an additional 11 women in the pregnant group and 6 women in the non-pregnant group. One pregnant woman was excluded from the analyses

since her full IQ scores were over 2 standard deviations above the mean during the 2nd trimester and postpartum testing sessions and over 3 standard deviations from the mean in the 1st and 3rd trimester testing sessions. High-IQ individuals exhibit a non-normative learning pattern that exaggerates practice effects (Kulik, Kulik, & Bangert, 1984). One non-pregnant participant was excluded since English was her second language, and it became clear as testing sessions progressed that her language skills made her scores impossible to interpretable. Excluding these two participants brought the sample used in our analyses to 18 pregnant and 18 non-pregnant women.

The four testing sessions occurred roughly every 12 weeks (pregnant mean intersession interval: 11.95 weeks, range 8-19) and included the first trimester (mean weeks pregnant = 11.6 SD = 2.2), the second trimester (mean weeks pregnant = 25.2, SD = 1.0), the third trimester (mean weeks pregnant = 35.4 SD = 1.4), and the postpartum (mean weeks postpartum = 7.6 SD = 2.7). Non-pregnant women were tested at matched intervals (non-pregnant mean inter-session interval: 12.54 weeks, range = 8-19). Six women in the pregnant group and four women in the non-pregnant group also completed a preconception (or non-pregnant equivalent) session.

Procedures

Cognitive performance was measured with the full scale of the Wechsler Adult Intelligence Scale (3rd Ed) (WAIS-III) (Wechsler, 1997), and the Stanford-Binet Intelligence Scales (5th Ed) (SB5) (Roid, 2003a). Participants were randomly assigned to either Group 1, which started with the WAIS-III, or to Group 2, which started with the SB5. Participants alternated between the WAIS-III and the SB5 in subsequent sessions in

order to reduce practice effects that can occur when standardized tests are taken repeatedly (Kulik et al., 1984). Thus, there were two sub-samples of participants who completed the tasks, those who completed the WAIS-III at the 1st and 3rd trimester testing sessions and completed the SB5 at the 2nd trimester and postpartum testing sessions, and those who completed the SB5 at the 1st and 3rd trimester testing sessions and completed the WAIS-III at the 2nd trimester and postpartum testing sessions. Although the WAIS-III and the SB5 are standardized to have a mean score of 100, and both have similar performance classifications, for example a classification of "average" is 90-109 for both scales (Weschler, , 1997, p. 25; Roid, 2003, p. 50), women in both groups reported that the SB5 was a more challenging test than the WAIS-III, and participants scored higher on the WAIS-III (mean score = 104.93, *SD* = 7.12) than the SB5 (mean score = 98.86, *SD* = 11.06, *t*(34) = -2.00, *p* = .05) at first administration (Table 1).

(Table 1 about here)

As it is common for researchers investigating cognition in pregnancy to obtain selfreports on current health (Rendell & Henry, 2008; Sharp, 1993; Casey, 2000), sleeping patterns (Casey, 2000; Janes et al., 1999, Rendell & Henry, 2008), and mood (Janes et al., 1999; Sharp, 1993), we also obtained energy and mood reports at each test session. As is typical with past research, we used a 5 point Likert scale (Casey, 2000; Sharp, 1993; Janes et al., 1999; Rendell & Henry, 2008). Subjective energy was measured from 1 =very tired to 5 = very energetic. Anxiety was measured from 1 = very anxious to 5 = not at all anxious. Mood was measured from 1 = very depressed to 5 = very happy. These measures were taken approximately 20 minutes before the administration of the IQ test.

Statistical Analysis

To test pregnancy effects on the FSIQ (Full scale IQ), VIQ (Verbal IQ), and PIQ (Performance IQ) we used three repeated measures ANCOVAs with pregnancy as the between levels factor (2) and test number (1,2,3) as the within-subjects factor (3). Parity was included as a covariate because there is evidence from the nonhuman animal literature that parity impacts cognitive functioning (reviewed in MacBeth & Luine, 2010). We compared the multigravid and primigravid pregnant participants and found no significant differences on any of our demographic variables between these two groups of women. Because pregnancy and the postpartum period are distinct reproductive phases, and may have distinctive effects on cognition, we analyzed test sessions that occurred during pregnancy and the postpartum period (and non-pregnant equivalent test sessions) separately. Results for FSIQ, PIQ, and VIQ were analyzed separately.

In order to examine early pregnancy-related and postpartum performance effects on the subscales we compared pregnant and non-pregnant performance at both the 1st trimester (or equivalent) and postpartum test session separately. (First trimester - WAIS-III subscales: pregnant n = 8, non-pregnant n = 6; SB5 subscales: pregnant n = 10, nonpregnant n = 12; Postpartum – WAIS-III subscales: pregnant n = 10, non-pregnant n = 12, SB5 subscales: pregnant n = 8, non-pregnant n = 6).

Because previous research has shown that pregnant women are more likely to report a pregnancy-induced cognitive deficit in the second and third trimester of

pregnancy, we collapsed across the 2^{nd} and 3^{rd} trimester test sessions and analyzed the performance of each participant (either pregnant or non-pregnant) on each subscale in order to characterize cognition in late pregnancy. To test performance differences on the subscales we performed a multivariate ANCOVA with group as the between-subjects factor and parity as a covariate. Subtasks in the verbal and non-verbal domain for both the WAIS and the SB5 were analyzed separately and the Bonferonni correction for multiple tests was used for each block of tasks (WAIS verbal tasks= 6, WAIS non-verbal tasks = 5, SB5 verbal tasks = 5, SB5 nonverbal tasks = 5).

In the pregnant group, eleven women signed up preconception and of these, eight continued with the study. Six of these eight women participated from preconception to postpartum without incident. One of the six missed her third trimester session (she gave birth early), and the second was excluded from analyses as an outlier. Four women in the non-pregnant group also completed a "pre-conception" session. Hence, a subset of the pregnant (n=6) and the non-pregnant participants (n=4) completed a pre-conception (or non-pregnant equivalent) session, and we ran statistical analyses on these participants in order to examine how cognitive performance fluctuates across preconception, pregnancy, and into the postpartum period. Small sample size exaggerated the difference between the SB5 and WAIS-III, hence, we only tested sessions that include the same test. This left us with 3 discrete time points including preconception, the 2nd trimester, and the early postpartum period. We examined pregnant and non-pregnant participants separately using a repeated-measures ANOVA with test number as the within-subjects factor (3).

Finally, as we found significant differences in both income and relationship status

between our pregnant and non-pregnant participants (see below) we repeated the above analyses on the cognitive measures excluding women from the pregnant group who were not in a committed relationship, resulting in a sample size of 12 non-pregnant women and 18 pregnant women. There were no significant differences between these smaller groups on any of the demographic variables, nor did analyzing this subset of non-pregnant women change any of the significance levels reported below.

3.5 Results

Group demographics

The pregnant and non-pregnant women did not differ significantly in age (pregnant mean age = 31.2 years, SD = 3.7; non-pregnant mean age = 29.1 years, SD = 4.7, t(34) = -1.49, p = n.s.), education (pregnant mean education = 4.3, SD = 2.0; non-pregnant mean education = 4.2 years, SD = 1.4; 4 representing a university degree, t(34) = -.27, p > .05), race (pregnant mean = 83% white, non-pregnant = 78% white, χ^2 (1, N = 36) = 0.18, p > .05), employment status (pregnant employed = 72% full time; non-pregnant employed = 77% full time, χ^2 (1, N = 36) = 2.84, N = 18, p > .05) and parity (pregnant participants: 61% mothers; non-pregnant: 33% mothers, χ^2 (1, N = 36) = 2.79, N = 18, p > .05). Pregnant participants were significantly more likely to be in a committed relationship (married or living common-law)(pregnant: 100% committed; non-pregnant: 67% committed, χ^2 (1, N = 36) = 7.2, N = 18, p = .01), and had higher household income (as measured in blocks: 0 = \$0.9,999; 1 = \$10,000-19,999; 2 = \$20,000-29,999; 3 = \$30,000-39,999; 4 = \$40,000-49,999; 5 = \$50,000-74,999; 6 =

\$75,000-99,999; 7 = \$100,000-149,999; 8 = \$150,000+) than non-pregnant participants (pregnant mean household income = 6.2 ± 1.2 ; 6 = \$75,000-\$99,000; non-pregnant mean household income = 4.7 ± 2.3 ; 4 = \$40,000-\$49,999, t(34) = -2.58, p = 0.01). See Table 2 for complete participant demographics.

(Table 2 about here)

Differences between groups across time on FSIQ, PIQ and VIQ

Figure 1 portrays the pattern of FSIQ scores across pregnancy and into the postpartum period for pregnant and non-pregnant participants. The main effects of pregnancy, F(1,33) = 2.53, p > .05, and test number, F(2,66) = 1.23, p > .05, were not significant; nor was the test number by pregnancy interaction, F(2,66) = .16, p > .05. When we compared postpartum and control participants the postpartum women scored significantly lower than non-postpartum women on FSIQ, F(1,33) = 7.11, p = .01.

(Figure 1 about here)

Figure 2 portrays the pattern of VIQ performance over time for pregnant and nonpregnant participants. For VIQ, we observed no main effects (test number, F(2,66) = .59, p > .05; and pregnancy, F(1,33) = 1.76, p > .05. Across pregnancy no significant changes were found; the test number by pregnancy interaction was not significant, F(2,66) = .19, p > .05. The postpartum and non-postpartum women did not differ on VIQ, F(1,33) = 1.60, p > .05.

(Figure 2 about here)

Figure 3 portrays the pattern of PIQ scores over pregnancy and into the postpartum period for pregnant and non-pregnant participants. Across pregnancy, we found no main effect of test number, F(2,66) = 1.69, p > .05, or pregnancy, F(1,33) = 2.72, p > .05. The test number by pregnancy interaction was likewise not significant, F(2,66) = .15, p > .05. Postpartum participants scored significantly lower on PIQ than women in the non-postpartum group, F(1,33) = 6.64, p = .02.

(Figure 3 about here)

WAIS-III & SB5 Subscale Results

Pregnant and non-pregnant performance at first trimester test session

In the first trimester test session pregnant women scored significantly lower than non-pregnant women on the non-verbal Matrix Reasoning - WAIS-III task (pregnant mean score = 10.38, SD = 1.19; non-pregnant mean score = 13.50, SD = 1.76), F(1,11) =20.20, p = .001, and the non-verbal Quantitative Reasoning - SB5 task (pregnant mean score = 7.50, SD = 1.58; non-pregnant mean score = 9.67, SD = 2.57) F(1,19) = 9.76, p< .01. There were no other differences between pregnant and non-pregnant women during the first trimester test session.

Pregnant and non-pregnant performance at combined 2nd or 3rdtest sessions

Three subscales showed a negative performance effect of late pregnancy. Compared to non-pregnant controls, pregnant women performed worse on Arithmetic – WAIS-III (verbal) (pregnant mean score= 8.89, SD = 2.76; non-pregnant mean score = 11.56 ± 2.15), F(1,33) = 7.10, p < .01, and Quantitative Reasoning – SB5 (non-verbal) (pregnant mean score = 8.89, SD = 2.19; non-pregnant mean score = 10.67 ± 2.17), F(1,33) = 8.26, p < .01. Digit Symbol-Coding – WAIS-III approached significance (pregnant mean score= 10.39, SD = 2.59; non-pregnant mean score = 11.94, SD = 3.21), F(1,33) = 4.24, p = .05.

Postpartum and non-postpartum performance on subscales at the postpartum test session

Previously pregnant women scored significantly lower on several subtasks during the postpartum test session than women from the non-pregnant group: Fluid Reasoning – SB5 (non-verbal) (pregnant mean score = 8.75, SD = 1.67; non-pregnant mean score = 11.67, SD = 1.63), F(1,11) = 10.12, p < .01, and Matrix Reasoning – WAIS-III (nonverbal)(pregnant mean score = 11.30, SD = 2.50; non-pregnant mean score = 14.00, SD =2.17), F(1,19) = 8.29, p = .01, showed a significant performance deficit in the early postpartum period. Working Memory – SB5 (non-verbal)(pregnant mean score = 9.13, SD = 1.36; non-pregnant mean score = 11.00, SD = 1.27), F(1,11) = 7.63, p = .02, Visual Spatial – SB5 (non-verbal) (pregnant mean score = 8.38, SD = 1.41; non-pregnant mean score = 11.00, SD = 3.29), F(1,11) = 5.02, p = .05, and Digit Span – WAIS-III (verbal) (pregnant mean score = 9.80, SD = 1.55; non-pregnant mean score = 12.00, SD = 2.45), F(1,19) = 6.34, p = .02, approached significance, with postpartum women tending to score lower than non-postpartum women. For full subscale results see table 3 (WAIS-III subscales) and table 4 (SB5 subscales).

(Table 3 about here)

(Table 4 about here)

Clustered performance on WAIS-III and SB5 subscales

Based on the above results, three clusters of cognitive ability appeared to be influenced as the result of either pregnancy or the postpartum period: abstract reasoning, mathematical reasoning, and working memory. Next, we collapsed across these three types of cognitive abilities (Abstract reasoning = Matrix Reasoning- WAIS-III + Performance Fluid Reasoning – SB5; Mathematical Reasoning = Arithmetic – WAIS-III + Performance Quantitative Reasoning – SB5 + Verbal Quantitative Reasoning – SB5; Working Memory = Digit Span – WAIS-III + Verbal Working Memory – SB5 + Performance Working Memory – SB5) and compared pregnant and non-pregnant performance throughout pregnancy and then again in the postpartum period.

Mathematical reasoning showed a significant main effect of pregnancy, with pregnant women performing worse across pregnancy than non-pregnant women, F(1,33)= 8.81, p < .01. We found no main effect of test number, F(2,66) = 1.32, p > .05, nor did we find a significant test number by pregnancy interaction, F(2,66) = .69, p > .05. We found no performance differences between women in the pregnant and the non-pregnant group in the final postpartum test session, F(1,33) = 3.42, p > .05.

Abstract reasoning showed no main effects throughout pregnancy (test number, F(2,66) = .42, p > .05; pregnancy status, F(1,33) = 2.33, p > .05, nor did we find a pregnancy by test number interaction, F(2,66) = 1.93, p > .05. Women in the postpartum group performed significantly worse than women from the non-pregnant group, F(1,33) =15.90, p < .001.

We did not observe any pregnancy-induced deficits in working memory, with the pregnancy by test number interaction, F(2,66) = .80, p > .05, as well as the main effects of test number, F(2,66) = .63, n.s., and pregnancy, F(1,33) = 1.45, p > .05, showing no difference between pregnant and non-pregnant participants. In the postpartum test session women caring for an infant performed significantly worse than women from the non-pregnant group, F(1,33) = 11.29, p < .01.

Preconception to postpartum performance for pregnant and non-pregnant participants

Figure 4 illustrates performance across time on FSIQ and PIQ for women in the pregnant and control groups. Women who subsequently became pregnant exhibited relatively consistent scores over time for FSIQ, F(2,6) = 2.61, p > .05, VIQ, F(2,6) = 1.28, p > .05, and PIQ, F(2,6) = .56, p > .05. Women in the non-pregnant group performed significantly better over time on FSIQ, F(2,6) = 8.01, p = .02, and PIQ, F(2,6) = 8.80, p = .02, and showed relatively consistent performance over time for VIQ, F(2,6) = 1.27, p > .05.

(Figure 4 about here)

Preconception to postpartum performance on subscales

Four women in both the pregnant and the control group completed three sessions with the WAIS. On Digit Symbol-Coding we found a significant test number by pregnancy interaction; only non-pregnant women showed improved performance over time, F(2,12) = 4.96, p = .03, while pregnant women showed a decrease in performance from the preconception to the second trimester session, followed by a slight increase (not yet back to preconception levels) in the postpartum session. The overall effect of pregnancy was not significant, F(1,6) = 1.97, p > .05. (Pregnant mean score: preconception = 11.50, SD = 3.70, 2^{nd} trimester = 10.25, SD = 3.30, postpartum = 10.75, SD = 5.19; non-pregnant mean score: 1^{st} test session = 12.50, SD = 1.29, 3rd test session= 14.25, SD = 2.22, final test session = 15.25, SD = 2.99).

For Digit Span we found a main effect of group with pregnant women scoring significantly lower than non-pregnant women, F(1,6) = 6.82, p = .04. There was no main effect of time, F(2,12) = 1.11, p > .05, nor was there a time by group interaction, F(2,12) = 1.11, p > .05. (Pregnant mean score: pre-conception = 8.25, SD = 1.41, 2^{nd} trimester = 9.00, SD = 1.35, postpartum = 8.75, SD = .99; non-pregnant mean score: 1^{st} test session = 12.75, SD = 1.41, 3^{rd} test session= 12.00, SD = 1.35, final test session = 13.75, SD = . 99). The remaining subtests showed no effect of pregnancy, although this may be due to small sample size. Arithmetic, in particular, seemed challenging for women in the pregnant group, especially during the 3^{rd} trimester session. For Arithmetic we found no difference between groups, F(1,6) = 2.81, p > .05, no group by time interaction, F(2,12) = .91, p > .05, and no main effect of time, F(2,12) = .64, p > .05. Matrix Reasoning produced similar results: no difference between groups, F(1,6) = 2.81, p > .05, and no main effect of time, F(2,12) = .64, p > .05. Matrix Reasoning produced similar results: no difference between groups, F(1,6) = 2.81, p > .05, and no main effect of time, F(2,12) = .95, p > .05, and no main effect of time, F(2,12) = .95, p > .05.

Subjective Mood and Energy Measure

Figure 5 portrays subjective energy levels over time for pregnant and nonpregnant participants. Energy levels showed a significant time by pregnancy interaction; pregnant women reported the lowest energy levels in the first trimester, increasing energy levels in the second trimester, a dip in energy levels in the third trimester and finally increased energy levels in the postpartum session, F(3,96) = 2.91, p = .05. Non-pregnant women reported the highest energy levels in the first test session. We found no main

effect of time, F(1,32) = 1.42, p > .05. Post-hoc *t*-tests revealed that pregnant women had lower subjective energy than non-pregnant women only in the first trimester (pregnant mean energy = 2.2 ± 1.1 ; non-pregnant mean energy = $3.2 \pm .9$, t(34) = 2.77, p = .01). We also analyzed data from pregnant and non-pregnant women separately. Here we found that subjective energy levels remained relatively consistent over time for both groups (Non-pregnant, F(3,48) = 1.40, p > .05; pregnant, F(3,48) = 1.60, p > .05).

(Figure 5 about here)

We found no differences between the groups in subjective anxiety; the time by pregnancy interaction was not significant, $F_{3,96} = .64$, p > .05, and there was no difference between the groups in subjective anxiety over time, $F_{1,32} = 1.28$, p > .05. There was no main effect of time for either group (non-pregnant, $F_{3,48} = 1.10$, p > .05; pregnant, $F_{3,48} = .10$, p > .05.

We found no differences between pregnant and non-pregnant women in subjective mood. Once again the time by pregnancy interaction was not significant, $F_{3,96} = 1.77$, p > .05, and nor was the main effect of pregnancy, $F_{1,32} = 1.60$, p > .05. Similar to anxiety, there was no main effect of time for either group (non-pregnant, $F_{3,48} = .75$, p > .05; pregnant, $F_{3,48} = 1.38$, p > .05.

3.6 Discussion

In this longitudinal study in which we tracked women from either preconception or

the first trimester of pregnancy into the first two months postpartum and compared them to control participants, we found evidence of a cognitive deficit in some tasks during pregnancy, and a general cognitive deficit during the early postpartum period. These cognitive changes suggest that there is burgeoning cognitive re-organization occurring during pregnancy, followed by a period of intense re-organization in the early postpartum period once infant care has begun.

We found no evidence of a pregnancy-induced generalized cognitive deficit: FSIQ, PIQ and VIQ scores showed no effect of pregnancy. However, performance on the WAIS-III and SB5 subscales revealed pregnancy related declines in performance on specific cognitive measures. During the first trimester women in early pregnancy performed worse on Arithmetic - WAIS-III (verbal), a test of mathematical problem solving and working memory, and Quantitative Reasoning - SB5 (nonverbal), a test of problem solving and math skills. Like Arithmetic, Quantitative Reasoning tests mathematical relationships, although it uses a pictorial as opposed to verbal format. Arithmetic and non-verbal Quantitative reasoning also showed a late pregnancy-induced deficit. Moreover, when we collapsed across the WAIS and SB5 tasks that required mathematical reasoning we found a pregnancy-induced deficit in mathematical reasoning throughout pregnancy.

Processing speed is also compromised during late pregnancy: not only did pregnant women tend to score lower than non-pregnant women in the full sample, but we also found a significant interaction with preconception participants showing a performance decrease from preconception to the 2nd trimester, and a performance increase from the

second trimester to the postpartum session. Taken together these results suggest that pregnancy impairs processing speed. We are not the first to report a late pregnancyinduced impairment in Digit Symbol-Coding (Oynper et al., 2010; Christensen et al. 2010). In contrast, de Groot, Hornstra, Roozendaal, & Jolles (2003) reported no difference between pregnant and non-pregnant participants on processing speed in early pregnancy (14 weeks). This suggests that it is only later in pregnancy, in the 2nd and 3rd trimesters, that pregnant women experience a deficit in processing speed.

The importance of a late pregnancy-related deficit in processing speed should not be underestimated. This finding corresponds with the timing of subjective memory complaints that commonly arise in late pregnancy (Casey, 2000; Crawley et al. 2003; Stark, 2000). We can only speculate that it may be this decline in processing speed that accounts for the subjective reports of memory, concentration, and attention impairment in pregnancy. If this is the case, then pregnant women, who are cognizant that their processing speed is impaired, are reporting a tangible pregnancy-related deficit. This may also help to explain why women do not report the same deficits in the postpartum period; processing speed, which is impaired in late pregnancy, has nearly recovered by two months postpartum. Further, processing speed is an excellent proxy for mental capacity (Kail & Salthouse, 1994), accounting for much of the age-related decline in cognitive performance (Nettleback & Rabbit, 1992). Digit Symbol-Coding is a multifactorial test; although it is primarily a task that evaluates processing speed, memory plays a real, although subordinate role, in performance on this task (Joy, Kaplan, & Fein, 2004). Thus, it is difficult to state with certainty what is underlying the observed

pregnancy-induced deficit, whether exclusively processing speed, or memory factors, or a combination of the two. However, as we found no effect of pregnancy on FSIQ, our results suggest that while pregnant women do experience a genuine decrease in cognitive performance as seen by decreased processing speed and impaired mathematical reasoning, these impairments can be overcome in broad scale test sessions.

Postpartum-induced cognitive change

Women in the early postpartum period showed a significant cognitive deficit in FSIQ and PIQ compared to women from the non-pregnant group. Thus, we found a generalized decline in cognitive functioning in the first two months postpartum, and found that this effect may be driven by deficits in the nonverbal domain. Women caring for an infant scored lower on FSIQ in the postpartum session than the first trimester session, and just above first trimester test levels for PIQ. In contrast, test scores for control participants continued the expected upward trend that results from practice when standardized tests are taken repeatedly. This idea that pregnant and non-pregnant women's scores diverge over time is supported by the subsample of "pre-conception" participants: while pregnant women showed no evidence of benefiting from practice effects and exhibited consistent scores from the pre-conception to postpartum test session in FSIQ, VIQ, and PIQ, non-pregnant women tested at similar intervals showed significant improvement over time in FSIQ and PIQ.

Postpartum women also showed a performance deficit on a number of subscales including Matrix Reasoning – WAIS-III (nonverbal), a test of problem solving and abstract reasoning, and Fluid Reasoning – SB5 (nonverbal), a test of problem solving and

abstract reasoning. The postpartum impairment in Matrix Reasoning and Performance Fluid Reasoning were especially pronounced; these two tasks vary similarly and agree across our two sub-samples. When we collapsed across these two tasks we found that abstract reasoning skills were diminished in the early postpartum period. Likewise, the deficit in both Digit span – WAIS-III (verbal) and Working Memory- SB5 (nonverbal) was observed across our two sub-samples. These subtests both test working memory and showed a trend towards decreased performance in the early postpartum period. When we collapsed across working memory tasks we found that working memory is impaired in the early postpartum period.

Our results suggest that there are distinct cognitive performance profiles in pregnancy and the early postpartum period; whereas women in the postpartum group showed a general decline in FSIQ and PIQ, we found no performance differences on FSIQ and PIQ between pregnant and non-pregnant women. In the postpartum period we found evidence of a deficit in abstract reasoning and working memory, and while we found no evidence of a pregnancy-induced deficit in these domains during pregnancy we did find evidence of a deficit in mathematical reasoning throughout pregnancy that was not present in the postpartum period. In late pregnancy we also found evidence of a deficit in processing speed. Hence, although postpartum cognitive performance shows an improvement in some areas (quantitative reasoning, processing speed), other tasks show a deficit in the postpartum period, including working memory and abstract reasoning skills.

Henry and Rendell (2007) argued that tasks requiring effortful processing, or an executive component, are more likely to show a pregnancy-induced deficit. Our study

presents mixed evidence for this broad claim. We did observe a pregnancy-induced deficit in Arithmetic – WAIS-III, which was evidently perceived as effortful given the participants' reactions to this task, and contains an executive component as it includes both a processing and a storage component (Arithmetic requires that participants solve mathematical problems from memory, without the use of pen and paper). The comparable SB5 task (Verbal – Quantitative Reasoning) does not include a storage component but instead tests only processing capacity; on its own, we found no differences between pregnant and non-pregnant women on this task. Again, participant reaction made it obvious that this task required quite a bit of effort. In fact, whereas the questions in Arithmetic- WAIS-III are relatively simple mathematical problems, Verbal Quantitative Reasoning – SB5 tests increasingly difficult "high-level mathematical reasoning and problem solving" (Roid, 2003, p. 106, b), suggesting that Verbal Quantitative Reasoning requires more cognitive effort than Arithmetic. We also found a pregnancy-induced deficit on Performance – Quantitative Reasoning – SB5, which tests mathematical reasoning skills, this time using a non-verbal pictorial format, and consisting solely of a processing and not a working memory component. The results of these three tasks suggest that although mathematical processing is impaired during pregnancy, it is not clear that it is the effort or the executive component of these tasks that is creating the deficit. Moreover, we cannot claim that it is the working memory component of the Arithmetic task that is creating the deficit; with the exception of poor performance on Arithmetic, we found no evidence of impaired working memory during pregnancy on any of the working memory tasks. Instead, we found that working memory

is impaired during the postpartum period. It may be that mathematical reasoning plus the requirement of an additional cognitive task (working memory, pictorial format) are interacting to produce the pregnancy-induced deficit observed here. It may also be that Henry and Rendell (2007) are partially correct and that certain tasks requiring an executive component are impaired during pregnancy. Like memory, however, executive cognition is multi-faceted, and more research is needed in order to determine what aspects of executive functioning are negatively affected as the result of pregnancy.

Subjective energy, anxiety, and mood measures do not explain our results. Pregnant and non-pregnant participants reported similarly consistent levels of anxiety and mood over time. Hence, anxiety and mood cannot account for cognitive performance differences in our sample. We did find that pregnant participants reported less energy during the first trimester session than non-pregnant participants, although there were no other differences between groups in reported energy levels. These results suggest that while fatigue may help to explain cognitive performance differences between pregnant and non-pregnant women in the first trimester testing session, fatigue does not account for performance differences in the postpartum session, or within the pregnant group over time. However, we did not use an objective measure of sleep disturbance. Although postpartum women did not perceive their energy levels as compromised compared to non-postpartum women, disturbed sleep and divided attention focused on infant care may explain the observed performance deficit in the postpartum test session.

The cognitive deficits in pregnancy and the postpartum period reported here contrast with the neural plasticity and cognitive advantage reported in the non-human

literature. While we investigated IQ change, investigations into motherhood-induced cognitive change in the rat have focused on skills that would serve a protective or survival function, such as the ability to navigate a maze, and the ability to find prey. Of the two studies that, to our knowledge, did examine pregnancy-related cognitive change in women from an evolutionary perspective, the results were enlightening. Christensen, Poyser, Pollit, and Cubis (1999) predicted that pregnant women would show a cognitive advantage when the material presented was relevant to their life circumstances (in contrast to the word-stem completion tasks that are typical in pregnancy and cognition research). Their results support their hypothesis; they found that pregnant women show increased memory performance when the material presented was pregnancy-related. Similarly, Anderson and Rutherford (2010) predicted that enhanced social cognition should serve a protective function during pregnancy, and show a pregnancy-related advantage. They found that pregnant women exhibit facilitated recognition of faces compared to non-pregnant women. Had we tested survival-related skills that offer a benefit to the mother or the offspring, such as being able to detect food items quickly in an array, we may not have found the same postpartum deficit that is being reported here.

However, it may also be that the neural plasticity and cognitive advantage reportedly occurring in nonhuman animals is also occurring in women and that we tested too early in the postpartum period for the cognitive advantage reported for rodents to have occurred. Results from studies investigating cognition in nonhuman mammals suggest that while cognitive skills show a marked improvement in the late postpartum

period after weaning has occurred (reviewed in MacBeth & Luine, 2010), there may be a deficit in the early postpartum period. Darnaudery et al. (2007) reported that in the early postpartum period spatial learning was impaired in rats; they speculate that the observed deficit in spatial learning may be an adaptation designed to promote pup-directed behaviors. Given that the early postpartum period is characterized by the learning of new skills and inevitable sleep disruptions, along with the fascination that newborn infants hold for their mothers in the early postpartum period, it is perhaps not surprising that we saw a decline in FSIQ, PIQ, abstract reasoning and working memory in the first two months postpartum.

Human females report extremely high levels of preoccupation with their newborn infants. Leckman et al. (1999) tested parental preoccupations at 8 months pregnant, and 2 weeks and 3 months postpartum. They found that while levels of preoccupation peaked at 2 weeks postpartum, in the second month postpartum mothers are still spending over 10 hours a day thinking about their infants, and report being nearly totally preoccupied with thoughts of their infants during this time. Rodent studies have shown that maternal devotion to neonates is so intense that new mothers will choose offspring over cocaine, sex, and feeding (reviewed in Kinsley & Lambert, 2006). It is plausible that while women are caring for neonates the motivation to perform FSIQ tasks is absent; it may be that a lack of motivation, as opposed to a true impairment in scoring potential, resulted in the postpartum performance deficit being reported here. Certainly the women in our sample were extremely capable: one participant ran for municipal office during her pregnancy and attended an all-candidates meeting the day after her baby was born. Others

successfully completed masters-level courses and started new jobs.

Two limitations associated with this study need to be addressed. The first is small sample size. As is the case with many studies investigating cognitive change in pregnancy, our sample was not as large as we would have liked. In particular, the subscale results in early pregnancy and the postpartum period need to be interpreted with caution. Interpretation of our results is further complicated by the demographic differences between our pregnant and non-pregnant sample. Pregnant women in our sample were more likely to be in a committed relationship (married or common-law) and reported higher household income than non-pregnant women; it is difficult to determine how these systematic sample differences may be impacting our results. Although low socioeconomic status (SES) has been reported as negatively affecting IQ and academic performance (reviewed in Sirin, 2005), the relationship between IQ and income is complex, with various factors influencing and mediating the relationship, including poor nutrition and increased stress in low-income households. Given that we asked women to report household income and pregnant women in our sample were more likely to be in a dual-income family, it is not clear how income differences may be impacting performance in our sample. Likewise, it is not clear how a committed relationship would influence the pattern of results reported here. Moreover, when we repeated our analysis with a subset of participants who were matched on all demographic variables by excluding non-pregnant participants without a partner our results remained the same. However, these limitations curtail the generalizability of our results; while the observed group differences observed here suggest that pregnant women who report relatively high

household income and are in a committed relationship are likely to show distinct cognitive performance profiles in pregnancy and the early postpartum period, the same may not be true of low income pregnant women, or pregnant women who are not in a committed relationship, or some interaction of those two factors.

While there has been much emphasis on cognitive decline during pregnancy, there has been a limited amount of research investigating cognitive performance during the postpartum period. Of the studies that have examined postpartum cognitive change the time span ranges from 1 week to more than 12 months postpartum, making it difficult to find a consistent pattern of effects. Our results suggest there is a significant cognitive impairment in the first two months postpartum; the results of past research suggest that this cognitive impairment has disappeared by 3-12 months postpartum. The postpartum period may be a fruitful area to investigate in order to understand maternal cognitive reorganization.
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3.8 Tables & Figures

Table 1. Mean scores on the WAIS-III and the Stanford-Binet for pregnant and non-

	Trimester	1 st	2 nd	3rd	Postpartum
SB5	Non-pregnant	100.67 ± 13.41	109.33 ± 11.29	104.58 ± 11.32	112.75 ± 12.22
Start	(12)	(SB5)**	(WAIS)*	(SB5)**	(WAIS)
	Pregnant (10)	96.70 ± 7.48	101.90 ± 9.63	98.00 ± 8.60	103.80 ± 7.60
		(SB5)*	(WAIS)**	(SB5)**	(WAIS)
WAIS	Non-pregnant	107.83 ± 6.37	98.50 ± 3.62	111.50 ± 5.99	104.33 ± 5.16
Start	(6)	(WAIS)*	(SB5)**	(WAIS)**	(SB5)
	Pregnant (8)	102.75 ± 7.25	98.25 ± 8.17	108.75 ± 7.67	98.50 ± 6.85
		(WAIS)	(SB5)**	(WAIS)**	(SB5)
** significant at $p > .01$ level for paired <i>t</i> -test with following test session. *significant at .					

pregnant women

05 level.

	Non-pregnant	Pregnant	<i>t</i> -test
	(N=18)	(N=18)	Pearson's χ^2
	Mean (SD)	Mean (SD)	
Age	29.11 (4.7)	31.17 (3.47)	t(34) = -1.49, p > .05
Race	83% White	78% White	$\chi^2(1, N = 36) = .18, p > .$
			05
Education	4.18 (1.38)	4.33 (1.97)	t(34) =27 p = n.s.
	(Bachelor's	(Bachelor's	
	Degree)	Degree)	
Motherhood	33%	61%	$\chi^2(1, N = 36) = 2.79, p > .$
			05
Household	4.67 (2.28)	6.22 (1.17)	t(34) = -2.58 p = .01 **
Income	(\$40,000-\$49,999)	(\$75,000-	
		\$99,999)	
Employment	77% employed full	72%	$\chi^2(1, N = 36) = 2.84, p > .$
Status	time	employed full	05
		time	
Relationship	67% in a	100% in a	$\chi^2(1, N = 36) = 7.20, p = .$
Status (%	committed	committed	01**
Common-law	relationship	relationship	
or married)			

 Table 2. Participant Characteristics

 Table 3.
 WAIS-III subscales results

	1 st Trimester	2 nd & 3 rd Trimester	Postpartum
	Pregnant:	Pregnant:	Pregnant:
	(N=8)	(N=18)	(N=10)
	Non-Pregnant:	Non-Pregnant:	Non-Pregnant:
WAIS-III Subscales	(N=6)	(N=18)	(N=12)
	Mean (SD)	Mean (SD)	Mean (SD)
WAIS - Vocabulary	11.38 (2.33)	11.56 (2.26)	11.10 (1.85)
-	11.67 (2.07)	12.17 (2.23)	12.50 (2.58)
WAIS - Similarities	11.00 (3.02)	10.11 (2.40)	10.30 (2.36)
	11.67 (2.50)	11.22 (2.94)	11.75 (2.38)
WAIS - information	10.88 (3.23)	10.83 (2.20)	10.50 (2.07)
	12.33 (1.51)	11.89 (1.97)	11.50 (1.98)
WAIS -Comprehension	10.25 (2.05)	10.72 (2.85)	10.90 (2.73)
	11.33 (1.21)	10.72 (2.56)	10.00 (2.45)
WAIS – Digit Span*	10.00 (2.20)	10.33 (2.83)	9.80 (1.55) *
	9.67 (1.63)	11.17 (2.71)	12.00 (2.45)
WAIS- Arithmetic*	9.00 (2.51)	8.89 (2.76)	9.30 (2.41)
	10.67 (1.75)	11.56 (2.15)	11.00 (3.02)
WAIS – Picture	9.62 (3.07)	10.50 (3.11)	10.70 (2.06)
completion	10.00 (2.90)	10.78 (2.39)	11.08 (2.68)
WAIS – Digit Symbol*	10.25 (1.98)	10.39 (2.59)	10.80 (3.36)
	12.17 (2.93)	11.94 (3.21)	11.83 (3.81)
WAIS – Block Design	11.75 (1.91)	11.50 (2.90)	10.90 (2.85)
	11.00 (1.90)	12.11 (2.81)	12.33 (3.26)
WAIS – Matrix	10.38 (1.19) *	12.22 (2.63)	11.30 (2.50) **
Reasoning*	13.50 (1.76)	12.72 (2.37)	14.00 (2.17)
WAIS – Picture	11.13 (3.48)	11.89 (2.97)	12.00 (1.49)
arrangement	9.83 (.98)	10.50 (2.53)	11.17 (2.52)

Table 4. SB5 subscales results

	1 st Trimester	2 nd & 3 rd Trimester	Postpartum
	Pregnant:	Pregnant:	Pregnant:
	(N=10)	(N=18)	(N=8)
	Non-Pregnant:	Non-Pregnant:	Non-Pregnant:
SB5 Subscales	(N=12)	(N=18)	(N=6)
	Mean (SD)	Mean (SD)	Mean (SD)
SB5- P. Fluid	10.20 (2.44)	9.78 (2.49)	8.75 (1.67)
reasoning*	10.75 (2.81)	10.28 (2.32)	11.67 (1.63)
SB5 – P. Knowledge*	9.20 (1.99)	10.72 (2.08)	11.25 (1.91)
	9.67 (2.81)	10.28 (1.87)	10.83 (1.94)
SB5 – P. Quantitative	7.50 (1.58)	8.89 (2,19)	9.50 (2.20)
reasoning*	9.67 (2.57)	10.67 (2.17)	10.00 (2.53)
SB5 – P. Visual-	8.60 (1.65)	9.11 (2.45)	8.38 (1.41)
spatial	9.67 (3.70)	10.28 (3.03)	11.00 (3.29)
processing*			
SB5 – P. Working	11.20 (2.62)	10.22 (2.32)	9.13 (1.36)
Memory*	11.67 (4.50)	11.72 (3.34)	11.00 (1.27)
SB5- V. Fluid	9.50 (1.76)	9.89 (2.89)	9.88 (3.00)
Reasoning	9.83 (2.48)	9.56 (2.64)	8.17 (1.72)
SB5- V. Knowledge	9.70 (1.25)	9.56 (1.46)	10.13 (2.36)
	10.17 (3.16)	10.50 (2.82)	10.17 (2.14)
SB5 – V. Quantitative	9.90 (2.08)	10.06 (2.26)	10.75 (2.38)
reasoning*	10.83 (3.41)	11.06 (1.77)	11.67 (1.37)
SB5 – V. Visual-	9.30 (1.83)	9.39 (2.52)	10.75 (1.98)
spatial	9.75 (2.70)	10.61 (2.48)	11.67 (1.75)
processing*			
SB5 – V.Working	10.50 (1.69)	9.67 (1.41)	10.00 (1.31)
Memory*	9.67 (1.21)	9.44 (1.65)	10.50 (2.43)

Figure Captions

Figure 1.	FSIQ over time.
Figure 2.	VIQ over time.
Figure 3.	PIQ over time.
Figure 4.	Pre-conception to postpartum (or non-pregnant equivalent) performance on FSIQ and PIQ.
Figure 5.	Processing speed over time (Digit Symbol- Coding).
Figure 6.	Perceived energy over time.













CHAPTER 4

RECOGNITION OF NOVEL FACES AFTER SINGLE EXPOSURE IS ENHANCED DURING PREGNANCY

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4.1 Preamble

In chapters 2 and 3 I described cognitive performance in pregnancy and the postpartum period. I argued that a new approach employing evolutionary theory and focusing on cognitive advantage, as opposed to deficit, may yield results that offer insight into human maternal psychology. In this chapter I adopt an evolutionary approach to the question of cognitive change in pregnancy, and investigate whether pregnancy results in enhanced memory of faces.

Reproductive state has been shown to modify the way that human females process social information, including social information denoting threat. For example, Conway et al. (2007) tested vigilance to threat in naturally cycling females. They found that when progesterone levels are high (as in pregnancy), females are more vigilant to fearful and disgusted faces than at other times of their menstrual cycle. Derntl, Kryspin-Exner, Ferbach, Moser, & Habel (2008) tested emotion accuracy in naturally cycling females and reported that women were more accurate during the follicular phase compared to the luteal phase. They further found that progesterone negatively correlated with performance and interpret their results as supporting the conclusions drawn by Conway et al. (2007); when progesterone levels are high, as in pregnancy, women are more vigilant

to threat. Although women in the luteal phase, with high progesterone, performed worse than women in the follicular phase, their errors reflected a bias in identifying any negative emotion (anger, disgust, fear, and sadness) as anger or disgust. A bias for identifying negative emotions as anger and disgust would trigger avoidance behaviours that may serve to protect a new pregnancy. Increased vigilance to anger may help women to avoid the threat of physical harm while increased vigilance to disgust may help women to avoid the threat of disease.

While reproductive state has been shown to modify the way that women process threat information, threat in turn has been shown to modify the way that emotions are processed and memories encoded. Becker et al. (2010) tested recognition memory after self-protective mechanisms had been triggered and showed that when faces denoting threat are presented participants tend to show increased recognition accuracy, despite decreased looking time as the result of averting their gaze from the threatening faces. Otgaar, Smeets, and van Bergen (2010) reported that when fitness-relevant information is presented memory is enhanced. Memory systems, then, appear to be tuned to information that enhances fitness, and facilitated encoding and processing of threat information is fitness-relevant.

Faces share information that is fitness-relevant. Emotions convey information regarding the relative safety or danger in a given situation. The sex of the face also conveys important information to humans: male conspecifics are more dangerous than female conspecifics, and as shown by Becker et al. (2010), male sex and masculinity act as heuristic cues triggering protective mechanisms. Faces also convey information on the

general health of an individual, communicating whether or not someone may be a pathogen threat.

Pregnant women have been shown to be particularly sensitive to information communicated by faces. Compared to non-pregnant women, pregnant women show a stronger preference for healthy faces (Jones et al., 2005). Pregnant women have also been shown to be more sensitive to emotions, and are more accurate than non-pregnant women in identifying emotions (Pearson, Lightman, & Evans, 2009). Given that pregnancy is a unique reproductive state where a physiologically and psychologically taxed female is tasked with the safeguarding of an important investment, her vulnerable fetus, it is perhaps not surprising that pregnant women show facilitated processing of the information communicated by faces. What is more curious, perhaps, is the memory deficit often associated with pregnancy.

Although investigations into memory decline as the result of pregnancy often report ambiguous results, one finding that has been consistently reported is that pregnant women themselves often report a decline in cognition as the result of pregnancy. Objective accounts attempting to describe this deficit have investigated implicit memory, explicit memory, and prospective memory, testing pregnant women on varying tasks in order to delineate the parameters of the memory impairment. One study took a different approach, reporting that pregnant women show a recognition advantage on material that is relevant to pregnancy (Christensen, Poyser, Pollit, & Cubis, 1999).

Given that pregnant women are vulnerable, and are more sensitive to information communicated by faces, along with evidence showing that memory performance

increases when the information presented is survival-relevant, pregnant women may be predicted to show enhanced recognition of faces, and especially male faces. To test whether pregnant women show facilitated recognition of faces, I tested recognition of novel faces, comparing the accuracy performance of pregnant and non-pregnant women. Results show that, as predicted, pregnant women show enhanced recognition of faces, and especially same-race male faces.

4.2 Abstract

Protective mechanisms in pregnancy include Nausea and Vomiting in Pregnancy (NVP) (Fessler, 2002; Flaxman and Sherman, 2000), increased sensitivity to health cues (Jones et al., 2005), and increased vigilance to out-group members (Navarette, Fessler, and Eng, 2007). While common perception suggests that pregnancy results in decreased cognitive function, an adaptationist perspective might predict that some aspects of cognition would be enhanced during pregnancy if they help to protect the reproductive investment. We propose that a reallocation of cognitive resources from nonessential to critical areas engenders the cognitive decline observed in some studies. Here, we used a recognition task disguised as a health rating to determine whether pregnancy facilitates face recognition. We found that pregnant women were significantly better at recognizing faces and that this effect was particularly pronounced for own-race male faces. In human evolutionary history, and today, males present a significant threat to females. Thus, enhanced recognition of faces, and especially male faces, during pregnancy may serve a protective function.

4.3 Introduction

Violence perpetrated by males against females has played a significant, albeit varied, role in primate evolutionary history (Smuts, 1992). Converging lines of evidence, including osteological (Martin and Frayer, 1997), ethnographic (Burbank, 1992; Hill and Hurtado, 1996; Shostak, 1981), and comparative (Boesch et al., 2008; Wrangham, Wilson, and Muller, 2006), suggest that conspecific males, including both in-group and out-group males, posed a significant threat to women. Women were recipients of lethal and non-lethal violence and may also have been abducted or killed in raiding attempts by neighboring groups.

Recent research is revealing cognitive processes designed to manage the threat posed by conspecific males. For example, Navarette et al. (2009) found that conditioned fear of out-group male exemplars resists extinction in male and female participants. They argued that, much like other fear-prepared stimuli (e.g., snakes and spiders), out-group males activate fear-preparedness mechanisms while in-group males and in-group and outgroup females do not. Miller, Maner, and Becker (2010) have also found that male sex is a heuristic cue signaling threat. They used a threat-based framework drawing on Error Management Theory to show that heuristic cues influence threat categorization. Heuristic cues are useful in that they allow quick and efficient processing of threat and therefore serve a self-protective function. These self-protective mechanisms are sensitive to both target and perceiver factors. Heuristic cues that trigger self-protective mechanisms associated with the target include male gender, especially masculine males, while selfprotective mechanisms associated with the perceiver include chronic vulnerability.

Because pregnancy impacts nearly all bodily systems, pregnant organisms are uniquely vulnerable. In the first trimester, when the fetus is undergoing organogenesis and the woman is immunosuppressed as a consequence of tolerating the foreign fetal genome, pregnant women often experience a host of symptoms including extreme fatigue and nausea and vomiting in pregnancy (NVP) (Lacroix, Eason, and Melzack, 2000; van Lier, Manteuffel, and Dilorio, 1993). A new set of challenges begins in the second trimester and continues into the third trimester, of which increased body mass is the most obvious. An increase of 10-12.5 Kg is typical in North American women (Dawes and Grudzinskas, 1991). Increased body mass as a result of pregnancy has been shown to inhibit locomotor performance, and hence modify foraging and predator avoidance behaviors. "Pregnant" lizards, birds, fish, and snakes (Ghalambor, Reznick, and Walker, 2004; Kullberg, Houston, and Metcalfe, 2002; Lee, Witter, Cuthill, and Goldsmith, 1996; Plaut, 2002; Schwarzkopf and Shine, 1992; Shine, 2003; Webb, 2004), have been shown to move more slowly and respond to environmental threats in a distinctive fashion compared to "non-pregnant" conspecifics. Thus, physiological changes associated with pregnancy modify threat avoidance behaviors across a variety of taxa.

Threat avoidance is salient for pregnant women who are not immune to male violence. Gazmararian et al. (2000) argue that violence towards pregnant women is common, with studies reporting rates of 4-8%, which is a higher prevalence than gestational diabetes and preeclampsia. Second only to motor vehicle accidents, homicide is the leading cause of death of pregnant and postpartum women in the United States (Chang, Berg, Saltzman, and Herndon, 2005). While most violence against pregnant

women comes from partners, partner violence highlights the potential for male perpetrated violence in pregnancy (Burch and Gallup, 2004), and also makes plain the potentially profound costs associated with violence during pregnancy. Compared to nonpregnant women, pregnant women are not only more vulnerable, they also have more to lose as they increasingly invest their reproductive efforts in the current pregnancy.

Violence perpetrated against pregnant females may result in harm to the mother and the fetus, and has been found to negatively impact pregnancy outcomes. Rachana, Suraiya, Hisham, Abdulaziz, and Hai (2002) found that 21.9% of the 7105 women in their study reported physical violence during pregnancy and that physical violence in pregnancy was associated with obstetrical complications such as increased risk of cesarean section, abruptio-placenta, and fetal distress. These contemporary statistics highlight how costly non-lethal violence and abduction would have been for ancestral pregnant women due to the stress they would impose on the fetus.

Considering the emotional, physiological, and cognitive changes associated with pregnancy, an expansive range of psychological mechanisms designed to keep the mother and the fetus safe should be expected. However, scientific exploration of self-protective processes in pregnancy is still in its infancy. NVP is now thought to serve a protective function by limiting the ingestion of foods that may result in illness during a period when the mother is immunosuppressed (Fessler, 2002; Flaxman and Sherman, 2000). Even more relevant to our predictions, there is also evidence of self-protective social processing in pregnancy. Navarette et al. (2007) reported that women in their first trimester exhibit increased negativity towards out-group members. They interpret their

results as reflecting a disease avoidance mechanism. Pathogen avoidance would be particularly important during the first trimester when the fetus is most susceptible to developmental perturbations and the woman is immunosuppressed. High progesterone, as is associated with pregnancy (Gregoire, 2005) and the luteal phase of the menstrual cycle, has also been shown to modify the way social information is processed. Conway et al. (2007) found that relatively high progesterone was associated with increased vigilance to threat in naturally cycling women.

While enhanced cognition during pregnancy should be predicted in order to safeguard the vulnerable mother and fetus, decreased memory function as the result of pregnancy is widely accepted and supported by past research (reviewed in Brett and Baxendale, 2001; Buckwalter et al., 1999; de Groot, Vuurman, Hornstra, and Jolles, 2006; de Groot, Hornstra, Roozendaal, and Jolles, 2003; Keenan, Yaldoo, Stress, Fuerst, and Ginsburg, 1998; Sharp, Brindle, and Brown, 1993). Although recent evidence suggests that the cognitive decline thought to occur as the result of pregnancy may have been exaggerated (Christensen, Poyser, Pollit, and Cubis, 2010; Crawley, Grant, and Hinshaw, 2008; Mickes, Wixted, Shapiro, and Scarff, 2008), brain imaging studies show that the hormones associated with pregnancy do result in a decline in visual face recognition (van Wingen, et al., 2007), and a majority of pregnant women report reduced cognitive and especially memory function during pregnancy (Crawley, 2002; Janes, Casey, Huntsdale, and Angus, 1999). In contrast, Christensen et al. (1999) found that pregnant women have a recognition advantage when stimuli were pregnancy related. They argue that pregnant women will show improved memory function when the

information is relevant. In light of the high stakes and vulnerability associated with pregnancy, enhanced memory function in pregnancy should be expected when the information is fitness-relevant.

Survival-related materials, including materials denoting threat, have been found to increase memory performance. In an eye tracking study paired with a disguised recognition task, Becker et al. (2010) found that, when self-protective mechanisms are triggered, women and men become more efficient at encoding facial information and that, despite truncated looking times, efficient coding of threatening faces results in enhanced recognition accuracy of out-group males. Otgaar, Smeets and van Bergan (2010) found that recall was enhanced when scenarios evoked survival processing. Thus, memory function is facilitated when materials denote threat and when self-protecting processing is activated.

Conspecific faces serve as an important tool for assessing the relative threat or safety in a given context. Faces denote a wealth of information and past research has shown that pregnant women are alert to facial cues (Jones et al., 2005; Navarette, Fessler, and Eng, 2007). Cues that signal a potential health impact have been found to be particularly salient to pregnant women. Navarette, Fessler, and Eng (2007) argue that sensitivity to health cues during pregnancy works much the same as NVP; women are sensitive to health cues for prophylactic purposes. Jones et al. (2005) found that women with high progesterone (i.e., pregnant women, women using oral contraceptives, and naturally cycling women in the luteal phase of the menstrual cycle), a hormone strongly associated with early pregnancy, also show increased attraction to apparent health in

faces. They suggest that increased attraction to apparent health in faces during periods of high progesterone serves as a mechanism to avoid infectious disease during pregnancy when the fetus is vulnerable and the mother is immunosuppressed (Jones et al., 2005; reviewed in Jones et al., 2008).

The current research examines the possibility that pregnant women are more vigilant to social threats than non-pregnant women. We propose that pregnant women are better at detecting and remembering threatening stimuli, whether they are physical or social. As a consequence of our evolutionary history, and the unique threat that conspecific males may pose to vulnerable pregnant women, we predict that pregnant women will show improved memory of male faces but not female faces. Like Becker et al. (2010), we believe that increased vigilance to threat ultimately results in more efficient processing and enhanced memory function, and specifically facilitated face recognition. This study was part of a larger project examining how pregnancy impacts cognition and social perception.

4.4 Materials and Methods

The aim of this study was to test whether pregnant women are better able to recognize faces than non-pregnant women. We ran a between-subjects experiment with each participant viewing the male or the female face set. Groups of participants were matched on key demographic variables including age, household income, and IQ.

Participants: Male condition

The participants who viewed male models were 20 pregnant (age: mean = 29.05 years, \pm 5.36, range = 20-38) and 20 non-pregnant women (age: mean = 27.05 years, \pm

7.76, range = 19-44 years). IQ, as measured by the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1997) (pregnant: mean = 106.15, \pm 12.82, range = 85-137; non-pregnant: mean = 108.30, \pm 12.94, range = 78-129), was matched across groups (t_{38} = 0.53, p = n.s.), as was household income (t_{34} = -0.19, p = n.s.). Participants also identified their ethnicity/race (White = 16 pregnant, 14 non-pregnant, Multiracial = 1 pregnant, 2 non- pregnant, Asian/Pacific Islander = 2 pregnant, 3 non-pregnant, East Indian = 2 non-pregnant, Aboriginal = 1 pregnant). Pregnant women were significantly more likely to be in a committed relationship, with 85% reporting being in a committed relationship compared to only 50% of the non-pregnant women in our sample (t_{34} = -2.48, p = 0.02). Pregnant participants were also more likely to have children, with 70% of pregnant women (t_{34} = -1.82, p = 0.08). The results of one control participant and two pregnant participants were lost due to equipment failure (Table 5 shows demographic information by group). The excluded participants are additional participants not included in the analysis.

Participants: Female condition

The participants who viewed female faces were 19 pregnant (age: mean = 30.16 years, \pm 4.17, range = 21-36) and 19 non-pregnant women (age: mean = 30.47 years, \pm 5.67, range = 19-42 years). IQ, as measured by the WAIS (Wechsler, 1997) (pregnant: mean = 108.42, \pm 13.41, range = 87-143; non-pregnant: mean = 108.39, \pm 10.36, range = 94-130), was not significantly different between the groups (t_{34} = -0.01, p = n.s.), nor was household income (t_{34} = -1.10, p = n.s.). Participants again identified their ethnicity/race (White = 17 pregnant, 15 non-pregnant, Multiracial = 2 pregnant, 3 non-pregnant, Latino

= 1 non-pregnant). Women in the pregnant group were significantly more likely to be in a committed relationship (t_{18} = -2.88, p = 0.01). The results of one control participant and one pregnant participant were lost due to technical error. The results of a second pregnant participant were excluded as she fell below the cut-off score of 70 on the WAIS (Wechsler, 1997) (Table 1). Again, the excluded participants are additional participants not included in the analysis.

(Table 1 about here)

Participant comparison across conditions

Pregnant participants viewing the female face set had significantly higher household income (as measured in blocks) than pregnant participants viewing the male face set (Female Face set mean = 5.79, Male face set = 4.55) (t_{37} = -2.02, p = 0.05). IQ, as measured by the WAIS, was matched across groups (Female Face Set: mean = 108.42, ± 12.82, range = 85-137; Male Face set = 106.15, ± 12.94, range = 78-129), as was relationship status (Female Face Set: 100% Committed; Male Face set: 85% Committed) (t_{19} = 1.83, p = 0.08), age (Female Face set mean = 30.16 years, ± 4.17, Male face set = 29.05 years, ± 5.36) (t_{36} = 0.72, p = n.s., and motherhood (Female Face set mean = 63%, Male face set = 50%) (t_{37} = 0.81, p = n.s.). (The number of pregnant participants in the first through third trimester for the male and female conditions can be found in Table 2.)

(Table 2 about here)

Non-pregnant participants viewing the male and female face sets were matched on all of the key variables including household income (Female Face set mean = 5.05, Male face set = 4.63) (t_{34} = 0.51, p = n.s.), IQ (Female Face set mean = 108.39, ± 10.36, Male face set = 108.05) (t_{37} = -2.02, p = 0.05), relationship status (Female Face set mean = 68%, Male face set = 53%) (t_{36} = 0.98, p = n.s.), age (Female Face set mean = 30.47 years, ± 5.67, Male face set = 27.05 years, ± 7.76) (t_{33} = -1.41, p = n.s.), and motherhood (Female Face set mean = 47%, Male face set = 26%) (t_{29} = 1.34, p = n.s.).

Procedure

The total set of 24 male and 24 female target face images came from six face database sets (The AR Face database, Martinez and Benavente, (1998) (Male models, n =5); Minear and Park, (2004), (Male models, n = 14, Female models, n = 17); Nottingham Scans (http://pics.psych.stir.ac.uk/), (Male models, n = 4), (Female models, n = 1); US Prison Database, Florida (n.d.) (Female models, n = 6); Yale Face Database (Georgiades, Belhumeur, and Kriegman, 2001) (Male models, n = 1). An additional 141 male and 141 female face images were drawn from the above datasets to serve as distractor images. The images were altered with Photoshop in order to produce a uniform appearance: conspicuous clothing and jewelry were removed and size of face and background were standardized. The set includes faces ranging in age from early twenties to late seventies, and were of Black, Caucasian and East Indian origin (Table 3 shows the characteristics of the target faces).

(Table 3 about here)

The training session of a surprise memory test was disguised as a health rating. In the training period, the "Perceived Health Rating", participants were seated in front of a Macintosh laptop computer. The program displayed the 24 target images of male or female faces in random order, each for 750 ms. Participants then rated the faces on how healthy they seemed on a scale of 1 (not at all healthy) to 7 (very healthy). Approximately an hour and a half later, after the participants had completed the WAIS (Wechsler, 1997), the test period occurred. In the test, the participants were again seated in front of a Macintosh laptop computer. They were shown twenty-seven displays consisting of a six-photo line-up with three faces images presented in the top half of the screen and three face images presented in the bottom half of the screen. Twenty-four of these displays contained one target image from the original health rating grouped with five foil face images. Foils were selected to match for apparent race, approximate age, and facial hair. Three of the displays contained only foil images. Displays containing only foil images forced participants to chose a face and were not included in the analysis. The program displayed the six photo- line ups in randomized order. The position of the target face was also presented in random order within the six-photo line-up. Participants were asked to select the one familiar face from the initial health rating, as quickly and as accurately as possible, using the keypad.

4.5 Results

We used an ANOVA to compare the four groups of participants: Pregnant and non-

pregnant in the male model condition and pregnant and non-pregnant in the female model condition. We found a significant main effect of pregnancy [$F_{1,74}$ = 8.30, p = 0.005], with pregnant women showing enhanced recognition of faces (Pregnant mean correct = 72.48%, ± 15.13; non-pregnant mean correct = 60.79%, ± 16.80). The main effect of model gender was not significant [$F_{1,74}$ = 0.64, p = n.s.]. The pregnancy by model gender interaction was also not significant [$F_{1,74}$ = 2.41, p = n.s.] (Figure 1).

(Figure 1 about here)

As apparent health in faces has been shown to be particularly salient to pregnant women (Jones et al., 2005) we next examined whether the initial health ratings influenced recognition accuracy for pregnant or non-pregnant participants. A regression with the initial health rating score as the predictor variable and recognition accuracy as the dependent variable showed that the initial health rating did not predict recognition for pregnant or non-pregnant participants in the male condition [$F_{3,36}$ = 3.47, p = n.s.] or the female condition [$F_{3,34}$ = 0.64, p = n.s.].

Controlling for the other-race effect

Past research has shown that the other race effect influencing recognition is robust; participants consistently show enhanced recognition of own-race over other-race faces (Meissner and Brigham, 2001). Since the majority of our participants were White and target images were apparently White, we next performed an ANOVA of White participant's performance on White targets in order to eliminate noise caused by the other race effect. Here we found a significant model sex by pregnancy interaction [$F_{1,53} = 3.90$, p = 0.05], (Pregnant mean correct Male condition= 71.56%, ± 17.39, Pregnant mean correct Female condition = 66.14%, ± 20.02 ; Non-pregnant mean correct Male condition = 59.23%, ± 14.27, Non-pregnant mean correct Female condition = 71.33%, ± 15.90). Neither of the main effects were significant [Model Sex: $F_{1,53} = 0.21$, p = n.s.; Pregnancy: $F_{1,53} = 0.65$, p = n.s.]. Follow-up tests using the Bonferroni correction revealed that White pregnant women are better than White non-pregnant women at recognizing White male, but not White female, faces ($t_{27} = -2.05$, p = 0.05) (Figure 2).

(Figure 2 about here)

4.6 Discussion

Using a disguised recognition task we found that, compared to non-pregnant women, pregnant women show enhanced recognition of faces. Faces convey information about the relative threat or safety of a given context and may therefore serve as a critical resource to vulnerable pregnant women invested in the safekeeping of their reproductive investment. Past research has found that memory function is enhanced when fitnessrelevant information is presented (Becker et al., 2010; Otgaar et al., 2010). Our results demonstrate that memory in special populations may be facilitated when the stimuli presented are especially relevant.

Pregnancy is energetically costly and somatically demanding. Increased vigilance to faces may be a low-cost means of attending to threat and pregnant women who were especially vigilant to the information presented by faces may have had a fitness advantage over pregnant women who were less attentive. This increased vigilance results in enhanced memory function of fitness-relevant information: male and female faces. As has been found in other species (Shine, 2003; Schwarzkpof and Shine, 1992; Lee et al., 1996) pregnant humans exhibit increased vigilance to threat cues in their environment in order to effectively implement threat avoidance behaviors at a time when the physiological changes associated with pregnancy result in impeded mobility, NVP, and extreme fatigue that limit the ability to effectively defend against environmental stressors and dangers. Hence, faces are cues that pregnant women may use in order to successfully navigate their environment.

In contrast to our threat-avoidance hypothesis for increased recognition of faces in pregnancy, an alternative hypothesis is suggested by past research: pathogen-avoidance. Jones et al. (2005, 2008) suggest that women with high progesterone profiles, such as is found in pregnancy, show increased attraction for apparent health in faces as a mechanism for avoiding infectious disease. Pregnant women have also been shown to exhibit increased ethnocentrism in the first trimester of pregnancy, a result that has also been attributed to a pathogen avoidance mechanism (Navarette, Fessler, and Eng, 2007). Apparent health in the individual models as measured by the initial health ratings did not impact recognition accuracy for pregnant or non-pregnant women, suggesting that these data are not best explained by a pathogen-avoidance mechanism. However, given that we had so few participants in the first trimester of pregnancy when disease-avoidance is most salient, our sample did not adequately allow a test of the impact of pathogen-avoidance

on recognition of faces during pregnancy. Had we been able to separate trimester effects and analyze women in the first trimester, when the fetus is most vulnerable to pathogens, it is possible that we may have seen a different pattern of results. While the pathogenavoidance, and violence-avoidance hypotheses are not mutually exclusive, our results suggest that pregnant women are vigilant to faces in general and to male faces in particular.

When we limited our analysis to White participants' performance on White targets, eliminating interference from the own-race effect, we found that pregnant women show enhanced recognition of male, but not female, faces. In examining recognition accuracy of out-group males we also found that pregnant women show enhanced recognition of male, and not female, faces. Moreover, when all targets and perceivers are included, our results suggest that pregnant women have enhanced recognition of male faces, not in comparison to female faces, but in comparison to non-pregnant women. If we take nonpregnant women to be the female baseline, then women have facilitated recognition of female compared to male faces. Indeed, a large body of research suggests that humans from infancy show facilitated processing of female faces and that adult women and girls exhibit increased recognition of females (Ramsey-Rennels and Langlois, 2006; Lewin and Hertlitz, 2002; Rehman and Herlitz, 2006). What is most interesting about our results, then, is why pregnant women show enhanced recognition of male faces and why male faces are equally as memorable to pregnant women as female faces. Evidently, pregnant women are especially vigilant to stranger males.

Our results contribute to an emerging body of empirical evidence that suggests that

conspecific males trigger self-protective mechanisms in men and women. Out-group males in particular have been found to activate self-protective processing. Thus, enhanced recognition of male faces in pregnancy may be explained by these same self-protective mechanisms. Given that males present a significant threat to pregnant and non-pregnant women, one might expect that vigilance towards males would translate into facilitated recognition regardless of reproductive status. However, pregnant women are not only more vulnerable to violence as a result of the physiological challenges associated with pregnancy; their fetus is also vulnerable. Pregnant women may be extending their outgroup, and thus their vigilance, to all unfamiliar males, although perceiver and target race may mediate this effect. In hominid evolutionary history males presented a threat; women were at risk of violence from in-group and out-group males. Vigilance towards this threat, and violence-avoidance mechanisms, are evidently a component of cognitive processing in pregnant women.

This study is an initial step in exploring adaptive cognitive changes in pregnancy. Future research will explore the mechanism underlying pregnant women's enhanced recognition of faces. Future research should also consider individual differences in pregnant women, such as physical condition and access to resources, and delineate the distinct challenges that occur within each trimester. Finally, future research could also obtain menstrual cycle information from non-pregnant participants. Evidence suggests that menstrual cycle phase influences cognitive processing of male, but not female, faces (Roberts, Newell, Simoes-Franklin, and Garavan, 2008), alters face preferences (Penton-Voak et al., 1999) and that naturally cycling women in the peak progesterone phase of the

menstrual cycle are more attentive to threat than women in other phases of the menstrual cycle (Conway et al., 2007). Menstrual cycle phase may allow a different pattern of results to emerge.

Pregnancy is a unique life phase characterized by specific adaptations designed to keep the fetus and the mother safe. While faces in general provide critical information, social others, and especially conspecific males, present a significant source of threat to women, including pregnant women, and psychological mechanisms designed to mitigate this threat are emerging. Just as NVP may result in a fitness advantage, pregnant women and their fetuses may benefit from increased vigilance towards, and recognition of, faces. Kinsley (2008) has argued that the demands of motherhood result in a superior "maternal" brain. There is no reason to confine cognitive advantages to the postpartum period. We would suggest that certain advantages of a maternal brain, insofar as one exists, begin at conception.

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4.8 Tables & Figures

Table 1. Demographic characteristics for pregnant and non-pregnant participants in

Model	Pregnancy	Age	Relationship	Income	WAIS
sex	Status		Status		
Male	Pregnant	29.05	85%	40,000-	106.15
Sex	(20) (± 5.37)			50,000	(± 12.82)
	Non-	27.05	50%	40,000-	108.30
	pregnant	(± 7.76)		50,000	(± 12.94)
	(20)				
Female	Pregnant	30.16	100%	50,000-	108.42
Sex	(19)	(± 4.17)		74,000	(± 13.41)
	Non-	30.47	68%	50,000-	108.39
	pregnant	(± 5.67)		74,000	(± 10.36)
	(19)				

the male and female conditions

Condition	1 st Trimester	2 nd Trimester	3 rd Trimester
Male	2	9	9
Female	2	8	9

Table 2. Participant characteristics: Pregnant participants, male and female condition

	Apparent Age				Apparent Race		
Model	20 -	30	45	60+	Caucasian	Black	East
Sex	30	-45	-60				Indian
Male	11	10	2	1	20	3	1
Female	10	6	7	1	19	4	1

 Table 3. Face model characteristics by model sex

Figure Captions

- *Figure 1.* Recognition accuracy of male and female faces by pregnant and non-pregnant women.
- *Figure 2.* White participants' performance on white targets.

Figure 1



Figure 2



CHAPTER 5

EVIDENCE OF A NESTING PSYCHOLOGY DURING

HUMAN PREGNANCY

5.1 Preamble

The chapters in this thesis thus far have described cognitive reorganization that occurs as the result of reproductive state, reporting evidence that shows that while there is a decline in cognitive functioning in some areas, there is a pregnancy-induced cognitive advantage in others. Chapter 4 showed that, compared to non-pregnant women, pregnant women show enhanced recognition of novel faces. Past research suggests that pregnant women are especially vigilant to negative emotions, and sensitive to cues suggesting pathogens. An advantage in social cognition serves a protective function: facilitated encoding of critical information communicated by faces helps to keep the vulnerable mother and fetus from harm.

As described in chapter 2, protective mechanisms in pregnancy include mitigated stress reactivity, nausea and vomiting in pregnancy (NVP), and enhanced social cognition. While NVP is generally the most frequent during the first trimester of pregnancy when the fetal organs are developing, like mitigated stress reactivity and facilitated social cognition, these protective mechanisms may serve a protective function and be beneficial at any point in pregnancy. To date, we haven't described protective mechanisms acting on the most vulnerable point in pregnancy: parturition.

Parturition is the point at which the mother and the fetus are the most vulnerable. Women have, at this point, invested 9 months in the fetus, which is a large reproductive

investment, and they are about to face the challenge of childbirth. Parturition is dangerous for the mother and her fetus, and this is especially true of human females. Evolutionary pressures, including the increasing size of the human brain competing with the structural demands of bipedalism, have resulted in a history of obstructed labour that is unique to human females, and has been labeled the human "obstetric dilemma" (Blackburn, Wittman & Lewis Wall, 2007). Internal adaptations designed to address the challenges posed by bipedalism and encephalization (increasing brain size) include morphological changes to the human pelvis, the rotational mechanism of human labour whereby the fetus rotates through the birth canal, especially large fontanelles, and the delivery of a less developed neonate (Blackburn et al., 2007). These adaptations, both to the fetus and to the maternal internal environment, serve to enhance survival. I predict

that, given the high stakes involved, there are also adaptations designed to address the external environment.

Nesting, a suite of parental behaviours designed to protect the mother and her neonate, has been described in several mammals. A safe nest protects the mother and her neonate from dangerous predators or conspecifics, facilitates pathogen avoidance, and promotes mother-offspring bonding. The expression of nesting varies across species dependent on ecological factors, such as whether parental care is the sole domain of the mother or whether the father is also involved in offspring care, and where parturition occurs (for example, in the trees or on the ground).

Although popular literature and media are rife with accounts of nesting, there has been little scientific study of nesting in human females. Here, I define nesting in women

as a set of measurable changes in behaviours and attitudes during pregnancy that have the function of preparing the physical environment for parturition. I report the development of the Nesting Questionnaire, along with longitudinal data showing that women exhibit nesting behaviors, peaking in the third trimester of pregnancy. I further show that nesting is comprised of two components: space preparation and social withdrawal.

5.2 Abstract

In altricial mammals nesting refers to a suite of parental (primarily maternal) behaviours including nest-site selection, nest building and nest defense (Weber & Olsson, 2008), and the many ways that nonhuman animals prepare themselves for parturition is well studied. In contrast, little research has considered pre-parturient preparation behaviours in human females from a functional perspective. Reports in the popular press assert that women experience "nesting" urges, in the form of cleaning and organizing behaviours (Skolnik, 2003). Anthropological data suggest that having control over the environment is a key feature of childbirth preparation in humans, including decisions about where the birth will take place, and who will be welcome in the birthing environment (Trevathan & McKenna, 2003). Here, we describe a Nesting Questionnaire that we developed. We used this Nesting Questionnaire, along with longitudinal data, to track pregnant women throughout their pregnancy and into the postpartum period. We also tested non-pregnant control women at similar time intervals. We found that while women exhibited nesting behaviours and attitudes, the popular conceptualization of nesting in women is only partially correct and too narrowly defined in its focus on cleaning as a method of nesting preparation. Nesting in women in fact also includes social withdrawal and space-preparation behaviours, which peak in the third trimester of pregnancy. As is the case with nonhuman mammals, nesting in human females may serve a protective function.

5.3 Introduction

Parturition and the early days postpartum are an extremely vulnerable and critical time. Not only is parturition itself dangerous to the mother and her emerging fetus, but preoccupied mothers and their newborn offspring are also at risk of harm, from both predators and conspecific males (reviewed in Hahn-Holbrook, Holbrook & Haselton, 2001). As newborns are extremely vulnerable to pathogens, conspecifics can also pose a threat as potential carriers of disease. Apart from social threats, newborn humans also have difficulty with thermoregulation, and are thus at risk from extreme temperatures. This extreme vulnerability renders the space in which the birth and first hours postpartum will take place of fundamental importance.

Nesting serves a protective function at a time when the mother and her offspring are extremely vulnerable. Nesting provides a safe place for parturition, and a safe place to house newborn offspring, and to protect it against the climate. Moreover, nests offer advantages in more subtle ways. A safe environment would facilitate mother-infant bonding, allowing, in some species, adaptive discriminatory capacities to develop. Securely attached human infants have been shown to exhibit a variety of benefits, including an increased ability to manage stress and emotions (reviewed Schore, 2001), more social play (Main, 1983), and enhanced language development (van Ijzendoorn, Dijkstra, & Bus, 1995).

Given that parturition and the early postpartum period are times of high stakes and vulnerability, and that nesting serves a protective function in a variety of ways, it is no wonder that nesting is observed in many mammalian species. The

nesting behaviours of rats (Rosenblatt & Lehrman, 1963), mice (Lisk, Pretlow, & Friedman, 1969), sows (Thodberg, Jensen, Herskin, & Jorgensen, 1999), rabbits (Ross et al. 1963), and primates (Stewart, 1977) have been well characterized. In contrast to the rigorous attention paid to nesting in nonhuman animals, our western treatment of nesting in women does not currently include an adaptive function. Instead, "nesting" probably evokes the image of a woman with bulging pregnant belly scrubbing invisible dirt or emptying items from the cupboard in a frenzy. Popular media focused on pregnancy and parenting often describe nesting as the presumably maladaptive actions of a woman who is out of control. For example, Wikiparenting states that while the urge to nest is variable, "Many moms find themselves hit hard by the instinct to nest and have the urge to completely redecorate a perfectly good living room, or sanitize the bathroom at 3 am. If you are in this category, take heart that the overwhelming urge to nest is perfectly normal." (wikiparenting, April, 2011). Similarly, pregnancy-info.net assures women that nesting is safe provided women aren't "pushing themselves too hard" and that men too can participate in nesting behaviours (pregnancy-info.net/nesting, April, 2011). Skolnik (2003) describes nesting in humans as an "...overwhelming urge to clean and organize your home...(that) strikes in mid- to late pregnancy, turning even the most laid-back housekeeper into a mop-wielding maniac." She cautions pregnant women to take care when indulging the urge to nest.

Clearly, there is a discrepancy between how nesting is understood in human and nonhuman mammals. In nonhuman mammals, nesting refers to a suite of

parental behaviours that serve an adaptive function, in the same way that nursing and grooming are functional parental behaviours. In humans, by contrast, "nesting" seems to be commonly understood as an irrational urge that can be energetically costly and even dangerous. Moreover, there is little research investigating functional species-typical birth preparation behaviours in women. This may be the reason why most midwifery textbooks abandoned the concept of nesting in the 1980's (Walsh, 2006).

Despite a paucity of research examining nesting in women, a few researchers have attempted to describe nesting in humans. For example, although she did not offer an operational definition of nesting, Malnory (1996) included nesting in her maternal-paternal developmental-psychological assessment tool designed to aid nurses when they estimate outcomes of low-risk pregnancies. She argues that nesting is a critical parental task required for the healthy development of the family and describes nesting as beginning for expectant mothers and fathers in the 2nd trimester. Rubin (1976), who defined nesting as the preparation of the physical environment, claims that nesting is a low priority maternal task that begins in the 8th month of pregnancy and continues into the postpartum provided that higher priority items are complete (higher priority maternal tasks including ensuring safe passage for the fetus and ensuring that the child will be accepted by significant others). Cranley (1981) initially included nesting as a subscale in her scale of maternalattachment. All items in the nesting subscale related to nursery preparation. However, she ultimately abandoned the nesting subscale when it failed to show

internal reliability. She speculated that cultural traditions might influence nesting behaviours and hinder reliability (she does not state what these varying cultural traditions may be).

We define nesting as measurable change in behaviours and attitudes during pregnancy focused on birth preparation. As is the case with other mammals, we expect that a suite of species-typical, preparatory maternal behaviours will typify nesting in women. We use the term "nesting" as a label for these behaviours as the term is commonly understood and widely used. Moreover, when characterized as a suite of species-typical maternal behaviours, nesting in women is analogous to acts of parental care undertaken by nonhuman mammals. We predict that there will be two components associated with nesting psychology: space preparation and social withdrawal. Both space preparation and social withdrawal behaviours have been observed in species that nest; across taxa, nesting apparently serves a protective function, and promotes mother and neonate survival.

Preparing the Physical Environment

Like other aspects of parental care nesting behaviours are expected to vary across species; space preparation behaviours are no exception. Observed behaviours involved in preparing the physical space are highly variable, ranging from literal nest building to birth site-selection. Depending on various life history factors such as the sociability and mobility of the species, several aspects of nesting show speciesspecific patterns, such as the length of time and amount of effort invested in

preparing the physical space, the complexity of the structure, and the timing of when nesting behaviours begin and end (how long before parturition the birthing environment is prepared and how long after parturition the birthing environment is used). For example, while Stewart recounts that a Mountain Gorilla "hastily built" (1977, p.967) one nest, and then made a second "crude nest" (1977, p.967) out of leaves as labour progressed, nest building by rabbits involves a great deal of time and effort. Rabbits begin nest construction during the last third of pregnancy. Rabbits first dig an underground burrow, next build a straw nest inside the burrow, and finally extract hair with which to line the nest (Gonzalez-Mariscal et. al., 1996).

While some mammals engage in nest building, other mammals, who are equally committed to giving birth in a safe environment, engage solely in birth-site selection. Both operate for the same purpose: to have a safe place to bear young and promote early infant-mother interactions. Alaskan Moose, for example, have been found to alter their habitat selection procedures when they are pregnant, prioritizing safety from predators over foraging quality (Bowyer, van Ballenberghe, Kie, & Maier,1999), as do female Caribou (Barten, Bowyer, & Jenkins, 2001). While women aren't expected to literally build nests, like some mammals they are predicted to exhibit careful birth-site selection behaviours. Based on accounts by pregnant women, and descriptions offered by the media, a certain amount of manipulation of the physical environment (cleaning and organizing) is also expected.

Preparing the Social Environment

The nonhuman literature suggests that nesting decisions determine not only where the birth occurs, but also who is permitted into the birthing environment. Isolation or partial isolation is observed in several species, including rodents; mice, rats, and hamsters alter their social behaviour as parturition approaches, becoming highly aggressive during the final stages of pregnancy (reviewed in Svare, 1981). Social withdrawal or isolation is also found in some nonhuman primates, including monkeys and apes (Trevathan & McKenna, 2003). Social withdrawal during parturition is a viable option for many primates as fetal emergence patterns allow the mother to manually aid in the birthing process, promoting neonate survival (Trevathan & McKenna, 2003).

Social withdrawal has even been observed amongst primates that are typically cooperative breeders. Price (1990) describes the birthing behaviours of fourteen captive cotton-top tamarins (*Saguinus oedipus*), noting that although cooperative breeding is extensive in these social primates, with the father, older offspring, and non-kin often participating in infant care, parturient females exhibit a decrease in intra-group interactions during parturition and immediately postpartum. He speculates that increased vigilance to predators by the vulnerable soon-to-be new mother results in the decrease in intra-group interactions.

Isolation serves a protective function in a number of ways: Isolation may help to reduce infanticide by conspecifics, allows the mother and neonate to identify each other, and decreases the risk of infectious disease (Turner et al., 2010). Decreasing the risk of infectious disease would have benefited human infants;

evidence from traditional societies has shown that pathogen-avoidance is critical in the early postpartum period. Mortality rates are the highest during the first year of life, and newborn infants are especially vulnerable in the first days postpartum, with infectious disease second only to congenital defects in causing infant death (reviewed in Hahn-Holbrook, Holbrook & Haselton, 2001). Even today infections present a significant threat to neonates, accounting for 36% of deaths in the immediate postnatal period in modern developing countries (Lawn, Cousens, & Zupan, 2005).

While isolation does certainly hold advantages, partial isolation is also adaptive in some mammals, including humans. Newton and Newton (2003) note that unattended childbirths would have been the exception, rather than the rule, during parturition in non-literate cultures. They report that the basic rule crossculturally has been for parturient women to be attended by at least two women. While the role of males was more variable, and other aspects of parturition are highly variable cross-culturally, birth attendants are a near universal aspect of human births (Trevathan & McKenna, 2003).

Trevathan & McKenna (2003) argue that there were strong evolutionary pressures acting on human females that transformed the previously isolated birthing experience to a social event. As the result of bipedalism, encephalization, and fetal emergence patterns, a significant survival advantage existed for women who had help during labour. Unlike some primates, the position of the human pelvis and the path made by the emerging fetus do not permit manual manipulation by the mother

during parturition. In other primates, such as the Japanese Macaque (*Macaca fuscata*), manually assisting offspring emerge from the birth canal is thought to increase offspring survival (Turner et al., 2010). In humans, birth attendants may facilitate stalled delivery, clear the infant's mouth of fluid, and remove the umbilical cord from around the infant's neck. Birth attendants have also been shown to enhance outcomes in other ways. In contemporary cultures 'doulas', professionals who offer emotional support during labour, have been found to offer a variety of advantages, including decreased labour time and reduced medical interventions (Klaus & Kennel, 1997). In contrast, women who do not have access to emotional support during labour are at higher risk for a number of risk factors postpartum, including postpartum depression (Essex & Picket, 2008; reviewed in Sauls, 2002).

Given that there are costs associated with including others in the birthing environment (risk of infectious disease, risk of violence), and that there are benefits associated with including others in the birthing environment (enhanced offspring and mother survival), it is clear that control over the social environment is an adaptive problem that women would have faced repeatedly in the past. As pointed out by Trevathan and McKenna (2003) anthropological data and evidence from early human ancestors suggest that the benefits outweighed the costs, and women in labour are typically attended by at least two birth attendants. In light of the potential costs and benefits associated with attended labour, a clear pattern of constrained sociality as a component of nesting should be observed in human females; as birth approaches women should show a preference for proximity to potential birth

attendants and people they know and trust, while distancing themselves from individuals who are less well-known.

The current study

The purpose of this research was twofold. We tested for the existence of nesting in women, defined as measurable change in attitudes and behaviours focused on parturition. Second, provided we should find evidence of nesting in women, we aimed to describe the adaptive birth preparation behaviours (i.e., nesting) exhibited by human females. To this end, we developed a questionnaire in order to characterize human maternal nesting: when does it occur? What behaviours does it entail? Based on evidence from nonhuman mammals and the anthropological literature, as well as anecdotal evidence from the popular press and pregnant women themselves, we focused broadly on behaviours pertaining to the birthing environment, including both physical and social aspects of the environment. We describe the development of the Nesting Questionnaire and the results of a longitudinal study tracking pregnant and non-pregnant women throughout pregnancy and into the postpartum period.

5.4 Methods

Participants

Participants were 20 pregnant women and 19 non-pregnant women. There were no significant differences between the two groups in age (pregnant participants' mean age = 30.7 years, \pm 3.7, non-pregnant participants' mean age = 29.1 years, \pm 4.6, t_{37} = -.95, p = n.s.), education (measured in blocks, see appendix A for how this was calculated) (pregnant mean educational blocks = 4.3 ± 1.9 , non-pregnant mean educational blocks = 4.1 ± 1.3 ; where 4 signifies a university degree, $t_{37} = -.37$, p = n.s.), years at current residence (pregnant mean years = 2.8 ± 2.7 , non-pregnant mean years = 4.2 ± 4.2 , $t_{37} = 1.93$, p = n.s.), and parity (55% of the pregnant participants were mothers; 32% of the non-pregnant women were mothers, $\chi^2 (1, N = 39) = 2.2$, p = n.s.)). Pregnant participants were more likely to be in a committed relationship (defined as married or living commonlaw)(100% of the pregnant participants were in a committed relationship; 68% of the non-pregnant participants were in a committed relationship) ($\chi^2 (1, N = 39) = 7.46 p = .$ 01)), and had significantly higher household income (measured in blocks, see appendix A for how this was calculated) compared to non-pregnant participants (pregnant mean household income = 6.1 ± 1.2 , non-pregnant mean household income = 4.4 ± 2.5 , $t_{37} = -2.75$, p = 0.01).

Procedure

After giving informed consent, participants were instructed to answer each question based on how they felt "right now". Test sessions occurred in the first trimester (mean = 11.4 ± 2.1 weeks), second trimester (mean = 25.3 ± 1.1 weeks), third trimester (mean = 35.2 ± 1.3 weeks), and early postpartum period (mean = 7.7 ± 2.6 weeks)(a small number of pregnant (n = 8) and non-pregnant women (n = 4) also completed a 5th pre-conception session); non-pregnant women completed test sessions at comparable time intervals. This study was part of a larger study examining pregnancy and cognition at McMaster University. The Nesting

Questionnaire occurred at approximately 45 minutes into experimental sessions that lasted, on average, 2.5 hours. Based on the participants' preference, test sessions took place either at McMaster University, or in the participants' homes. Regardless of location, testing occurred in a quiet room, free from distractions (including the telephone, television, and family members). Seven of the 19 non-pregnant women, and 16 of the 20 pregnant women chose to participate in their homes.

Questionnaire Development

The original 40-item questionnaire was developed based on interviews with midwives, feedback from pregnant women who were participating in related research (Anderson & Rutherford, 2010), and a review of the scientific research examining nesting in non-human pregnancies (Stewart, 1977; Thodberg, Jensen, Herskin, & Jorgensen, 1999; Rheingold, 1963). As nesting in women has received little scientific attention we were unable to focus the questionnaire on known human behaviours, drawing instead from accounts in the popular press, anecdotal reports, and interviews with pregnant women in order to formulate our items. The original questionnaire was designed to probe a wide range of possible pregnancy-related behaviours, and was deliberately broad, with the intention of paring down redundant items (Clark & Watson, 1995). Because 9 items were directly related to pregnancy or nursery preparation we prepared a pregnant and a non-pregnant version of the nesting questionnaire; for non-pregnant participants these 9 items were modified slightly. We used the Difference of Proportions test to compare pregnant and nonpregnant responses on each of the 40 items at the third trimester (or non-pregnant

equivalent) test session; the results of the 9 items that had pregnant and non-pregnant versions should be interpreted with caution. The full questionnaire, with non-pregnant alternatives where applicable, and the results of the Difference of proportions test, is displayed in Table 1.

(Table 1 about here)

Analysis of the initial questionnaire

Items were tested with binary yes/no responses; analyses were performed on the mean number of yes responses in each group. A 2x4 repeatedmeasures analysis of variance on the original 40 items with pregnancy as the between subjects factor (pregnant and non-pregnant) and time as the within subjects factor (first, second, third trimester, and postpartum), including relationship status, income, and motherhood as covariates, showed a significant time by pregnancy interaction [$F_{3,102}$ = 3.57, p < .02]. Women in the pregnant group scored progressively higher across the trimesters of pregnancy, and then their scores dropped in the postpartum session to well below first trimester levels. Women in the non-pregnant group scored relatively consistently over time. We found no main effect of time [$F_{3,102}$ = 1.25, p = n.s.], nor did we find a main effect of pregnancy [$F_{1,34}$ = .02, p =n.s.]. Follow up *t*-tests using the Bonferroni correction for multiple tests showed that pregnant women scored significantly higher than non-pregnant women in the 3rd trimester test session only (pregnant mean score = 23.5 ± 6.6, non-

pregnant mean score = 18.5 ± 5.2 , $t_{37} = -2.64$, p = .01).

We next ran the same analysis on the 31 items that were identical for pregnant and non-pregnant participants, removing items that were presented with both a pregnant and a non-pregnant version. Our results were essentially the same: we found a significant time by pregnancy interaction [$F_{3,102}$ = 4.36, p < .02], with scores for the pregnant group peaking sharply in the third trimester and scores for the nonpregnant group remaining relatively unchanged over time. We found no main effect of time [$F_{3,102}$ = 1.60, p = n.s.], nor pregnancy [$F_{1,34}$ = .37, p =n.s.]. Once again, follow up *t*-tests using the Bonferroni correction for multiple tests showed that pregnant women in the 3rd trimester of pregnancy were more likely to report nesting behaviours than non-pregnant women (pregnant mean score = 18.8 ± 5.4, nonpregnant mean score = 13.3 ± 4.4, t_{37} = -2.64, p < .01).

The next step in our analysis was to identify items that scored low in an interitem correlation matrix, and to identify items that did not vary as the result of reproductive status; several items were excluded based on these analyses. Items that did not pertain specifically to nesting but were included as a check for honest reporting, such as "Right now, I find it difficult to stand for extended periods of time" were also excluded at this time. Three of the items are described below in the results section on "lethargy" as we did find a significant effect of pregnancy. Next, we analyzed the validity and internal reliability of our items.

Internal Validity and Reliability of the 16 item Nesting Scale

Based on reliability and Principle Components analyses the remaining items

were reduced to a 16-item nesting scale. A confirmatory Principle Components Analysis showed that the nesting scale consists of two subscales, space preparation (see Table 2) and social withdrawal (see Table 3). An exploratory Principle Components Analysis showed that the space preparation subscale is best captured by two factors; one factor pertaining to cleaning and energy levels, and the second factor pertaining to attitude; a mental focus on household projects, as opposed to work or other projects outside of the home. We combined the two factors into one subscale as both constructs pertain to complementary aspects of space preparation.

(Table 2 about here)

(Table 3 about here)

The social withdrawal subscale contains items related to social behaviours and a preference for familiar environments. The items in this scale highlight the prediction that social withdrawal in women does not result in complete isolation, but will instead manifest as a preference for familiar places (e.g., "Currently, I prefer familiar environments."), and people (e.g., "Currently, I prefer if my partner/husband stays close to home."). (The few participants in the non-pregnant group who did not have a partner or boyfriend were instructed to answer the question thinking about the most important person in their life with whom they normally do activities). Results of the Principle Components Analysis can be found in Table 4.

(Table 4 about here)

Reliability

In order to determine internal reliability we analyzed the social withdrawal and space preparation subscales separately for each trimester for the pregnant participants. In the first trimester session, the space preparation subscale did not exhibit good internal consistency (Cronbach's alpha = -.18). However, the social withdrawal subscale did show good internal consistency (Cronbach's alpha = .68). In the second trimester session, the space preparation subscale showed moderate internal consistency (Cronbach's alpha = .56), and the social withdrawal subscale again showed good internal consistency (Cronbach's alpha = .73). In the 3rd trimester session, the space preparation subscale (Cronbach's alpha = .84). As will be made clear by the results of the longitudinal study listed below, we consider the 3rd trimester as the critical time period for evaluating nesting behaviours.

Because we performed a longitudinal study we were also able to examine the test-retest reliability of the nesting scale. We expected moderate test-retest correlations for non-pregnant participants; although women in the non-pregnant group are not expected to change over time, scores may be sensitive to changes in mood, menstrual cycle, or season. We found that, for women in the non-pregnant

group, there was a significant correlation between all time points for the full nesting scale (see Table 5). Results were similar for the space preparation and social withdrawal subscales, although for the space preparation subscale the correlation between the second and fourth test session was not significant, and neither was the correlation between the first and fourth test session for the Social Withdrawal subscale. Overall, these results suggest that there is adequate test-retest reliability to be found in the Nesting Questionnaire and subscales.

(Table 5 about here)

Item Justification

Appendix B shows the inter-item correlation matrix for the full 40 items for pregnant and non-pregnant women at the 3rd trimester (or non-pregnant equivalent) test session. We used a Difference of Proportions test to compare pregnant and nonpregnant responses during the 3rd trimester test session. Pregnant women were significantly more likely to report "true" for 6 of 8 items on the space preparation subscale and 4 of the 8 social withdrawal items. (Question 7 of the social withdrawal subscale showed a significant main effect of pregnancy in the 2nd trimester test session.)

We chose to use a dichotomous response format; although a dichotomous response format is advantageous for shortened survey length when testing busy pregnant women, this format is not as sensitive to group differences. As a result, half of the items in the social withdrawal subscale and a quarter of the items in the space preparation subscale did not, by themselves, show a significant difference between pregnant and non-pregnant women in the third trimester test session. Additional items showed graphically an effect of pregnancy over time. Item selection was therefore a combination of examining the effect of pregnancy on individual items paired with reliability and validity analyses to determine which items clustered together. Table 6 summarizes the item-to-total correlations for the social withdrawal subscale and the two factors of the space preparation subscale.

(Table 6 about here)

Statistical Analysis

In order to measure change in reported nesting behaviours over time, and to compare reported nesting behaviours in pregnant and non-pregnant women, we used a repeated-measures analysis of variance with time as the within-subjects factor (3 levels) and pregnancy as a between-subjects factor (2 levels) on the final 16 item Nesting Questionnaire. Parity was included as a covariate. As pregnancy and the postpartum are distinctive reproductive phases, the postpartum and pregnant test sessions were analyzed separately. The full nesting scale, the space preparation subscale, and social withdrawal subscale were analyzed separately. Because we found a significant difference in reported household income and relationship status between the pregnant and non-pregnant participants we ran additional analyses

excluding any non-pregnant participants who were not in a committed relationship. When we included only pregnant (n=20) and non-pregnant (n = 13) women who were currently in a committed relationship we found no difference between the groups on any of the demographic variables; the results of the statistical analysis on the nesting, space preparation, and social withdrawal scales remained essentially unchanged from the full sample at all time points. The results presented below are with the full sample.

We also tested the energy and lethargy (a lack of energy) levels of our pregnant and non-pregnant participants. Although lethargy is often typical of late pregnancy in nonhuman mammals, the results of our Principle Components Analysis showed that two items pertaining to an "energy burst" showed high internal reliability and validity with items on the space preparation subscale: "I have experienced a burst of energy in the past week", "I have experienced a burst of energy in the past 24 hours". We ran a repeated measures ANOVA comparing reported energy bursts in pregnant and non-pregnant women, using pregnancy status as the between groups factor (2 levels) and time as the within subject factor (4 levels), with parity included as a covariate.

Three items on the original 40-item questionnaire also allowed us to examine reported lethargy over time; using these 3 items we created a lethargy scale at each testing session (see Table 7). The lethargy scale showed good internal reliability (Cronbach's alpha = .72). We used a repeated-measures ANOVA with pregnancy as the between subjects factor (2 levels) and time as the within subjects factor (4
levels). Parity was again included as a covariate.

(Table 7 about here)

5.5 Results

Changes in nesting behaviours across pregnancy

Overall Nesting

Figure 1 portrays nesting in pregnancy; we found that pregnant women were significantly more likely to engage in nesting behaviours across pregnancy than non-pregnant women $[F_{1,36} = 5.00, p = .03]$; the main effect of time was not significant $[F_{2,72} = 1.14, p = n.s.]$. We also found a significant group by time interaction $[F_{2,72} = 5.02, p = .01]$. Pregnant women reported a sharp increase in nesting behaviours from the first to the third trimester of pregnancy. Follow up multivariate analysis of variance using pregnancy as the fixed factor and including motherhood as a covariate showed that pregnant women reported significantly more nesting behaviours in the 3rd trimester test session only $[F_{1,34} = 10.69, p < .01]$. We found no significant difference between postpartum and non-pregnant control women in this last (postpartum for the previously pregnant women) test session $[F_{1,36} = 2.16, p = n.s.]$.

(Figure 1 about here)

Space Preparation

Figure 2 portrays the results of the space preparation subscale. We found a significant main effect of pregnancy $[F_{1,36} = 8.59, p < .01]$, indicating that, throughout pregnancy, pregnant women are more likely to engage in space preparation behaviours than non-pregnant women. The group by time interaction was not significant $[F_{2,72} = 1.80, p = n.s.]$, nor was the main effect of time $[F_{2,72} = ...$ 28, p = n.s.]. There were no significant differences between postpartum women and non-pregnant women in reported space preparation behaviours $[F_{1,34} = 1.55, p =$ n.s.]. Because one of the items on the space preparation subscale was tested with both pregnant and non-pregnant versions (Pregnant: "I am too busy to spend time thinking about or planning the baby room"; Non-pregnant: "I am too busy to spend time thinking about or planning my home") we removed this item and re-ran the analysis on the remaining 7 items. Our results were the same as the 8 item space preparation subscale. When comparing pregnant and non-pregnant women, the group by time interaction was not significant [$F_{2,68} = 1.73$, p = n.s.], nor was the main effect of time $[F_{2,68} = .81, p = n.s.]$. We found that pregnant women were significantly more likely to report space preparation behaviours than non-pregnant women $[F_{1,34} = 4.69, p = .04]$. Again, we found no significant differences between groups during the postpartum test session $[F_{1,36} = 3.23, p = n.s.]$.

(Figure 2 about here)

Social Withdrawal

Figure 3 portrays social withdrawal behaviours of pregnant and non-pregnant women. We found a significant group by time interaction $[F_{2,72} = 4.53, p = .01]$: non-pregnant women showed a slight decrease in reported social withdrawal behaviours over time, whereas pregnant women showed similar scores in the first and second trimester of pregnancy, and a marked increase in reported social withdrawal behaviours in the third trimester. We found no main effect of time $[F_{2,72} = 1.34, p \text{ n.s.}]$ or pregnancy $[F_{1,34} = .79, p = \text{ n.s.}]$. Postpartum women were not more likely to engage in social withdrawal behaviours than non-pregnant women $[F_{1,36} = .13, p = \text{ n.s.}]$.

(Figure 3 about here)

Lethargy across pregnancy

Figure 4 portrays patterns of lethargy over time. Pregnant women reported significantly more lethargy than non-pregnant women $[F_{1,35} = 9.94, p < .01]$. We also found that pregnant women were more lethargic in the first and third trimester, while non-pregnant women reported relatively consistent lethargy levels over time $[F_{3,105} = 3.53, p = .02]$. The main effect of time was not significant $[F_{3,105} = 1.35, p = n.s.]$. Follow up multivariate ANCOVA using pregnancy as the fixed factor and

parity as a covariate, along with the Bonferonni correction for multiple tests (.05/4) showed that pregnant women reported more lethargy in the 3rd trimester compared to non-pregnant women ($F_{1,35} = 17.71$, p < .001). We also found a trend approaching significance of pregnant women reporting more lethargy during the first trimester than non-pregnant women (pregnant mean lethargy = 1.65 ± 1.18 ; non-pregnant mean lethargy = $.79 \pm .92$, $F_{1,35} = 6.29$, p = .02), which is consistent with the crushing fatigue that is commonly reported during the first trimester.

(Figure 4 about here)

Next, we tested group differences in reported energy bursts over time. Here we found a significant group by time interaction with pregnant and non-pregnant women reporting distinctive patterns of energy bursts over time $[F_{3,108} = 2.71, p = .$ 05]: Compared to non-pregnant women, pregnant women reported an increase in energy bursts in the 3rd trimester and postpartum test sessions. Non-pregnant women, in contrast, reported a peak in energy bursts during the equivalent testing period that coincided with the 2nd trimester test session. Their scores fell to the lowest point during the postpartum test session. The main effect of pregnancy was not significant [$F_{1,36} = .97, p = n.s.$], nor was the main effect of time [$F_{3,108} = .26, p$ = .n.s.]. Although post-hoc multivariate ANCOVA showed an effect of pregnancy in the post-partum test session only [$F_{1,36} = 4.49, p = .04$], what is most interesting is that pregnant women, in the third trimester, reported an increase in energy bursts while simultaneously reporting an increase in lethargy.

5.6 Discussion

In a longitudinal study tracking pregnant and non-pregnant women we found evidence of change in behaviour peaking in the 3rd trimester of pregnancy that is consistent with a nesting psychology in human females. Nesting as an act of parental care is widespread in mammals; it is a fundamental preparatory parental behaviour, and apart from a protruding belly, one of the earliest observable signs of impending motherhood in many mammals. As in other species, nesting in women includes space preparation and social withdrawal. Rosenblatt (1990) describes the space preparation behaviours of the rabbit as a gradual development that occurs over the course of pregnancy in response to the hormones associated with pregnancy. We found a similar pattern: pregnant women reported more space preparation behaviours than non-pregnant women throughout pregnancy, peaking in the third trimester. Social withdrawal behaviours also showed a sharp increase in the third trimester of pregnancy.

Aspects of space preparation include a focus on home renovations and completion of projects, an energy burst, and the purging and sorting of household items. Evidently ridding the birthing and post-natal environment of unwanted items is prioritized as highly as organizing the items that will remain after the baby is born. Because of its prominence in popular discussions of nesting, we were surprised to find that cleaning behaviours were not a fundamental feature of nesting in women;

instead organization and project completion are prioritized more highly by preparturient women. Alternatively, cleanliness may be an important aspect of nesting that is not differentiated from non-nesting cleaning behaviours due to the modern preoccupation with cleanliness and hygiene. Given the high social value placed on cleanliness in our society, our results may also represent a report bias in both the pregnant and non-pregnant women. Future cross-cultural research investigating nesting during pregnancy may shed light on this possibility. However, it may also be the case that cleanliness is more important in the first trimester when organogenesis results in a fetus that is highly vulnerable to pathogens, and the mother is immunosuppressed; past research has found that pregnant women are more sensitive to cues denoting pathogen threat in the first trimester (Navarette, Fessler, & Eng, 2007).

One of the apparent paradoxes of nesting is the energy burst that occurs at the same time as a general decrease in physical vigor. As two items in the space preparation subscale attest, accounts in the popular press of an "energy burst" contributing to nesting are correct. Compared to non-pregnant women, pregnant women report a distinct pattern of energy bursts over time, with an increase in energy during the third trimester and the postpartum period. Pregnant women are also more likely than non-pregnant women to report a burst in energy during the last 24 hours in the 3rd trimester. At the same time, women in the third trimester of pregnancy are experiencing increased lethargy; compared to non-pregnant women, women in late pregnancy report being extremely tired, and have trouble standing for

long periods of time. Nor do women late in pregnancy report enjoyment in engaging in physical activities that they used to enjoy before becoming pregnant. These seemingly contradictory results suggest that although women in the third trimester are experiencing a significant degree of lethargy, the urge to nest is a powerful motivating source, making nesting behaviours resistant to late pregnancy lethargy. Perhaps the energy burst associated with nesting is necessary in order to overcome the increased lethargy associated with the late pregnancy, and allow for the space preparation and the social withdrawal behaviours to occur.

Social withdrawal is also a fundamental feature of nesting psychology. Compared to non-pregnant women, nesting women in late pregnancy show a preference for being close to home, and do not want to travel. At the same time, new people and places are not appealing during late pregnancy. As the items in the social withdrawal subscale attest, social withdrawal as a feature of nesting in human females does not mean isolation. Nesting women show a strong preference for kin and close friends, and they also report a desire to keep their husbands or partners close to home. In the evolutionary past kin served as birth attendants; their presence during labour and early postpartum may offer a critical advantage (Trevathan, 1988). Although fathers have been shown to aid with parturition in some species, including hamsters (Jones & Wynne-Edwards, 2000) and mice (Lee & Brown, 2002), fathers were not typically birth attendants. However, fathers have been shown to participate in pre-parturient space preparation (Jordan, 1990), and there are several reasons why a preference for keeping the father close to home is an adaptive feature of nesting in

human females. First, fathers may contribute to nest building. For example, Gabb (1875) reports that men in tribal Costa Rica go out into the woods and prepare a hut when labour pains begin. Contributing to nesting and being part of the birthing experience may also promote father-infant bonding (Vehvilainen-Julkunen & Liukkonen, 1998; Chandler & Field, 1997). Engaging in nesting behaviours together may promote cooperation between the mother and the father at a time when cooperation is crucial. Finally, fathers may play an important role keeping the infant safe in the immediate postpartum period.

Three limitations of this study need to be addressed. First, this study used a relatively small sample. Small samples are not ideal for scale development; future research could investigate nesting in a large-scale design, perhaps using an online methodology. In addition to using a relatively small sample, we also used a dichotomous response format. Although dichotomous and multichotomous response formats have been shown to produce similar results (Netemeyer, Bearden, & Sharma, 2003, p. 101), had we employed a multichotomous response format we would have had more power to assess how pregnancy effects individual items. A dichotomous response format paired with the small sample size used herein is therefore a serious limitation of this study. However, longitudinal data tracking pregnant and non-pregnant women over several time points did allow us to measure test-retest reliability while the expected peak in nesting in the 3rd trimester of pregnancy, show that nesting as a functional parental task warrants further investigation in human females. This study is also limited in the demographic

differences between the pregnant and non-pregnant participants; pregnant women were more likely to be in a committed relationship and reported higher household income than non-pregnant participants. It is difficult to assess how increased income and likelihood of being in a committed relationship may be influencing the results reported here. However, when we compared pregnant and non-pregnant women who were in a committed relationship only, we found the same pattern of results reported above, suggesting that differences in reproductive status (pregnancy, the postpartum period) are the best explanation for our results.

As there has been little scientific attention directed at nesting behaviours in women we conclude by suggesting areas of future research. An emerging and controversial trend in Western culture is a preference for home births (Wax et al., 2010; Keirse, 2010). Future research could examine whether women with a strong urge to nest are more likely to select home births, and whether birthing environments that permit nesting behaviours to occur, such as birth centers and personal homes, result in more satisfaction with the birthing experience or improved mother-neonate interaction. There is evidence suggesting that mothers who select home births believe that they are able to exert more control over the physical environment (Morison et al., 1998); controlling the physical environment seems to be a key feature of nesting in human females. Future studies could also evaluate whether nesting during pregnancy influences the experience of pregnancy, parturition, or the postpartum period. Walsh (2006), who investigated the experiences of women who chose a birthing center over a hospital, reports that birthing centers, as opposed to

hospitals, allow women to experience nesting, thereby decreasing the anxiety often associated with parturition.

Future research could also examine when, exactly, nesting behaviours end in women. That we see a decline in nesting behaviours at 8 weeks postpartum indicates that women, who were preoccupied with space preparation and control over their immediate social environment in the weeks approaching parturition, have switched their priorities in a new direction during the early postpartum period. Caring for their infants is now the primary concern. This may be one reason that nesting during pregnancy is so important; human infants are extremely vulnerable and dependent, and as a result infant care is all consuming in the early postpartum period. A safe environment must be built during pregnancy; there is no time in the early postpartum period, once the baby is born. Space preparation behaviours are predicted to show a sharp decline in the first few days postpartum as a result of secondary altriciality; future research could also examine when social withdrawal behaviours are complete. We would predict that, compared to space preparation behaviours, social withdrawal behaviours may be longer lasting. There is evidence that the first 28 days postpartum are the most critical to infant survival (Lawn, Cousens, & Zupan, 2005), and a period of seclusion for the mother and infant in the first 20-40 days postpartum is common cross-culturally (Winch et al., 2005; reviewed in Dennis, 2007); future research could determine more precisely the timeframe when nesting behaviours conclude in human females. Future research could also examine whether there are different behaviours associated with nesting in

the 3rd trimester generally, and more specific nesting behaviours in the hours approaching childbirth and during parturition.

The nesting scale is a formalized conceptualization of nesting in human females. It is a starting point in allowing researchers and clinicians to evaluate nesting behaviours in women. There is anecdotal evidence suggesting that women may delay the onset of labour if the environment does not feel safe (Johnston, 2004). The behaviours associated with nesting include space preparation and social withdrawal, both of which peak in the third trimester of pregnancy. Together, they serve a protective function in reducing harm from predators, conspecific males, and pathogens, and providing a safe environment in which to give birth. As has been described in other mammals, nesting in human females helps mothers prepare for parturition and their newborns.

5.7 References

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5.8 Tables & Figures

Table 1.	The 40	item	Nesting	Instinct	Question	naire.

Qu	estion	Difference of Proportions
1.	In the past 6 months, I have spent a great deal of	$(z = -1.45, \Phi =23, p = .07)$ •
	energy on home renovations.	
2.	Currently, I would prefer if my husband/partner	$(z =83, \Phi =13, p = n.s.)$
	stayed close to home.	
3.	I like to keep a tidy house.	$(z =08, \Phi =01, p = n.s.)$
4.	I find that I prefer to spend time at home with close family and friends.	$e (z = .34, \Phi = .05, p = n.s.)$
5.	I have a strong desire to finish projects before the	$(z =83, \Phi =13, p = n.s.)$
	baby arrives.	
	NP: I have a strong desire to finish up my projects	
	in the next few months.	
6.	Lately, I've had a strong urge to withdraw into my	$(z = -1.13, \Phi =18, p = n.s.)$
	house and get everything inside just the way I like	
	it.	
7.	At this time I would prefer not to leave the house,	$(z =71, \Phi =11, p = n.s.)$
	even to go grocery shopping.	
8.	I find it stressful that my house is not as organized	$(z = .52, \Phi = .08, p = n.s.)$
	as I would like.	
9.	When thinking about the baby, I often get the urge	$(z =09, \Phi =02, p = n.s.)$
	to organize my home.	
	NP: When I am stressed, I often get the urge to re-	
	organize my home.	
10.	Recently, I have experienced an uncontrollable urge	$e(z = -1.14, \Phi =23, p = .07)^{\bullet}$
	to re-organize and cleanse my home.	
11.	Although some people may find my house messy,	$(z =54, \Phi =09, p = n.s.)$
	the clutter makes me feel at home.	
12.	In the past 3 years, I have been compulsive about	$(z = .46, \Phi = .07, p = n.s.)$
	cleaning and organizing my home.	
13.	I prefer not to travel at this time.	$(z = -4.25, \Phi =69, p < .001)$ **
14.	Recently, I've surprised myself by how much I care	$e(z = -1.21, \Phi =19, p = n.s.)$
	about having my house perfect in terms of	
	organization and cleanliness.	
15.	Recently, I have spent a lot of time sorting through	$(z =81, \Phi =13, p = n.s.)$
	and purging household items.	
16.	I am too busy to spend time thinking about or	$(z = -1.99, \Phi =32, p = .02)*$
	planning the baby room.	
	NP: I am too busy to spend time thinking about or	
	planning my home.	

17.	I find myself thinking often about re-decorating/re-	$(z =57, \Phi =09, p = n.s.)$
	organization details.	
18.	Lately, I've felt that even close personal friends are	$e (z = -1.56, \Phi = .25, p = .06)$ •
	invading my personal space when they visit my	
	home.	
19.	Currently, I prefer familiar environments.	$(z =79, \Phi = .30, p = n.s.)$
20.	I have experienced a burst of energy in the past	$(z =91, \Phi =15, p = n.s.)$
	week.	
21.	I find myself imagining exotic places and wishing l could be traveling.	$(z = -3.05, \Phi =49, p < .01)$ **
22.	I prefer not to travel within Ontario at this time.	$(z = -1.98, \Phi =32, p = .02)*$
23.	I am anxious about the fact that the baby room is not ready.	$(z =79, \Phi = .13, p = n.s.)$
	NP: I am anxious about the fact that my home	
$\frac{1}{2^{1}}$	L have changed the haby room to make sure that it.	$(z - 11 \Phi - 02 p - p_{c})$
24.	is perfect more than once	$(211, \Psi02, p - 11.5.)$
	NP: I have changed the kitchen (or other room) to	
	make that it is perfect more than once	
25	I have changed the baby room to make sure that it	$(z = 04 \ \Phi = -01 \ n = n s)$
23.	is perfect more than three times	$(2 .07, \Psi .01, p, p)$
	NP. I have changed the kitchen (or other room) to	
	make sure that it is perfect more than three times	
26	Lately things Lused to tolerate in terms of	$(z = 11 \ \Phi = -02 \ n = n s)$
20.	cleanliness and organization have become	(2 .11, 1 .02, p 11.0.)
	intolerable I need everything just so	
27	Recently things that didn't use to bother me such	$(z = -46 \Phi = -07 p = n s)$
_,.	as family members leaving mess or clutter around	
	the house makes me angry/upset/anxious	
28	I enjoy working out and engaging in all of the	$(z = -3.04 \ \Phi = -49 \ p < 01)**$
_0.	physical activities I enjoyed before I became	
	pregnant	
	NP. I enjoy working out and engaging in all the	
	physical activities	
29.	How the baby room looks is not a matter of great	$(z = -1.67, \Phi =28, p = .05.)*$
_>.	importance	(2 1.07, 1 .20, p 1.001)
	NP. How my home looks is not a matter of great	
	importance.	
30.	Right now, I find it difficult to stand for extended	$(z = -4.32, \Phi =69, p < .001)**$
	periods of time.	

31. I want to ensure that the baby room is appropriate	$(z = -2.67, \Phi =43, p < .01)$ **
for the gender of the baby.	
NP: It is important that my home offers a certain	
ambience.	
32. I wouldn't characterize myself as having an above	$(z =91, \Phi =15, p = n.s.)$
average amount of concern with the level of	
hygiene in my home.	
33. At this time I find new places and people exciting.	$(z = -2.72, \Phi =44, p < .01)$ **
34. Currently, I find being around strangers	$(z =34, \Phi =05, p = n.s.)$
uncomfortable.	2 ND trimester test session:
	$(z = -1.81, \Phi =29, p = .04)*$
35. I have experienced a burst of energy in the past 24	$(z = -1.81, \Phi =29, p = .03)*$
hours.	
36. I would rather focus on getting my work complete	$(z = -2.12, \Phi =34, p < .02)*$
than fixing up my home.	
37. Personal space in my home is not currently a top priority.	$(z = -2.72, \Phi =44, p < .01)$ **
38. Currently, I prefer staying close to home.	$(z = -2.49, \Phi =40, p = .01)$ **
39. I find that I am constantly tired at this time.	$(z = -2.08, \Phi =33, p = .02)*$
40. I would not characterize myself as wanting to purg the dirt from my home	$pe(z = .96, \Phi = .15, p = n.s.)$
Note Items with a non-pregnant alternative question a	re labeled "NP" The

tvote. Items with a non-pregnant alternative question are labeled, "NP". The difference of proportions test compares pregnant and non-pregnant responses at the 3rd trimester (or equivalent) test session.

 Table 2. The space preparation subscale.

1	In the past 6 months, I have spent a great deal of energy on	Т
	home renovations.	F
2	I am too busy to spend time thinking about or planning the	Т
	baby room/my home. ®	F
3	Recently, I have experienced an uncontrollable urge to re-	Т
	organize and cleanse my home.	F
4	I would rather focus on getting my work completed than on	Т
	fixing up my home. ®	F
5	Recently, I have spent a lot of time sorting through and	Т
	purging household items.	F
6	I have experienced a burst of energy in the past week.	Т
		F
7	I have experienced a burst of energy in the past 24 hours.	Т
		F
8	I find myself imagining exotic places and wishing I could	Т
	be traveling. ®	F

Reverse-score items.

Table 3. The social withdrawal subscale.

1	I find that I prefer to spend time at home with close family	Т
	and friends.	F
2	Lately, I've had a strong urge to withdraw into my house	Т
	and get everything inside just the way I like it.	F
3	Currently, I would prefer if my partner/husband stayed clos	еТ
	to home.	F
4	I prefer not to travel at this time.	Т
		F
5	Currently, I prefer familiar environments.	Т
		F
6	At this time I find new places and people exciting. ®	Т
		F
7	Currently, I find being around strangers uncomfortable.	Т
		F
8	Currently, I prefer staying close to home.	Т
		F

Reverse-score items.

Table 4. Nesting Questionnaire: Principle components analysis factor loadings on the items pertaining to space preparation (2 factors) and social withdrawal (1 factor) (n=20).

Item	Space Preparation	Space	Social Withdrawal
	1.	Duananatian	
	1:	Preparation	
	Mental Focus and	2:	
	Projects	Cleaning and	
		Enormy	
In the past 6 months I	51	Ellergy	
have spent a great deal	.01		
of energy on home			
renovations			
I am too busy to spend	.45		
time thinking about or			
planning my home. ®			
I find myself imagining	g.82		
exotic places and			
wishing I could be			
traveling. ®			
I would rather focus on	1.73		
getting my work			
completed than on			
fixing up my home. ®			
Recently, I have		.52	
experienced an			
uncontrollable urge to			
re-organize and cleanse	2		
my home.			
Recently, I have spent a	a	.64	
lot of time sorting			
through and purging			
household items.			
I have experienced a		.81	
burst of energy in the			
past week.			
I have experienced a		.86	
burst of energy in the			
past 24 hours.			

(1	
.61	
.45	
.38	
.54	
.72	
.77	
.50	
.80	
	.61 .45 .38 .54 .72 .77 .50 .80

Nesting:		1 st test	2 nd test	3 rd test	4 th test
Full Scale		session	session	session	session
Non-pregna	nt participants				
1 st test	Nesting		.77**	.50*	.48*
session	Space		.58**	.50*	.52*
	Preparation				
	Social		.60**	.50*	.32
	Withdrawal				
2 nd test	Nesting	.77**		.71**	.57*
session	Space	.58**		.58**	.39
	Preparation				
	Social	.60**		.76*	.76**
	Withdrawal				
3 rd test	Nesting	.50*	.71**		.60**
session	Space	.50*	.58**		.55*
	Preparation				
	Social	.50*	.76*		.56*
	Withdrawal				
4 th test	Nesting	.48*	.57*	.60**	
session	Space	.52*	.39	.55*	
	Preparation				
	Social	.32	.76**	.56*	
	Withdrawal				

 Table 5. Correlations between nesting scale scores for non-pregnant women.

Significant at the .05 level * Significant at the .01 level **

	Scale mean	Scale Range	Item-to-total	Item-to-total
			minimum	maximum
Social	.71	.65	.28	.89
Withdrawal				
Space	.78	.30	.24	.67
Preparation				
Factor 1				
Space	.51	.42	.43	.70
Preparation				
Factor 2				

Table 6. Summary of scale means and item-to-total correlations for the space preparation subscale, and the two factors of the space preparation subscale, for pregnant women in the 3^{rd} trimester (n=20).

Table 7. Lethargy scale. Principle components analysis factor loadings on the three items pertaining to lethargy (n=20).

Item	
I find that I am constantly tired at this time.	.84
I enjoy working out and engaging in all of the physical activities I enjoyed	.84
before I became pregnant.	
Right now, I find it difficult to stand for extended periods of time.	.69

Figure Captions

- *Figure 1.* Nesting across pregnancy and into the postpartum period.
- *Figure 2.* Space preparation across pregnancy and into the postpartum period.
- *Figure 3.* Social withdrawal across pregnancy and into the postpartum period.
- *Figure 4.* Lethargy across pregnancy and into the postpartum period.













Figure 4



5.9 Appendices

	canng of cauce		
Education	0	Grammar school	
	1	High school or equivalent	
	2	Vocational/technical school	
	3	Some college	
	4	Bachelor's degree	
	5	Master's degree	
	6	Doctoral degree	
	7	Professional degree (MD, JD)	
	0	\$0-9,999	
	1	\$10,000-19,999	
	2	\$20,000-29,999	
	3	\$30,000-39,999	
	4	\$40,000-49,999	
Household	5	\$50,000-74,999	
Incomo	6	\$75,000-99,999	
licome	7	\$100,000-149,999	
	8	\$150,000+	

Appendix A. Scaling of education and household income.

Appendix B. Pregnant and non-pregnant inter-item correlation matrix on the full 40 items at the 3rd trimester (or non-pregnant equivalent) test session (40*35). (3 non-pregnant participants and 1 pregnant participant were not included in this table as they had missing responses on one or more items).

Inter-item correlation matrix										
	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10
Q.1	1.000	090	.117	029	.308	.183	115	.079	.116	.151
Q.2	090	1.000	222	.238	043	.180	.272	.183	.147	047
Q.3	.117	222	1.000	.000	.103	.221	.000	.117	053	.047
Q.4	029	.238	.000	1.000	316	.391	.250	172	.360	.029
Q.5	.308	043	.103	316	1.000	.343	.000	.435	.062	.326
Q.6	.183	.180	.221	.391	.343	1.000	.361	.304	.539	.421
Q.7	115	.272	.000	.250	.000	.361	1.000	.029	.131	.115
Q.8	.079	.183	.117	172	.435	.304	.029	1.000	.379	.382
Q.9	.116	.147	053	.360	.062	.539	.131	.379	1.000	.409
Q.10	.151	047	.047	.029	.326	.421	.115	.382	.409	1.000
Q.12	.200	.194	.077	.158	160	.057	.000	.073	.083	.308
Q.13	026	.121	093	.200	.235	.461	.229	.089	.179	.485
Q.14	.180	037	.123	.060	.324	.395	060	.421	.287	.666
Q.15	004	075	.075	031	.253	.289	123	.367	.447	.621
Q.17	015	.458	053	.196	.207	.401	.294	.379	.402	.277
Q.18	.146	147	.053	.294	207	.150	.196	116	.047	146
Q.19	047	.250	.167	.467	.129	.516	.262	.070	.320	.515
Q.20	.231	145	024	.089	.093	.182	089	.112	.182	.363
Q.22	062	.250	221	.060	.057	.395	.391	.180	.287	.304
Q.23	.200	.344	103	.158	.260	.190	.316	.073	.083	.181
Q.24	.127	.075	.101	.185	.019	.359	.431	.251	.257	.491
Q.25	.157	.093	420	.086	.108	.124	.343	187	.101	.187
Q.26	054	.043	.258	.316	020	.190	.158	.200	.227	.435
Q.27	215	196	.306	.000	.219	.226	144	.248	.019	.447
Q.28	.141	257	.257	200	.018	220	372	.026	179	370
Q.30	.026	.152	.093	.086	.271	.382	.343	.141	.082	.433
Q.31	059	.180	.049	.241	.076	.112	.211	.183	.264	.059
Q.34	.029	.272	.000	.250	158	.211	.464	115	033	.115
Q.35	.090	190	167	.102	.043	037	.068	183	.009	.047
Q.38	059	.324	123	.391	057	.620	.361	.183	.401	.421
Q.39	.079	.183	211	.258	073	.183	.315	036	.247	.266
R.11	.031	.018	147	180	028	070	045	.031	006	.149
R.16	.258	.068	.000	.464	158	.241	.071	172	.196	.029
R.21	.304	028	.167	.029	.129	.270	.117	.187	.454	.632
R.29	.115	.068	.000	.107	.158	060	.071	.115	.196	.029
R.32	.127	218	.101	123	117	030	.123	.004	024	.244
R.33	.079	.183	211	.258	.054	.425	.315	.079	.379	.266
R.36	.183	.037	.221	211	.076	014	.060	.062	012	.059

Inter-item correlation matrix										
	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10
Q.1	1.000	090	.117	029	.308	.183	115	.079	.116	.151
Q.2	090	1.000	222	.238	043	.180	.272	.183	.147	047
Q.3	.117	222	1.000	.000	.103	.221	.000	.117	053	.047
R.37	.026	257	070	343	.145	.021	.057	089	049	.203
R.40	.181	194	.103	.000	.160	057	316	.054	.062	.073
	Q.12	Q.13	Q.14	Q.15	Q.17	Q.18	Q.19	Q.20	Q.22	Q.23
Q.1	.200	026	.180	004	015	.146	047	.231	062	.200
Q.2	.194	.121	037	075	.458	147	.250	145	.250	.344
Q.3	.077	093	.123	.075	053	.053	.167	024	221	103
Q.4	.158	.200	.060	031	.196	.294	.467	.089	.060	.158
Q.5	160	.235	.324	.253	.207	207	.129	.093	.057	.260
Q.6	.057	.461	.395	.289	.401	.150	.516	.182	.395	.190
Q.7	.000	.229	060	123	.294	.196	.262	089	.391	.316
Q.8	.073	.089	.421	.367	.379	116	.070	.112	.180	.073
Q.9	.083	.179	.287	.447	.402	.047	.320	.182	.287	.083
Q.10	.308	.485	.666	.621	.277	146	.515	.363	.304	.181
Q.12	1.000	235	.343	.019	.083	.207	.258	.168	057	120
Q.13	235	1.000	.262	.289	.179	179	.443	.199	.623	.145
Q.14	.343	.262	1.000	.489	.150	150	.344	.317	014	.209
Q.15	.019	.289	.489	1.000	.165	165	.075	.393	.230	.019
Q.17	.083	.179	.150	.165	1.000	.047	.320	.317	.287	.372
Q.18	.207	179	150	165	.047	1.000	.080	.089	150	.062
Q.19	.258	.443	.344	.075	.320	.080	1.000	.266	.098	.258
Q.20	.168	.199	.317	.393	.317	.089	.266	1.000	057	093
Q.22	057	.623	014	.230	.287	150	.098	057	1.000	.076
Q.23	120	.145	.209	.019	.372	.062	.258	093	.076	1.000
Q.24	.253	.204	.159	.193	.398	.306	.427	.371	.159	.253
Q.25	108	.176	124	.116	.101	101	.140	.223	.237	.271
Q.26	.300	.145	.343	.156	.227	083	.258	.037	.209	.020
Q.27	.037	.149	.382	.409	113	019	.236	051	104	.037
Q.28	145	542	141	165	179	.049	327	.155	502	018
Q.30	145	.716	.341	.204	049	213	.373	081	.341	.108
Q.31	.190	141	112	.030	.401	.425	.270	.182	112	.190
Q.34	.158	.229	.090	123	.131	.196	.262	089	.241	.474
Q.35	043	.152	.037	.222	.165	.147	.028	.708	.037	194
Q.38	.057	.702	.395	.159	.264	.012	.639	.182	.522	.190
Q.39	.073	.318	.059	127	015	116	.187	363	.300	.200
R.11	.028	010	.070	.144	211	200	110	096	.070	.028
R.16	.158	.200	241	185	.033	.131	.321	.237	.060	158
R.21	.258	.327	.344	.327	.053	187	.524	.266	.221	.000
R.29	.000	.200	090	.123	.196	033	.029	059	.211	.158
R.32	019	042	.159	072	024	.024	075	138	100	019

	Q.12	Q.13	Q.14	Q.15	Q.17	Q.18	Q.19	Q.20	Q.22	Q.23
Q.1	.200	026	.180	004	015	.146	5047	.231	062	.200
Q.2	.194	.121	037	075	.458	147	.250	145	.250	.344
Q.3	.077	093	.123	.075	053	.053	.167	024	221	103
R.33	181	.662	.059	127	.116	.015	.421	125	.421	.200
R.36	.057	.220	.014	.030	287	264	.025	068	.268	209
R.37	018	.258	.220	.081	310	213	.023	.155	021	145
R.40	.260	271	.190	.117	.062	.083	.129	.224	343	020
	Q.24	Q.25	Q.26	Q.27	Q.28	Q.30	Q.31	Q.34	Q.35	Q.38
Q.1	.127	.157	054	215	.141	.026	059	.029	.090	059
Q.2	.075	.093	.043	196	257	.152	.180	.272	190	.324
Q.3	.101	420	.258	.306	.257	.093	.049	.000	167	123
Q.4	.185	.086	.316	.000	200	.086	.241	.250	.102	.391
Q.5	.019	.108	020	.219	.018	.271	.076	158	.043	057
Q.6	.359	.124	.190	.226	220	.382	.112	.211	037	.620
Q.7	.431	.343	.158	144	372	.343	.211	.464	.068	.361
Q.8	.251	187	.200	.248	.026	.141	.183	115	183	.183
Q.9	.257	.101	.227	.019	179	.082	.264	033	.009	.401
Q.10	.491	.187	.435	.447	370	.433	.059	.115	.047	.421
Q.12	.253	108	.300	.037	145	145	.190	.158	043	.057
Q.13	.204	.176	.145	.149	542	.716	141	.229	.152	.702
Q.14	.159	124	.343	.382	141	.341	112	.090	.037	.395
Q.15	.193	.116	.156	.409	165	.204	.030	123	.222	.159
Q.17	.398	.101	.227	113	179	049	.401	.131	.165	.264
Q.18	.306	101	083	019	.049	213	.425	.196	.147	.012
Q.19	.427	.140	.258	.236	327	.373	.270	.262	.028	.639
Q.20	.371	.223	.037	051	.155	081	.182	089	.708	.182
Q.22	.159	.237	.209	104	502	.341	112	.241	.037	.522
Q.23	.253	.271	.020	.037	018	.108	.190	.474	194	.190
Q.24	1.000	.253	.389	.338	081	.042	.359	.277	.071	.359
Q.25	.253	1.000	108	198	176	.167	.124	.343	.315	.124
Q.26	.389	108	1.000	.292	145	.108	.057	.158	043	.190
Q.27	.338	198	.292	1.000	.083	.198	017	.000	216	.104
Q.28	081	176	145	.083	1.000	601	.141	086	016	461
Q.30	.042	.167	.108	.198	601	1.000	341	.200	016	.502
Q.31	.359	.124	.057	017	.141	341	1.000	.211	.106	014
Q.34	.277	.343	.158	.000	086	.200	.211	1.000	102	.361
Q.35	.071	.315	043	216	016	016	.106	102	1.000	037
Q.38	.359	.124	.190	.104	461	.502	014	.361	037	1.000
Q.39	.004	.157	.200	099	548	.485	300	.172	320	.304
R.11	144	.062	.028	.052	.010	.010	070	045	018	070
R.16	.339	.086	.158	.000	057	057	.090	.071	.102	.241
R.21	.302	.140	.258	.000	443	.373	098	029	.028	.393
R.29	.185	.086	.158	144	200	057	.391	.071	068	.090
	Q.24	Q.25	Q.26	Q.27	Q.28	Q.30	Q.31	Q.34	Q.35	Q.38
------	------	------	------	------	------	------	------	------	------	------
Q.1	.127	.157	054	215	.141	.026	059	.029	.090	059
Q.2	.075	.093	.043	196	257	.152	.180	.272	190	.324
Q.3	.101	420	.258	.306	.257	.093	.049	.000	167	123
R.32	.205	116	.253	.213	081	.165	289	185	075	030
R.33	.127	.157	.073	099	433	.600	059	.315	183	.666
R.36	159	237	.057	139	100	.262	268	090	180	.239
R.37	.042	.167	018	.083	258	.428	461	086	.121	.141
R.40	.019	271	160	.091	.145	235	057	474	.043	190

Inter-Item Correlation Matrix

	Q.39	R.11	R.16	R.21	R.29	R.32	R.33	R.36	R.37	R.40
Q.1	.079	.031	.258	.304	.115	.127	.079	.183	.026	.181
Q.2	.183	.018	.068	028	.068	218	.183	.037	257	194
Q.3	211	147	.000	.167	.000	.101	211	.221	070	.103
Q.4	.258	180	.464	.029	.107	123	.258	211	343	.000
Q.5	073	028	158	.129	.158	117	.054	.076	.145	.160
Q.6	.183	070	.241	.270	060	030	.425	014	.021	057
Q.7	.315	045	.071	.117	.071	.123	.315	.060	.057	316
Q.8	036	.031	172	.187	.115	.004	.079	.062	089	.054
Q.9	.247	006	.196	.454	.196	024	.379	012	049	.062
Q.10	.266	.149	.029	.632	.029	.244	.266	.059	.203	.073
Q.12	.073	.028	.158	.258	.000	019	181	.057	018	.260
Q.13	.318	010	.200	.327	.200	042	.662	.220	.258	271
Q.14	.059	.070	241	.344	090	.159	.059	.014	.220	.190
Q.15	127	.144	185	.327	.123	072	127	.030	.081	.117
Q.17	015	211	.033	.053	.196	024	.116	287	310	.062
Q.18	116	200	.131	187	033	.024	.015	264	213	.083
Q.19	.187	110	.321	.524	.029	075	.421	.025	.023	.129
Q.20	363	096	.237	.266	059	138	125	068	.155	.224
Q.22	.300	.070	.060	.221	.211	100	.421	.268	021	343
Q.23	.200	.028	158	.000	.158	019	.200	209	145	020
Q.24	.004	144	.339	.302	.185	.205	.127	159	.042	.019
Q.25	.157	.062	.086	.140	.086	116	.157	237	.167	271
Q.26	.200	.028	.158	.258	.158	.253	.073	.057	018	160
Q.27	099	.052	.000	.000	144	.213	099	139	.083	.091
Q.28	548	.010	057	443	200	081	433	100	258	.145
Q.30	.485	.010	057	.373	057	.165	.600	.262	.428	235
Q.31	300	070	.090	098	.391	289	059	268	461	057
Q.34	.172	045	.071	029	.071	185	.315	090	086	474
Q.35	320	018	.102	.028	068	075	183	180	.121	.043
Q.38	.304	070	.241	.393	.090	030	.666	.239	.141	190
Q.39	1.000	.031	.115	.304	029	.374	.655	.062	.256	326
R.11	.031	1.000	.045	.073	180	.243	.031	.119	.190	028
R.16	.115	.045	1.000	.321	.107	123	.258	.090	.086	.000

	Q.39	R.11	R.16	R.21	R.29	R.32	R.33	R.36	R.37	R.40
Q.1	.079	.031	.258	.304	.115	.127	.079	.183	.026	.181
Q.2	.183	.018	.068	028	.068	218	.183	.037	257	194
Q.3	211	147	.000	.167	.000	.101	211	.221	070	.103
R.21	.304	.073	.321	1.000	.175	.050	.304	.393	.373	.129
R.29	029	180	.107	.175	1.000	277	.115	.241	200	.000
R.32	.374	.243	123	.050	277	1.000	.127	030	.165	.019
R.33	.655	.031	.258	.304	.115	.127	1.000	.183	.256	326
R.36	.062	.119	.090	.393	.241	030	.183	1.000	.141	.076
R.37	.256	.190	.086	.373	200	.165	.256	.141	1.000	108
R.40	326	028	.000	.129	.000	.019	326	.076	108	1.00
										0

Inter-Item Correlation Matrix

CHAPTER 6 GENERAL DISCUSSION

6.1 Summary of Findings and Contributions

This thesis investigates cognitive processes in pregnancy and the postpartum period. Pregnancy is a distinct phase in a woman's life, marked overtly by increased body mass, varicose veins, melasma (a cosmetic skin condition also referred to as the "pregnancy mask"), and stretch marks. The internal changes that occur as the result of pregnancy are even more dramatic. Like other female mammals, women experience changes to their cardiovascular, metabolic, and endocrine systems as the result of pregnancy. Moreover, these changes are occurring at a time when women are uniquely vulnerable: not only are they undergoing a transformative experience psychologically and physiologically, they are also responsible for the safekeeping of an important reproductive investment, their fetuses. Although women often report that pregnancy results in cognitive impairment, the results reported herein suggest that cognition in pregnancy is better understood in terms of cognitive reorganization. Pregnancy-induced cognitive reorganization is complex, involving compromised cognitive function in some areas and enhanced cognition in others.

The research described in this thesis sought to answer three main questions. First, I examined whether human pregnancy results in a decline in cognitive functioning in general or specific domains. Second, I tested a novel hypothesis, derived from the logic of evolutionary psychology, that pregnancy results in an advantage in social cognition. Third, I investigated nesting in human females from a functional perspective. Taken together, the results suggest that pregnancy does not result in a general decline in

cognitive functioning, but that instead while there are specific pregnancy-induced impairments in some aspects of cognition, such as quantitative reasoning and processing speed, there are also other specific cognitive advantages. Face recognition, especially of same-race male faces, is facilitated during pregnancy. Nesting occurs in women, characterized by space preparation and social withdrawal. Both facilitated social processing and nesting may serve a protective function.

6.1.1. Cognitive performance in pregnancy and the postpartum period

In chapters 2 and 3, I examined pregnancy-induced cognitive performance, first establishing the theoretical background and next describing an empirical test of predictions derived from this theoretical consideration. The purpose of these chapters was twofold. First, I sought to make sense of the equivocal results that have often been reported in human females surrounding memory deficits as the result of pregnancy. I contrasted the prevailing "deficit" view held by most researchers investigating pregnancy-induced cognitive change in human females with the neural plasticity and cognitive advantage view that typifies the literature describing pregnancy-related cognitive changes in nonhuman animals. In particular, past research investigating cognitive change in women has focused on memory decline, with researchers employing diverse methods and testing only specific memory processes, often with limited samples. As a result, we are still unable to adequately describe pregnancy-induced cognitive change in humans.

Second, I wanted to contribute longitudinal data comparing the cognitive performance of pregnant and non-pregnant women, and also this performance from preconception through postpartum. My aim was to find evidence either for or against pregnancy-induced cognitive change using standardized cognitive instruments that have been tested on large populations (WAIS-III and Stanford-Binet 5).

While I found no evidence of a general cognitive decline in pregnancy, I did find evidence of compromised cognitive functioning in some areas, including mathematical reasoning and processing speed. A late pregnancy deficit in processing speed has been reported in other recent studies (Oynper, Searleman, Thacher, Maine, & Johnson, 2010; Christensen, Leach, & MacKinnon, 2010). Because processing speed is an important marker of general cognitive functioning (Kail & Salthouse, 1994), and has been found to possess a memory component (Joy, Kaplan, & Fein, 2004), I speculate that it is possible that it is this impairment that underlies the common reports of cognitive impairment made by pregnant women.

The results of this longitudinal study also suggest that the cognitive performance of pregnancy and the postpartum period are distinct; and that there are important differences occurring at each of these reproductive stages. Although processing speed returned to nearly pre-conception levels by 2 months postpartum, I found evidence of a general decline in cognitive functioning in the early postpartum period, especially in nonverbal performance. This general deficit was not present in pregnancy. Future studies could examine whether the performance deficit represents an actual impairment in cognitive functioning, or is instead related to motivational factors, or other factors such as

sleep disruptions. It may be that the single-minded focus that human females devote to their newborn infants in the first few months of life undermines the motivation required to perform well on FSIQ and PIQ tasks, rather than there being an actual decrease in cognitive potential.

6.1.2 Enhanced social cognition

Recognition of novel faces by pregnant and non-pregnant women was reported in chapter 4. In contrast to the focus on pregnancy-induced memory deficits of previous studies, I sought to show that by adopting an adaptationist perspective surprising new results could be uncovered. I predicted that the high stakes involved in pregnancy would result in a cognitive advantage in face processing: pregnant women, who are at their most vulnerable, are hosting an important investment, their fetuses, who are also vulnerable. Pregnant women, today and in the past, are vulnerable to the threat of male violence. Conspecific males are capable of harming non-pregnant women, but they are also capable of pregnant women, their fetuses, and their infants. An adaptive reply to this social challenge would have been increased vigilance to the social environment, specifically to novel males. Past research suggests that women are particularly sensitive to outgroup males, and that recognition of outgroup males is enhanced when self-protective mechanisms are activated (Becker et al., 2010). The results of this chapter show a pregnancy-induced advantage of recognition memory for threatening social stimuli. Women who were more vigilant with respect to face information may have possessed an

advantage in the environment of evolutionary adaptedness (EEA) over women who were less alert, resulting in the recognition advantage reported here.

6.1.3 Nesting in human females

In chapter 5, I presented a novel "nesting" questionnaire, along with longitudinal data showing that pregnant women exhibit frequent nesting behaviours. Pregnancy-related nesting behaviours, defined as measurable change in attitudes and behaviours focused on parturition, peak in the 3rd trimester of pregnancy before declining in the early postpartum period. Like other nonhuman mammals, nesting women have solved two categories of problems: finding and preparing an acceptable birth-site, and regulating who is present during parturition.

Space preparation in women includes two aspects: 1) a behavioural aspect involving energy bursts and cleaning and organizing behaviors, and 2) a mental aspect where tasks within the home are prioritized more highly than tasks outside the home (work), in comparison with non-pregnant women. Social withdrawal behaviors also occur in women. However, the social withdrawal behaviours of pregnant women do not result in isolation, but rather a reduction and selection of the individuals who will be tolerated. Social withdrawal behaviours associated with nesting includes a preference for familiar environments and staying close to home, as well as a dislike of traveling. Nesting behaviours apparently serve a protective function in ensuring that the environment for parturition and the early postpartum period offers a safe haven, and that the individuals present during parturition will promote maternal and fetal survival.

6.2 Limitations

Adopting a new perspective and new approaches to the study of cognitive change during and after pregnancy may help to disambiguate the equivocal findings that are characteristic of this field. Despite emphasizing the importance of an evolutionary framework, I first tested cognitive change in pregnant women using standardized psychological measures, the reasons for which are described in chapter 3. As the results of the meta-analysis and longitudinal study show, it is now evident that pregnant women experience a mild decline in some aspects of cognitive functioning. Future work should concentrate on tasks that are ecologically valid and motivated by evolutionary theory in order to describe cognitive reorganization as the result of reproductive state.

One of the oft-cited reasons for the equivocal results surrounding memory decline in pregnancy is small sample size. Unfortunately, the studies in this thesis are similarly limited. Small sample size is an important issue as it may lead to biased results. This is especially true when the groups differ on important demographic variables, such as household income or marital status. Unfortunately, recruiting busy pregnant women is often time-consuming and challenging. Fortunately, some of the results reported here replicate conclusions drawn by past research. For example, three recent studies have reported that there is a deficit in processing speed associated with late pregnancy (Onyper et al., 2010, Christensen et al., 2010, Henry & Sherwin, 2012), and there is also mounting evidence to suggest that pregnancy results in enhanced social cognition (see chapter 2). Future research investigating cognitive reorganization as the result of pregnancy and the

postpartum period in women may benefit by making use of modern technology in order to boost sample size, perhaps by utilizing an online study design, where it is easier to recruit large samples.

6.3 Future Directions

Evolutionary psychologists examining pregnancy-induced cognitive change (Navarette, Fessler, & Eng, 2007; Pearson, Lightman, & Evans, 2009) have shown that by focusing on protective mechanisms, such as a pregnancy-induced bias in attending to threatening stimuli, the research can yield important insights, such as describing areas where pregnant women show an advantage over non-pregnant women. Protective mechanisms of pregnancy include nausea and vomiting in pregnancy (NVP), mitigated stress reactivity, and facilitated social cognition, namely threat detection (Profet, 1992; Glynn, Wadhwa, Dunkel-Schetter, Chicz-DeMet, & Sandman, 2001). Future research could investigate other pregnancy-induced protective mechanisms, such as other aspects of threat-detection or social cognition that occur as the result of pregnancy.

Future research could also investigate the possibility that there are cognitive processes other than social cognition that are buffered by protective mechanisms in pregnancy. The fact that processing speed was hindered during pregnancy while full scale IQ (FSIQ) was not suggests that although there is a real cognitive deficit associated with pregnancy, the deficit does not impair all aspects of cognitive functioning, Moreover, the results of past research suggest that the deficit in processing speed may be specific to certain nonessential tasks, and that reaction time to identify threatening stimuli

is not impaired during pregnancy (Anderson & Rutherford, 2009). More research is needed in order to adequately address these questions.

The naturalistic prospective memory (memory for future intentions) work by Rendell and Henry (2008) and Cuttler, Graf, Pawluski, and Galea (2011), along with the driving task employed by Crawley, Grant, and Hinshaw (2008) suggest that employing naturalistic testing methodologies will yield important insight into pregnancy-induced cognitive reorganization. Rendell and Henry (2008) and Cuttler et al. (2011) showed evidence of a pregnancy-related decline on a natural prospective memory task, leading these researchers to conclude that pregnant women may have a challenge completing delayed intentions in everyday life. One source of the equivocal findings in the pregnancy and cognition literature may be because the laboratory environment is not adequately sensitive to detect pregnancy-induced cognitive change, because it lacks ecological validity. The use of novel, naturalistic testing procedures, that hold ecological relevance, may be more successful in describing the cognitive change experienced by pregnant women.

Finally, the results of the longitudinal study investigating IQ change across pregnancy and the postpartum period in chapter 3 suggest that the postpartum period is a time of cognitive decline in human females. The nonhuman animal literature suggests that pup exposure is extremely important in instigating maternal cognition, and that the postpartum period results in enhanced cognition. However, it is only after weaning that many of these studies report a cognitive advantage of parous over nulliparous females. Had we tested again later in the postpartum period, after 12 or 24 months when weaning

would be more likely to have occurred, we may have found a different pattern of results; past research suggests that the cognitive disadvantage reported in chapter 3 has disappeared by 12 months postpartum (Christensen et al., 2010) Moreover, had we tested different tasks with survival-relevance to mothers or their newborns, we may also have found a different pattern of results. Future research could examine cognitive performance in the postpartum period in order to determine when this deficit disappears. Future research could also investigate the cause of the performance deficit, and attempt to separate motivational from performance factors.

6.4 Conclusions

These chapters show evidence that women experience cognitive reorganization as the result of reproductive state. In the introduction I suggested that the reports of cognitive decline could be explained in one of two ways: first, given the high costs associated with pregnancy, pregnant women experience a genuine decline in general or overall cognitive processing. Second, given the high stakes involved in pregnancy and the postpartum, there may be a functional trade-off between nonessential tasks and those that serve a protective function. The chapters herein suggest that the second possibility is more likely to be correct: pregnant women do show a decline in cognitive functioning in some areas, such as processing speed, but results also suggest that pregnancy may facilitate cognitive functioning, especially social cognition. Research on protective mechanisms in pregnant women and mothers is in its infancy; by broadening the current

focus away from deficit to advantage, future research may yield important insights into the maternal brain.

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