Rutherford, M.D. & Anderson, M.V. (2020). Changes in intelligence across pregnancy and the postpartum period. Human Ethology, 35, 91-105. https://doi.org/10.22330/he/35/091-105

Human Ethology 35(2020): 91-105
Research Article

CHANGES IN INTELLIGENCE ACROSS PREGNANCY AND THE POSTPARTUM PERIOD

M. D. Rutherford & Marla V. Anderson

Department of Psychology, Neuroscience & Behaviour, McMaster University, Hamilton, Canada

rutherm@mcmaster.ca

ABSTRACT

Although the popular press describes pregnancy-related cognitive decrements, sometimes called "baby brain", controlled studies have not consistently found reliable evidence of a decline in cognitive function during pregnancy. A functional approach measuring components of intelligence as they change across the trimesters of pregnancy and into the postpartum may help resolve this puzzle. The current study was a longitudinal study in which pregnant women and a control group took standardized IQ tests at 12-week intervals. We found no evidence of overall cognitive decline in the pregnant group, and the IQ scores of pregnant women increased more than non-pregnant control participants across matched time intervals. The increase in raw scores of fluid intelligence subscales was not statistically significant, nor was it significantly different than the increase in the control group.

Keywords: *Pregnancy, Postpartum, Cognition, Intelligence*

submitted: 12.June 2020; revised: 08.Oct. 2020; accepted: 11.Nov. 2020

CHANGES IN INTELLIGENCE ACROSS PREGNANCY AND THE POSTPARTUM PERIOD

The belief that women experience pregnancy-related changes in memory and cognition is pervasive in the popular literature (Murkoff, 2016) and among pregnant women (Jarrahi-Zadeh, Kane, Van de Castlf, Lachenbruch, & Ewing, 1969; Poser, Kassirer, & Peyser, 1986; Parsons & Redman, 1991). Up to 81% of people who are pregnant report experiencing "baby brain", a subjective decline in cognitive ability during pregnancy (Brindle, Brown, Brown, Griffith, & Turner, 1991). These reported declines span a range of cognitive function, including impaired memory, concentration, and reading, and an increase in confusion and absentmindedness (Parson and Redman, 1991; Davies et al., 2018). However, decades of research have yielded both reports of cognitive costs to pregnancy, and reports of little or no pregnancy-related change in cognition.

Pregnancy-related cognitive decline

Some researchers have reported pregnancy-related cognitive deficits (Brindle et al., 1991; Christensen et al., 1999; de Groot et al., 2003; Glynn, 2010; Parson et al., 2004; Raz, 2014; Sharp et al., 1993; Farrar et al., 2014). Most studies that have reported impairment during pregnancy focus on memory. One study reported lower scores in a pregnant group compared to non-pregnant controls from a general sample on a word recall task, though not on a recognition memory task (Sharp, Brindle, Brown, & Turner, 1993). Keenan and colleagues reported a decline in performance on a story-recall task in the pregnant group between the first and second trimester (Keenan, Yaldoo, Fuerst, & Ginsburg, 1998). Shetty and Pathak (2002) reported that women in the third trimester performed lower on the Weschler memory scale than a matched control group. Another study reported a pregnancy-related deficit in performance on tests of intentional learning when pregnant women in their first trimester were compared to matched controls (Groot, Hornstra, Roozendaal, & Jolles, 2003). Onyper and colleagues reported a lower performance on recall and subjective reports of memory decline, but no decrement in executive function in a group of pregnant women measured in the second or third trimester compared to a non-pregnant matched control group. This effect disappeared when sleep quality was included as a covariate (Onyper et al., 2010). A review of 38 studies reported a modest reduction in memory function (verbal recall, working memory, and prospective memory) in pregnant women, but primarily in women who were experiencing depression or anxiety (Ouellette and Hampson, 2018). A recent meta-analysis concludes that there is evidence of a pregnancy-related decline in memory and executive function during the third trimester (Davies et al., 2018), in agreement with a previous meta-analysis reporting a selective impairment in working memory and recall (Henry & Rendell, 2007). Two studies also reported executive function deficits when comparing pregnant women in their third trimester to matched controls (Crawley, Grant & Hinshaw, 2008; Raz, 2014).

Some reports suggest little or no pregnancy-related cognitive change

Other attempts to document pregnancy-related changes in memory and cognition have instead reported little or no pregnancy-related change (Casey et al., 1999; Logan et al., 2014; Crawley, Grant & Hinshaw, 2008; Cuttler, Graf, Pawluski, Galea, 2011). Brindle and colleagues reported no deficit in explicit memory function (Brindle et al., 1991). A longitudinal study in which two pregnant groups (one enrolled prior to pregnancy, one enrolled in the first trimester) and a control group were tested at 3-month intervals revealed no significant differences in cognitive performance on any objective measure of cognition or memory, although the pregnant group enrolled prior to pregnancy self-reported an increase in forgetting during pregnancy (Casey, 2000). McDowall and Moriarty report no significant pregnancy-related differences in either tasks requiring word fragment completion and graphic cued recall or tasks involving semantic cued recall and category generation when comparing a pregnant to a non-pregnant sample (McDowall & Moriarty, 2000). Crawley and colleagues described a longitudinal study in which a pregnant group was tested in the second and third trimester and 6 weeks and 1 year postpartum, and a control group was tested at matched intervals. No group difference in cognitive function were significant between pregnant women and matched controls. Surprisingly, the same group of pregnant women reported experiencing cognitive decline in self-assessment measures (Crawley, Dennison, & Carter, 2003).

Pregnancy-related cognitive improvements

Three studies have reported pregnancy-related improvements in cognitive function. One reported greater improvement in the pregnant group than in a matched control group on a verbal learning task (Silber, Almkvist, Larsson, & Uvnäs-Moberg, 1990). Christensen and colleagues reported that during the third trimester, pregnant women were better than matched controls at stem completion, but only when the material was pregnancy-related (Christensen, Poyser, Pollitt, & Cubis, 1999). Anderson and Rutherford (2011) reported that pregnant women were better than matched controls at recognizing unknown male faces after a single exposure.

Cognitive Changes in non-human animals during pregnancy

In rats, evidence suggests that pregnancy and the postpartum period result in cognitive enhancement, including cognitive changes that may be adaptive, promoting maternal or fetal fitness. In rats, pregnancy-related hormones have been shown alter the maternal brain, and neuroendocrine changes result in enhanced cognitive functioning, including facilitated problem solving, spatial memory, and learning (MacBeth & Luine, 2010; Kinsley & Lambert, 2008). Pregnant rats show enhanced spatial skills, foraging, and predator detection (MacBeth & Luine, 2010). Kinsley and Lambert (2006) reported enhanced hunting skills in pregnant rats compared to virgins. Nesting behaviors during pregnancy have been well-documented in rats (Rosenblatt & Lehrman, 1963), mice (Lisk, Pretlow, & Friedman, 1969), sows (Thodberg, Jensen, Herskin, & Jorgensen,1999), rabbits (Ross et al. 1963), and gorillas (Stewart,1977). In general, an adaptationist perspective, with a focus on psychological changes that enhance the fitness of the mother or offspring is characteristic of the literature on pregnancy in non-human animals. This contrasts with the characterization of the human "baby brain" in which a pregnant woman becomes forgetful and is cognitively impaired.

Refining the question

We propose refining the question in three ways. First, we will use a longitudinal design measuring intelligence during each trimester and postpartum and taking these same measures in a non-pregnant control group at matched intervals. Authors of a recent meta-analysis reported differences in general cognitive function only in the third trimester, and suggested that future research should have a longitudinal design "to clarify the progression of these cognitive differences during pregnancy" (Davies et al., 2018, p.40). This between-group longitudinal might reveal a dynamic trajectory that is obscured in a static group wise comparison. That is, if a pregnant and non-pregnant group differ on IQ for any reason (e.g. higher IQ women are more likely to remain childless (Kanazawa, 2014)), this confound would thwart our interpretation of a static group differences. Given a longitudinal design, we are able to compare changes in IQ across the two groups independent of any group difference in overall mean IQ.

Second, we will use standardized IQ tests to measures cognitive performance (Wechsler, 1997; Roid, 2003). Previous longitudinal studies have reported a self-reported sense of cognitive decline but provided no objective evidence of pregnancy-related cognitive decline (Casey, 2000; Crawley, et al., 2003). Each of those studies used a small, idiosyncratic battery of measures to test for cognitive decline. Standardized testing will allow us to objectively compare the two groups to each other using measures whose normative performance is known.

Third, it is possible that the mixed results reported across studies of cognitive changes in pregnancy might be explained by measuring specific types of intelligence. In order to examine more specific changes in IQ across pregnancy, we compare changes in fluid and crystallized intelligence. Fluid intelligence is the ability to solve novel problems, independent of accumulated past knowledge, and includes inductive and deductive reasoning. Crystallized intelligence relies on the use of knowledge and experience held in long-term memory (Cattell, 1963; Horn, 1965). Although crystallized and fluid intelligence are correlated with one another, they can vary independently.

Fluid intelligence is thought to be measurable by performance subscales, such as block design completion, digit symbol, matrix reasoning, and picture completion subscales of the Wechsler Adult Intelligence Scales (David Wechsler, 2008). The block design completion task requires the participant to use one-color or two-color blocks to recreate a design viewed as a two-dimensional picture within a prescribed time limit. The digit symbol task requires the participant copy symbols below their corresponding digit given a template as quickly as possible. It is designed to assess information processing speed and visual perception. The matrix reasoning task requires the participant to view an array of pictures with one missing square and select an image to complete the array from five options in order to satisfy the implied pattern. It measures inductive reasoning. The picture completion task requires the participant to identify what is missing from a drawn image and measures the perception of visual detail.

Crystallized intelligence is thought to be measurable by the verbal IQ subscales such as the vocabulary, information, and comprehension subscales of the Wechsler Adult Intelligence Scales. The vocabulary subscale requires participants to define words from a prepared word list. The information task requires participants to answer general knowledge questions, the answers to which one is expected to know from immersion in the culture. The comprehension subscale challenges participants to provide the proper response to social or cultural situations and tests the ability to describe abstract social conventions.

If a decline in intelligence measures during pregnancy is a result of a reallocation of resources, we would expect that fluid intelligence and crystallized intelligence could change differently in the two groups. Pregnancy-related changes in metabolic or cardiovascular function would be more likely influence fluid intelligence than crystallized intelligence. Crystallized intelligence is less likely to change across the lifespan (Cavanaugh & Blanchard-Fields, 2018). As new mothers prepare for their important new roles with new cognitive demands, there may be a pregnancy-related increase in fluid intelligence. The dissociation of these two intelligence types during pregnancy and the postpartum may shed light on the equivocal results across studies regarding changes in intelligence across pregnancy.

Current Study

This longitudinal study included a group of pregnant women and a group of non-pregnant control participants. Participants completed a standardized IQ test and an affective questionnaire at 12-week intervals starting during the first trimester for the pregnant group. Specific goals of the study were to test

1) whether changes in IQ across the trimesters of pregnancy differ between pregnant and non-pregnant samples,
2) whether these groups differ in IQ in the postpartum period and
3) whether measures of crystallized and fluid intelligence differed across groups across the duration of the pregnancy.

METHODS

Participants

The study included 25 pregnant women (age M = 30.72, SD = 3.29) and 25 non-pregnant women (age M = 30.28, SD = 3.78). Women in both groups were childless at the start of the study: The pregnant women were pregnant for the first time, and the control group did not have any children. The two groups did not differ significantly in terms of years of education, employment status, income, race or age. The two groups did not differ on Full scale IQ (FSIQ) during the first session ($t(48) = .52$, $p = .55$), nor did any subscale differ significantly between the two groups at the first session. Table 1 includes group demographics and group-wise comparisons. Participants in both groups were recruited through advertisements posted in McMaster University, and doctor's and midwives offices. This work was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Informed consent was obtained, and research was approved by the McMaster Research Ethics Board. A power analysis relying on effect size (1.21) reported in a recent meta-analysis when pregnant and non-pregnant women were compared on memory tasks (Davies et al., 2018) suggested a sample size of 32 (16 in each group) would have 80% power of detecting between-group cognitive differences. Recruiting a sample of 50 participants allowed for some data loss.

Table 1: Demographic information by Group

	Pregnant (25)	**Non-pregnant (25)**	
Years of Education	16.25 (Range = 13 to 20) (SD = 1.70)	15.88 (Range = 12 to 19) (SD = 1.30)	$t(48) = .395$, $p = 0.69$
Employment Status	19 Employed full time 6 Not employed	18 Employed full time 7 Not employed	$\chi^2(1, N=50) = 0.104$, $p = .747$
Income	94,497 (Range = 25,000 to 163,000) (SD = 43,200)	66,300 (Range = 5,000 to 175,000) (SD = 40,104)	$t(48) = .022$, $p = 0.98$
Race	22 White 1 South Asian 1 Black 1 Mixed or Other	21 White 1 South Asian 1 East Asian 2 No Reply	$\chi^2(1, N=50) = 0.166$, $p = .68$
Age	30.72 (Range = 23 to 38) (SD = 3.29)	30.28 (Range = 26 to 39) (SD = 3.78)	$t(48) = 1.36$, $p = 0.25$

Procedures
Participants completed four testing sessions. Pregnant participants were tested in the first, second and third trimesters plus a final test session about 12 weeks postpartum (mean inter-session interval: 12.12 weeks, 95%CI [11.70, 12.53]). A control group was tested at matched intervals (mean inter-session interval: 12.12 weeks, 95%CI [12.16, 12.98]). Test sessions lasted approximately an hour and a half, and participants were encouraged to take breaks as needed. Sessions were completed in a quiet laboratory setting by the experimenter who was trained on the administration of these standardized tests. The same experimenter administered tests to both the Pregnant and control groups, but due to the changing physical appearance of the Pregnant participants, the experimenter could not remain blind to participants' conditions. Participants were compensated $20 per session.

There is a concern that in a longitudinal study of IQ, scores tend to increase with repeated exposure to a standardized test. In order to minimize the practice effects that are a challenge in a longitudinal study of intelligence, cognitive performance was measured with the full scale of the WAIS-III, the Wechsler Adult Intelligence Scale, 3rd Ed (D. Wechsler, 1997), and the SB5, the Stanford-Binet Intelligence Scales, 5th Ed. (Roid, 2003) according to the following schedule: Participants were randomly assigned to either Group 1, and started with the WAIS-III, or to Group 2, and started with the SB5. Participants alternated between the WAIS-III and the SB5 in subsequent sessions. Participants also completed a questionnaire providing demographic information, including information about age, ethnicity, education level, relationship status, parity, employment status, and income.

Data Analysis Plan
Prior to our main analyses, we tested whether Test Order (whether participants saw the WAIS-III or the SB-5 first) had a significant effect on IQ, to ensure that that these groups are comparable. Next, we tested whether the Pregnant and Non-pregnant group had different trajectories across the trimesters of pregnancy, by comparing two multi-level models with IQ as the dependent variable, including analyses for FSIQ, Verbal IQ (VIQ) and Performance IQ (PIQ). Next, ANOVAs were conducted across the fourth sessions to see if the groups differed in the Postpartum, using IQ as the dependent variable. Finally, raw scores were standardized separately for crystallized and fluid subscales, and the change in these scores across the pregnancy was examined.

RESULTS

All participants completed all sessions; there was no attrition, and no data imputations were required. Prior to testing our planned hypotheses, in order to ensure that we could compare the two groups that differed with respect to which test they started with, we tested whether Test Order had an effect by comparing IQ between Order 1 (those who started with a WAIS-III test, N = 22) and Order 2 (those who started with a SB-5 test, N = 28). Because these two tests are standardized tests, we did not expect any differences between these groups. The two Test Order groups did not differ on FSIQ ($t(48) = .33$, $p = .74$), on VIQ ($t(48) = .175$, $p = .86$), nor on PIQ ($t(48) = .50$, $p = .62$). Therefore, these groups were collapsed for further analyses.

Does IQ change differently in the Pregnant and Non-Pregnant samples?
One of the main goals of this study was to test whether the relationship between IQ in pregnant and

non-pregnant samples changed across the trimesters of pregnancy. To test the effect of Gravidity on the FSIQ (Full scale IQ), VIQ (Verbal IQ), and PIQ (Performance IQ), we compared a two-level random slope model with IQ score as the dependent variable, Gravidity as the between-subjects variable, and session number as the within-subjects variable to a random intercepts model without Gravidity as a factor. The model including Gravidity as a fixed factor was a better predictor of FSIQ across the three sessions than a model that did not include Gravidity (Wald χ^2 (1) = 6.738, p = .009), suggesting that Gravidity impacts the slope of FSIQ scores across the three sessions. The model including Gravidity as a fixed factor was a better predictor of VIQ across the three sessions than a model that did not include Gravidity (Wald χ^2 (1) = 4.347, p = .037), suggesting that Gravidity impacts the slope of VIQ scores across the three sessions. The model including Gravidity as a fixed factor was a better predictor of PIQ across the three sessions than a model that did not include Gravidity (Wald χ^2 (1) = 3.997, p = .045), suggesting that Gravidity impacts the slope of PIQ scores across the three sessions. These analyses were executed with IBM SPSS statistical software. Mean session scores appear in table 2.

Table 2: Mean Session scores (and standard deviations) by Gravidity

	Session One **First trimester**	**Session Two** **Second trimester**	**Session Three** **Third trimester**	**Session Four** **Postpartum**
Pregnant (N=25)				
Verbal IQ	101.96 (9.51)	103.60 (12.57)	105.32 (12.33)	106.44 (11.38)
Performance IQ	104.04 (12.55)	103.72 (10.11)	109.68 (13.12)	106.52 (11.53)
Full Scale IQ	103.36 (10.25)	104.04 (10.92)	107.68 (12.55)	106.48 (11.57)
Non-Pregnant (N=25)				
Verbal IQ	100.24 (10.26)	102.04 (10.20)	103.56 (10.16)	104.68 (9.86)
Performance IQ	103.48 (12.79)	105.32 (12.20)	106.96 (11.56)	112.12 (13.84)
Full Scale IQ	101.76 (11.40)	103.88 (10.33)	105.16 (10.37)	108.52 (11.35)

Does IQ Differ across the groups in the postpartum?

Another goal of this study was to test whether the groups differed in measures of IQ during the postpartum. There were no significant effects of Group on VIQ (Postpartum M = 106.44 , SD = 11.38; Control M = 104.68, SD = 9.86; $t(48)$ = .58, p = .56, d = .165), PIQ (Postpartum M = 106.52 , SD = 11.54; Control M = 112.12, SD = 13.84; $t(48)$ = 1.55, p = .13, d = .44), nor FSIQ (Postpartum M = 106.48 , SD = 11.60; Control M = 108.52, SD = 11.35; $t(48)$ = .63, p =.53, d = .18).

Do changes in fluid and crystallized intelligence differ across groups?

Finally, the third goal of this study was to test whether measures of crystallized and fluid intelligence differed across groups during pregnancy. An index of Fluid intelligence and another index of

Crystallized intelligence was created by summing each participant's raw scores for subscales of each intelligence type (See table 3 for a list of subscales by intelligence type) and then converting these scores into *z*-scores. The increase in Fluid intelligence scores in the pregnant group did not increase significantly from the first (M = -.008, SD = .97) to the third trimester (M = .064, SD = 1.06; $t(24)$ = .49, p = .62, d = .07)). Moreover, the interaction between Gravidity and change across pregnancy was not significant ($F(1,48)$ = .75, p = .39, η^2_p = .02). Table 3 shows raw scores of each subscale by group. No item was individually statistically significantly different between the two groups, and *t* and *p* values are included in Table 3.

Table 3a: First session raw performance on Crystallized and Fluid intelligence subscales by Group. Greater averages are in **bold**.

	Session 1 Pregnant Mean (SD)	Session 1 Control Mean (SD)	*t*	*p*	*df*	Cohen's *d*
Crystallized intelligent sub scales						
Vo - vocabulary WAIS-III	**11.17** (2.37)	10.80 (3.05)	.32	.75	20	0.14
Info - information WAIS-III	**11.08** (2.68)	9.80 (3.58)	.32	.75	20	0.40
V-QR - verbal quantitative reasoning S-B 5	**10.85** (2.58)	10.67 (2.74)	.96	.35	26	0.07
Sim - similarities WAIS-III	**11.00** (2.44)	10.50 (2.95)	.43	.67	20	0.18
Comp - comprehension WAIS-III	**11.33** (2.81)	9.80 (2.53)	1.33	.20	20	0.57
Ar - arithmetic WAIS-III	**9.83** (2.59)	8.80 (3.08)	.86	.40	20	0.36
P-KN - performance knowledge S-B 5	10.23 (2.52)	**10.27** (2.05)	.04	.97	26	0.02
V-KN - verbal knowledge S-B 5	**10.85** (2.67)	10.20 (1.66)	.78	.44	26	0.29
V-WM - verbal working memory S-B 5	9.23 (1.69)	**9.53** (1.46)	.51	.62	26	0.19
DS - digit span WAIS-III	9.92 (2.11)	**9.40** (2.76)	.50	.62	20	0.21
Fluid intelligence subscales						
PC - picture completion WAIS-III	9.50 (2.58)	**10.00** (2.79)	.44	.67	20	0.19
BD- block design WAIS-III	**12.08** (2.97)	10.30 (2.21)	1.57	.13	20	0.70
MR - matrix reasoning WAIS-III	11.25 (1.96)	**11.50** (1.51)	.33	.75	20	0.14
P-FR - performance fluid reasoning S-B 5	10.38 (2.47)	**11.13** (2.17)	.86	.40	26	0.32
DC/DSy - digit coding/digit symbol WAIS-III	**11.25** (2.49)	11.00 (3.30)	.20	.84	20	0.09
PA - picture arrangement WAIS-III	**12.75** (3.72)	10.50 (2.22)	1.68	.11	20	0.73
P-QR - performance quantitative reasoning S-B 5	8.69 (2.53)	**9.60** (2.92)	.87	.39	26	0.33
P-VS - performance visuospatial S-B 5	10.08 (2.84)	**11.33** (3.77)	.98	.34	26	0.37
P-WM - performance working memory S-B 5	11.31 (2.21)	**11.47** (3.85)	.13	.90	26	0.05
V-FR - verbal fluid reasoning S-B 5	**10.38** (2.75)	10.33 (2.06)	.06	.96	26	0.02
V-VS - verbal visuospatial S-B 5	9.69 (1.80)	**10.73** (2.31)	1.31	.20	26	0.50

Table 3b: Second session raw performance on Crystallized and Fluid intelligence subscales by Group. Greater averages are in **bold**.

	Session 2 Pregnant Mean (SD)	Session 2 Control Mean (SD)	*t*	*p*	*df*	Cohen's *d*
Crystallized intelligent sub scales						
Vo - vocabulary WAIS-III	12.08 (1.93)	**12.13** (2.09)	.07	.76	26	0.02
Info - information WAIS-III	**11.15** (3.05)	10.93 (2.22)	.22	.83	26	0.08
V-QR - verbal quantitative reasoning S-B 5	**11.25** (3.02)	9.04 (2.17)	1.62	.12	20	0.84
Sim - similarities WAIS-III	9.62 (2.60)	**11.47** (2.53)	1.91	.07	26	0.72
Comp - comprehension WAIS-III	10.77 (2.71)	**10.80** (1.82)	.04	.97	26	0.13
Ar - arithmetic WAIS-III	**10.08** (3.30)	10.07 (3.65)	.01	.99	26	0.003
P-KN - performance knowledge S-B 5	**10.58** (2.19)	9.8 (1.99)	.87	.40	20	0.37
V-KN - verbal knowledge S-B 5	9.25 (1.86)	**9.40** (1.51)	.21	.84	20	0.09
V-WM - verbal working memory S-B 5	**10.08** (1.73)	9.40 (1.43)	1.00	.32	20	0.43
DS - digit span WAIS-III	**10.31** (2.59)	10.13 (2.67)	.18	.86	26	0.07
Fluid intelligence subscales						
PC - picture completion WAIS-III	9.62 (2.66)	**10.07** (2.52)	.46	.65	26	0.17
BD- block design WAIS-III	**12.31** (2.95)	11.73 (3.51)	.46	.65	26	0.18
MR - matrix reasoning WAIS-III	**12.00** (2.55)	10.13 (2.58)	.34	.74	26	0.73
P-FR - performance fluid reasoning S-B 5	9.83 (2.62)	**10.70** (2.87)	.74	.47	20	0.32
DC/DSy - digit coding/digit symbol WAIS-III	11.38 (2.72)	**12.73** (3.49)	1.13	.27	26	0.43
PA - picture arrangement WAIS-III	**11.00** (2.64)	10.80 (2.96)	.19	.85	26	0.07
P-QR - performance quantitative reasoning S-B 5	**10.08** (3.53)	8.80 (1.48)	1.07	.30	20	0.47
P-VS - performance visuospatial S-B 5	9.83 (3.93)	**10.10** (1.20)	.21	.84	20	0.09
P-WM - performance working memory S-B 5	10.08 (3.00)	**11.20** (2.10)	.99	.33	20	0.43
V-FR - verbal fluid reasoning S-B 5	**10.58** (2.84)	9.80 (3.36)	.99	.33	20	0.25
V-VS - verbal visuospatial S-B 5	10.08 (2.68)	**10.30** (2.06)	.21	.84	20	0.09

Table 3c: Third session raw performance on Crystallized and Fluid intelligence subscales by Group. Greater averages are in **bold**.

	Session 3 Pregnant Mean (SD)	Session 3 Control Mean (SD)	*t*	*p*	*df*	Cohen's *d*
Crystallized intelligent sub scales						
Vo - vocabulary WAIS-III	**11.75** (2.30)	11.58 (3.29)	.30	.76	20	0.06
Info - information WAIS-III	**11.67** (2.53)	10.30 (3.47)	1.07	.30	20	0.03
V-QR - verbal quantitative reasoning S-B 5	**11.62** (3.01)	11.33 (2.19)	.29	.78	26	0.11
Sim - similarities WAIS-III	**11.92** (2.23)	11.90 (2.02)	.02	.99	20	0.01
Comp - comprehension WAIS-III	**10.83** (2.59)	10.20 (3.08)	.52	.61	20	0.22
Ar - arithmetic WAIS-III	**9.33** (2.90)	8.70 (2.98)	.50	.62	20	0.21
P-KN - performance knowledge S-B 5	**11.38** (2.25)	11.13 (1.68)	.34	.74	26	0.13
V-KN - verbal knowledge S-B 5	**10.92** (2.29)	10.67 (1.84)	.33	.75	26	0.12
V-WM - verbal working memory S-B 5	9.46 (1.27)	**9.53** (1.60)	.13	.90	26	0.05
DS - digit span WAIS-III	**11.50** (3.23)	10.40 (2.91)	.83	.42	20	0.36
Fluid intelligence subscales						
PC - picture completion WAIS-III	**11.58** (2.47)	11.00 (2.36)	.52	.61	20	0.24
BD- block design WAIS-III	**12.67** (2.99)	10.70 (2.80)	1.71	.10	20	0.68
MR - matrix reasoning WAIS-III	**12.92** (2.19)	12.00 (2.40)	.94	.36	20	0.40
P-FR - performance fluid reasoning S-B 5	**10.54** (2.47)	10.53 (2.17)	.006	.99	26	0.004
DC/DSy - digit coding/digit symbol WAIS-III	11.58 (3.28)	**12.10** (3.38)	.36	.72	20	0.16
PA - picture arrangement WAIS-III	**12.75** (2.26)	11.30 (2.83)	1.34	.20	20	0.57
P-QR - performance quantitative reasoning S-B 5	9.62 (2.43)	**10.13** (2.67)	.53	.60	26	0.20
P-VS - performance visuospatial S-B 5	11.38 (3.88)	**11.87** (2.97)	.37	.71	26	0.14
P-WM - performance working memory S-B 5	11.08 (1.55)	**12.00** (3.02)	.99	.33	26	0.38
V-FR - verbal fluid reasoning S-B 5	10.69 (2.98)	**10.73** (2.34)	.04	.97	26	0.02
V-VS - verbal visuospatial S-B 5	10.62 (3.10)	**11.27** (2.19)	.65	.52	26	0.24

DISCUSSION

A persistent characterization in the popular press is that women experience pregnancy-related cognitive deficits, or baby brain (Murkoff, 2016), and pregnant women themselves report the perception that there are cognitive changes that take place during pregnancy (Parsons & Redman, 1991; Crawley et al., 2003). In this longitudinal study, IQ measures of pregnant women did not decrease across pregnancy, and actually increased more than non-pregnant control participants across matched time intervals. There have been other studies reporting no significant cognitive decrement during pregnancy (Casey et al., 1999; Logan et al., 2014; Crawley, Grant & Hinshaw, 2008; Cuttler, Graf, Pawluski, Galea, 2011) including both group-wise comparisons (McDowall & Moriarty, 2000) and within-subject changes using a longitudinal design (Crawley et al., 2003). The current study contrasts with a recent report suggesting that across published studies, pregnancy is associated with a cognitive decline that is greatest in the third trimester (Davies et al., 2018).

A report of cognitive improvement during pregnancy is not unprecedented, as some previous studies have reported increased cognitive performance among pregnant samples, specifically testing recognizing unknown male faces (Anderson and Rutherford, 2011) stem completion using pregnancy-related material (Christensen, Poyser, Pollitt, & Cubis, 1999), and a verbal learning task (Silber, Almkvist, Larsson, & Uvnäs-Moberg, 1990). These findings appear to add further ambiguity to the study of cognitive changes during pregnancy but highlight the importance of considering the types of intelligence or cognition that is being probed. Some cognitive tasks may become more important during pregnancy, while others are not prioritized.

An adaptive approach suggests that cognitive resources might be reallocated during pregnancy, and that as different energetic and metabolic demands change across pregnancy, cognitive performance may change too. A strategy of restricting resources that are spent on some types of cognition in order to divert such resources to other physiological and energetic priorities during pregnancy may be adaptive (Anderson & Rutherford, 2012). Apparent deficits in cognition in pregnancy and the postpartum period may reflect a trade-off whereby cognitive demands that are pregnancy-relevant are facilitated, less pressing cognitive functions are deprioritized, and priorities change across the trimesters of pregnancy (Anderson & Rutherford, 2012). Although we predicted an increase in fluid IQ in the Pregnant group, the increase in raw scores of fluid intelligence subscales was not statistically significant, nor was it significantly different than the increase in the control group. Caution is warranted in interpreting these results since increased age (in the age range of our samples) is associated with declines in fluid intelligence and improvements in crystallized intelligence.

The current study found no evidence of group differences in the postpartum period. In contrast, there is clear evidence that a subset of women experiences changes in mood postpartum including cases of debilitating depression (Gavin et al., 2005). Indeed, one study suggests that over the first two years after giving birth a woman's cognitive improvements are not independent of improvements in mood (Buckwalter et al., 1999).

One open question is whether the group differences measured in this study are associated with temporary or long-lasting pregnancy-related changes. Although in the current study, group differences in IQ measures have already resolved by the postpartum session, there is evidence of long-term changes in the brain after pregnancy. A recent review paper reported better cognitive function in older women who had never had children, compared to age-matched mothers. Among the women who were mothers, giving birth at a younger age was associated with lower cognitive performance (Duarte-Guterman, 2019). There is evidence that pregnancy leads to a reduction in grey matter in brain regions associated with social cognition. This reduction was measurable up to 2-years postpartum, and the magnitude of these changes were positively associated with maternal attachment (Hoekzema, et al., 2017). It is unclear what impact this change could have on cognition, specifically measures of IQ. Of course, for many people, a pregnancy is associated with new parenthood, and parenthood itself is associated with changes in both mood and physiology (Saxbe et al., 2018). Future research could be designed to isolate these factors, perhaps by using an adoption paradigm.

This research focused on women rather than men because an adaptationist perspective, previous research, and reflections in the popular press led us to believe that women may experience cognitive changes during pregnancy. There is widespread discussion about cognitive changes women experience during pregnancy and the postpartum, but relatively less discussion about cognitive changes expectant fathers may experience during their partner's pregnancy. Some evidence has suggested an increase in obsessive-compulsive behavior and ideation among expectant fathers (Coehlo et al., 2014). Expectant fathers can experience intrusive harm-avoidant thoughts (Leckman et al., 1999). A minority of new fathers experience post-partum depression, and the incidence of paternal post-partum depression correlates with depression in the father's female partner (Paulson & Bazemore, 2010).

Limitations

One of the biggest challenges in interpreting this study is the possibility of learning across the repeated sessions. The scales of these standardized test are broad enough that ceiling effects were not a concern. Still, we attempted to mitigate learning by using different standardized tests, but across the four sessions, it was necessary to repeat each standardized test, so learning was possible. Therefore, the comparison between groups is critical to understanding any cognitive changes that took place in our pregnant sample.

A second limitation of the study is sample size. A larger sample would be more representative and could possibly reveal more nuanced differences in cognitive changes across pregnancy. No subscale was significantly different between the Pregnant and Non-Pregnant groups, but it is possible that a much larger sample would reveal such differences. The effect sizes of the apparent differences suggest that experimental and control groups of 2500 each might reveal whether group differences in performance on subscales are robust.

Like all human studies on the effects of pregnancy, this study is not experimental. Therefore, results must be interpreted with caution. Although our experimental and control group did not differ significantly with respect to years of education, employment, income, race or age, without random assignment one cannot distinguish a causal relationship from the effects of other variables that might be associated with pregnancy like the anticipation of a baby, the desire for a baby, partnership dynamics, or stereotype threat, just to name a few examples. Related to this concern is the fact that it was impossible for the experimenter to remain naïve to the participants' condition, due to the changing physical appearance of the Pregnant group. This may frustrate our efforts to interpret results because it is possible that experimenter bias or demand characteristics impact performance. In order to mitigate these effects, we advertised and described the study as assessing cognitive *changes* during pregnancy rather than *decline*, as is typical.

Finally, we did not track the stage in the menstrual cycle (or use of hormonal birth control) of the non-pregnant control participants. Although pilot studies in our lab suggest that it makes no difference, and others have found that menstrual cycle stage does not impact IQ (Pletzer, et al., 2019), others have reported that hormones are associated with changes in cognition (Glynn, 2010). Thus, it is possible that menstrual cycle stage or hormonal birth control impacted performance in our non-pregnant control group.

Conclusion

Despite a consistent public perception that pregnancy leads to a decline in some cognitive functions, controlled research does not always report such declines. In a longitudinal study using standardized IQ measures, we found evidence of an increase in IQ scores in a pregnant sample that was greater than the change in the control sample, but no statistically significant evidence of an increase in measures of fluid intelligence in the pregnant sample.

ETHICAL STATEMENT

These studies were approved by the ethics committee of McMaster University [certificate number 2014 018].

REFERENCES

Anderson, M. V., & Rutherford, M. (2011). Recognition of novel faces after single exposure is enhanced during pregnancy. *Evolutionary Psychology, 9*(1), 147470491100900100. DOI

Anderson, M. V., & Rutherford, M. D. (2012). Cognitive reorganization during pregnancy and the postpartum period: an evolutionary perspective. *Evolutionary Psychology, 10*(4), 147470491201000420. DOI

Blalock, H. M. (1972). *Social Statistics*. New York: McGraw-Hill.

Brindle, P. M., Brown, M. W., Brown, J., Griffith, H. B., & Turner, G. M. (1991). Objective and subjective memory impairment in pregnancy. *Psychological Medicine, 21*(3), 647–653. DOI

Buckwalter, J. G., Stanczyk, F. Z., McCleary, C. A., Bluestein, B. W., Buckwalter, D. K., Rankin, K. P., ... & Goodwin, T. M. (1999). Pregnancy, the postpartum, and steroid hormones: effects on cognition and mood. *Psychoneuroendocrinology, 24*(1), 69-84. DOI

Casey, P. (2000). A longitudinal study of cognitive performance during pregnancy and new motherhood. *Archives of Women's Mental Health, 3*(2), 65–76. DOI

Casey, P., Huntsdale, C., Angus, G., & Janes, C. (1999). Memory in pregnancy. II: Implicit, incidental, explicit, semantic, short-term, working and prospective memory in primigravid, multigravid and postpartum women. *Journal of Psychosomatic Obstetrics & Gynecology, 20*(3), 158-164. DOI

Cattell, R. B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology, 54*(1), 1. DOI

Cavanaugh, J. C., & Blanchard-Fields, F. (2018). *Adult development and aging*. Cengage Learning.

Christensen, H., Poyser, C., Pollitt, P., & Cubis, J. (1999). Pregnancy may confer a selective cognitive advantage. *Journal of Reproductive and Infant Psychology, 17*(1), 7–25. DOI

Coelho, F. M., Silva, R. A. D., Quevedo, L. D. Á., Souza, L. D., Pinheiro, K. A., & Pinheiro, R. T. (2014). Obsessive-compulsive disorder in fathers during pregnancy and postpartum. *Brazilian Journal of Psychiatry, 36*(3), 272-272. DOI

Crawley, R., Dennison, K., & Carter, C. (2003). Cognition in pregnancy and the first year post-partum. *Psychology and Psychotherapy: Theory, Research and Practice, 76*(1), 69–84. DOI

Crawley, R., Grant, S., & Hinshaw, K. (2008). Cognitive changes in pregnancy: mild decline or societal stereotype?. *Applied Cognitive Psychology, 22*(8), 1142-1162. DOI

Cuttler, C., Graf, P., Pawluski, J. L., & Galea, L. A. (2011). Everyday life memory deficits in pregnant women. *Canadian Journal of Experimental Psychology, 65*(1), 27. DOI

Davies, S. J., Lum, J. A., Skouteris, H., Byrne, L. K., & Hayden, M. J. (2018). Cognitive Impairment During Pregnancy: a Meta-Analysis. *Medical Journal of Australia, 208*(1), 35-40. DOI

Duarte-Guterman, P., Leuner, B., & Galea, L. A. (2019). The long and short term effects of motherhood on the brain. *Frontiers in Neuroendocrinology, 53*, 100740. DOI

Farrar, D., Tuffnell, D., Neill, J., Scally, A., & Marshall, K. (2014). Assessment of cognitive function across pregnancy using CANTAB: a longitudinal study. *Brain and Cognition, 84*(1), 76-84. DOI

Gavin, N. I., Gaynes, B. N., Lohr, K. N., Meltzer-Brody, S., Gartlehner, G., & Swinson, T. (2005). Perinatal depression: a systematic review of prevalence and incidence. *Obstetrics & Gynecology, 106*(5), 1071-1083. DOI

Glynn, L. M. (2010). Giving birth to a new brain: hormone exposures of pregnancy influence human memory. *Psychoneuroendocrinology, 35*(8), 1148-1155. DOI

de Groot, R., Hornstra, G., Roozendaal, N., & Jolles, J. (2003). Memory performance, but not information processing speed, may be reduced during early pregnancy. *Journal of Clinical and Experimental Neuropsychology, 25*(4), 482–488. DOI

Henry, J. D., & Rendell, P. G. (2007). A review of the impact of pregnancy on memory function. *Journal of Clinical and Experimental Neuropsychology, 29*(8), 793–803. DOI

Hoekzema, E., Barba-Müller, E., Pozzobon, C., Picado, M., Lucco, F., García-García, D., Ballesteros, A., Carmona, S., & Vilarroya, O. (2017). Pregnancy leads to long-lasting changes in human brain structure. *Nature Neuroscience, 20*(2), 287-296. DOI

Horn, J. L. (1965). *Fluid and crystallized intelligence: a factor analytic study o the structure among primary mental abilities*. Doctoral dissertation, University of Illinois at Urbana-Champaign.

Jarrahi-Zadeh, A., Kane, F., Van de Castlf, R., Lachenbruch, P., & Ewing, J. (1969). Emotional and cognitive changes in pregnancy and early puerperium. *The British Journal of Psychiatry, 115*(524), 797–805. DOI

Kanazawa, S. (2014). Intelligence and childlessness. *Social science research, 48*, 157-170. DOI

Kataja, E.-L., Karlsson, L., Huizink, A., Tolvanen, M., Parsons, C., Nolvi, S., & Karlsson, H. (2017). Pregnancy-related anxiety and depressive symptoms are associated with visuospatial working memory errors during pregnancy. *Journal of Affective Disorders, 218*, 66–74. DOI

Keenan, P., Yaldoo, D., Fuerst, D., & Ginsburg, K. (1998). Explicit memory in pregnant women. *American Journal of Obstetrics & Gynecology, 179*(3), 731–737. DOI

Kinsley, C.H., & Lambert, K.G. (2006). The maternal brain: pregnancy and motherhood change the structure of the female mammal's brain, making mothers attentive to their young and better at caring for them. *Scientific American, 294*, 72-79.

Kinsley, C.H., & Lambert, K.G. (2008). Reproduction-induced neuroplasticity: Natural behavior and neuronal alterations associated with the production and care of offspring. J*ournal of Neuroendocrinology, 20*(4), 515-525. DOI

Leckman, J. F., Mayes, L. C., Feldman, R., Evans, D. W., King, R. A., & Cohen, D. J. (1999). Early parental preoccupations and behaviors and their possible relationship to the symptoms of obsessive-compulsive disorder. *Acta Psychiatrica Scandinavica, 100*, 1-26. DOI

Logan, D. M., Hill, K. R., Jones, R., Holt-Lunstad, J., & Larson, M. J. (2014). How do memory and attention change with pregnancy and childbirth? A controlled longitudinal examination of neuropsychological functioning in pregnant and postpartum women. *Journal of Clinical And Experimental Neuropsychology, 36*(5), 528-539. DOI

Lisk, R.D., Pretlow, R.A., and Friedman, S.M. (1969). Hormonal stimulation necessary for elicitation of maternal nest-building in the mouse (Mus Musculus). *Animal Behaviour, 17*(4), 730-737. DOI

MacBeth, A.H., & Luine, V.N. (2010). Changes in anxiety and cognition due to reproductive experience: a review of data from rodent and human mothers. *Neuroscience and Behavioral Reviews, 34*(3), 452-467. DOI

McDowall, J., & Moriarty, R. (2000). Implicit and explicit memory in pregnant women: An analysis of data-driven and conceptually driven processes. *The Quarterly Journal of Experimental Psychology: Section A, 53*(3), 729–740. DOI

Murkoff, H. (2016). *What to expect when you're expecting*. Workman Publishing.

Onyper, S. V., Searleman, A., Thacher, P. V., Maine, E. E., & Johnson, A. G. (2010). Executive functioning and general cognitive ability in pregnant women and matched controls. *Journal of Clinical and Experimental Neuropsychology, 32*(9), 986-995. DOI

Ouellette, S. J., & Hampson, E. (2019). Memory and affective changes during the antepartum: A narrative review and integrative hypothesis. *Journal of Clinical and Experimental Neuropsychology, 41*(1), 87-107. DOI

Parsons, C., & Redman, S. (1991). Self-reported cognitive change during pregnancy. *The Australian Journal of Advanced Nursing: A Quarterly Publication of the Royal Australian Nursing Federation, 9*(1), 20–29.

Paulson, J. F., & Bazemore, S. D. (2010). Prenatal and postpartum depression in fathers and its association with maternal depression: a meta-analysis. *Jama, 303*(19), 1961-1969. DOI

Pletzer, B., Harris, T., Scheuringer, A. et al. (2019). The cycling brain: menstrual cycle related fluctuations in hippocampal and fronto-striatal activation and connectivity during cognitive tasks. *Neuropsychopharmacology, 44*, 1867–1875. DOI

Poser, C. M., Kassirer, M. R., & Peyser, J. M. (1986). Benign encephalopathy of pregnancy preliminary clinical observations. *Acta Neurologica Scandinavica, 73*(1), 39–43. DOI

Raz, S. (2014). Behavioral and neural correlates of cognitive–affective function during late pregnancy: An event-related potentials study. *Behavioural Brain Research, 267*, 17-25. DOI

Roid, G. H. (2003). *Stanford-Binet intelligence scales*. Itasca, IL: Riverside Publishing.

Rosenblatt, J.S. and Lehrman, D.S. (1963). Maternal behavior of the laboratory rat. In H.L. Rheingold (Ed.), *Maternal Behavior in Mammals* (pp.8-57). New York: John Wiley and Sons, Inc.

Ross, S., Sawin, P.B., Zarrow, M.X., and Deneberg, V.H. (1963). Maternal behavior in the rabbit. In H.L. Rheingold (Ed.), *Maternal Behavior in Mammals* (pp.94-121). New York: John Wiley and Sons, Inc.

Saxbe, D., Rossin-Slater, M., & Goldenberg, D. (2018). The transition to parenthood as a critical window for adult health. *American Psychologist, 73*(9), 1190. DOI

Sharp, K., Brindle, P. M., Brown, M. W., & Turner, G. M. (1993). Memory loss during pregnancy. *BJOG: An International Journal of Obstetrics & Gynaecology, 100*(3), 209–215. DOI

Shetty, D. N., & Pathak, S. S. (2002). Correlation between plasma neurotransmitters and memory loss in pregnancy. *The Journal of Reproductive Medicine, 47*(6), 494-496.

Silber, M., Almkvist, O., Larsson, B., & Uvnäs-Moberg, K. (1990). Temporary peripartal impairment in memory and attention and its possible relation to oxytocin concentration. *Life Sciences, 47*(1), 57–65. DOI

Stewart, K.J. (1977). The birth of a wild mountain gorilla (Gorilla gorilla beringei). *Primates, 18*, 965-976. DOI

Thodberg, K., Jensen, K.H., Herskin, M.S., and Jorgensen, E. (1999). Influence of environmental stimuli on nest building and farrowing behaviour in domestic sows. *Applied Animal Behaviour Science, 63*, 131-144. DOI

Wechsler, D. (1997). *WAIS-III, Wechsler adult intelligence scale: Administration and scoring manual*. Psychological Corporation.