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## Short Communication

## Working memory from pregnancy to postpartum: Do women really change?

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## ABSTRACT

Studies indicate that pregnancy is associated with declines in working memory (WM), potentially due to intense pregnancy hormonal fluctuations. These declines extend into the postpartum period and may even be worsened due to sleepless nights and continued hormonal changes. However, previous studies finding WM stability from pregnancy to postpartum have not used a control group to examine practice effects on WM tests. The current study used a well-matched control group, fathers, to examine a) whether mothers and fathers differ on tests of WM during pregnancy and postpartum, and b) whether mothers show a postpartum WM decline, taking into account the practice effects of fathers. Results revealed that mothers (N = 75) and fathers (N = 44) performed equally well on a WM task at both time points and improved across time at a statistically equivalent rate. Use of a Reliable Change Index and a regression-based sensitivity analysis bolstered these results, indicating that taking practice effects into account, the majority of women did not improve or decline in WM from pre- to postpartum. These findings add to the literature on pregnancy-related changes in cognition and raise new questions about potential cognitive changes in men during the same period.

## 1. Introduction

Many pregnant women report cognitive complaints, such as difficulties concentrating and forgetfulness, and these claims are substantiated by research (Davies et al., 2018). The cognitive abilities most often reported to deteriorate during pregnancy are higher-order cognitive processes, such as executive functions, including planning, dual- and multi-tasking, and working memory (Lezak et al., 2012). WM in particular seems to be affected, with meta-analyses showing decreased performance on neuropsychological tasks during pregnancy (Anderson and Rutherford, 2012; Henry and Rendell, 2007). Scholars have suggested that deteriorated cognitive performance during pregnancy may be a consequence of rapidly fluctuating levels of hormones, including estrogen and cortisol (e.g., Henry and Sherwin, 2012). In line with this reasoning, one could argue that cognitive problems should persist postpartum, since this period is also characterized by hormonal fluctuations due to recovery and lactation. Given new mothers' persistent

sleep disruptions and childcare duties, WM capabilities might decline even further after delivery. Nonetheless, the scarce research exploring WM changes from pregnancy to postpartum suggests stability rather than further decline (e.g., Anderson and Rutherford, 2012).

Importantly, however, results of previous studies may be biased due to their methodological approach. That is, most studies in humans to date have examined within-subject changes in women before, during, and after pregnancy using repeated measures analysis of variance, but failed to include a control group to take non-specific practice effects into account. Practice effects refer to the observation that scores on cognitive tests automatically improve with multiple testing occasions, even when parallel versions are used. Practice effects occur as a result of increased familiarity with tests and assessment procedures (e.g., Goldberg et al., 2015). Given that previous studies have not taken practice effects into account, we argue that practice effects may actually be hiding the presence of larger decreases in WM from pregnancy to postpartum than those reported earlier.

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The aim of the current investigation is to examine changes over time in WM from pregnancy to the postpartum in mothers relative to a comparison group – fathers. Fathers were used as a reference category instead of non-pregnant women, as they experience a similar life situation that may be associated with changes in psychological function and cognition, but without the same intense physical changes and hormonal fluctuations. We use two types of analyses. First, in line with previous studies, we use a classic  $2 \times 2$  Repeated Measures ANOVA, examining WM changes over time in mothers and fathers. We hypothesize that in this analysis fathers will outperform mothers and will show clear practice effects, improving from pre- to post-pregnancy. Contrarily, we hypothesize that women will show similar performance in pregnancy and postpartum. Second, we use a Reliable Change Index (RCI; Iverson, 2017) with fathers as a reference category, to take into account whether practice effects might be masking maternal WM declines from pregnancy to postpartum. We expect that RCI analyses will uncover a maternal decline in performance postpartum. Finally, given that RCIs may be considered conservative (e.g., Maassen et al., 2009), we conduct a sensitivity analysis using a regression-based approach to determine whether mothers' scores differed from T1 to T2, taking into account the practice effects of the fathers. Studying WM performance in the postpartum is highly relevant; research has shown that poor maternal executive functioning, including WM, is a risk factor for a host of negative outcomes, including negative caregiving behaviors (e.g., Sturge-Apple et al., 2014).

## 2. Methods

### 2.1. Participants

Data are part of a longitudinal project called BINGO (e.g., Bos et al., 2018), aimed at delineating prenatal and postnatal predictors of infant health and development. Healthy expectant parents were recruited for a specified period of time through midwife practices, pregnancy courses, and baby stores in the Netherlands. Inclusion criteria were a healthy, uncomplicated singleton pregnancy and understanding of the Dutch language. Exclusion criteria were (non-prescribed) drug and alcohol use during pregnancy. Women were encouraged to participate with their partners, but could participate individually as well. A total of 88 women and 57 of their partners were recruited. For the current investigation, only mothers and fathers who completed the N-back WM test in both data collection waves were included, resulting in a sample of 75 mothers and 44 fathers (Table 1). A post-hoc power analysis in G\*Power (Faul et al., 2009) indicated that this sample size provided adequate statistical power (> 99%) to detect a medium effect size.

**Table 1**  
Descriptive statistics for mothers and fathers.

|  | Mothers (N = 75)<br>M (SD); range | Fathers (N = 44)<br>M (SD); range |
|--|-----------------------------------|-----------------------------------|
| Age (years)                              | 31.49 (3.79);<br>25.13–40.82      | 33.21 (4.37);<br>24.68–46.90      |
| Gestational age at first testing (weeks) | 33.81 (1.13); 30–39               |                                   |
| Postpartum week at second testing        | 6.74 (0.81); 6–11.29              |                                   |
| Parity (% primiparous)                   | 85                                |                                   |
| Highest level of education (%)           |                                   |                                   |
| Secondary school                         | 1.3                               | 6.8                               |
| Vocational training                      | 16                                | 15.9                              |
| Tertiary education                       | 30.7                              | 27.3                              |
| University degree                        | 46.7                              | 50                                |
| Paid employment (% yes)                  | 95.9                              | 97.7                              |
| Pregnancy N-back score                   | 32.31 (2.44); 26–35               | 32.73 (2.40); 24–35               |
| Postpartum N-back score                  | 33.47 (1.84); 27–35               | 34.25 (1.10); 31–35               |

Note. M = mean. SD = standard deviation.

### 2.2. Procedure

The study consisted of several assessment waves, from late pregnancy until child age 3-years. For the current investigation, only data from late pregnancy (T1) and 6 weeks postpartum (T2) were used (days between testing: mothers'  $M = 88.9$ ,  $SD = 17.7$ ; fathers'  $M = 89.6$ ,  $SD = 17.3$ ). On both testing days participants first completed several questionnaires. Then, participants completed the N-back WM task five times with different sounds playing in the background (e.g., a baby crying). Here, we use the N-back that was completed in silence. Finally, participants completed a handgrip dynamometer and interacted with a crying infant simulator doll (e.g., Bos et al., 2018). When both parents participated, they were tested separately. Testing took place in the afternoon or early evening. Families received a €20 voucher and two small baby gifts. This study was approved by the ethical committee of the Faculty of Social Sciences of the Radboud University [ECSW2014–1003-189] (see Hechler et al., 2018, for more details).

### 2.3. Measurements

#### 2.3.1. Working memory

The visuospatial N-Back test (Kirchner, 1958) assessed working memory. We used Inquisit software to present the 2-back version (see also Hechler, et al., 2015), requiring participants to update their working memory buffer continuously. Participants saw a 3 by 3 grid on a computer screen (Fig. 1). Every 2 s, one cell in the grid turned red. Participants indicated by pressing the space bar whether the cell that turned red was identical to the cell that turned red two trials before. Participants completed ten practice trials and then five 90-s rounds of 35 trials, each with a different sound (including silence) playing in the background. Scores are the number of trials in which the participant correctly pressed or did not press the space bar in the silence condition only, reflecting 35 total trials at a constant level of difficulty. Possible scores ranged from 0 to 35; higher scores indicate a better performance. The 2-back was used to obtain an optimal balance between ceiling effects (that are often present when using the 1-back version) and poor performance in many individuals (which is often found when using the 3-back version; e.g., Schmidt et al., 2009).

## 3. Results

### 3.1. Preliminary analyses

A *t*-test demonstrated that fathers were slightly older than mothers ( $t(117) = 2.26$ ,  $p = .026$ , Cohen's  $d = 0.42$ ) (Table 1).

### 3.2. Pre- to postnatal changes in working memory

A  $2 \times 2$  Repeated Measures ANOVA, with *time* (T1 vs T2) as a within-subject factor, *group* (mothers vs fathers) as between-subject factor was performed to examine changes in working memory from pre- to postpartum. The main effect of *time* was significant ( $F(1, 117) = 39.64$ ,  $p < .001$ ,  $\eta_p^2 = .25$ ); performance was better postnatally (T2  $M = 33.86$ ) than prenatally (T1  $M = 32.52$ ). However, the main effect of *group* ( $F(1, 117) = 3.38$ ,  $p = .068$ ,  $\eta_p^2 = .03$ ) and the interaction between *time* and *group* ( $F(1, 117) = 0.73$ ,  $p = .396$ ,  $\eta_p^2 = .01$ ) were nonsignificant, indicating that mothers and fathers performed similarly at both time points and improved across time at similar rates.

### 3.3. Reliable change index

RCI analysis (Iverson, 2017) was performed to examine maternal changes in WM using paternal change in WM as a control. First, maternal difference scores (T2 – T1) were calculated for each mother. Second, a mean paternal difference score (i.e., practice effect; T2 – T1) was calculated as a control. Third, the paternal mean difference score was

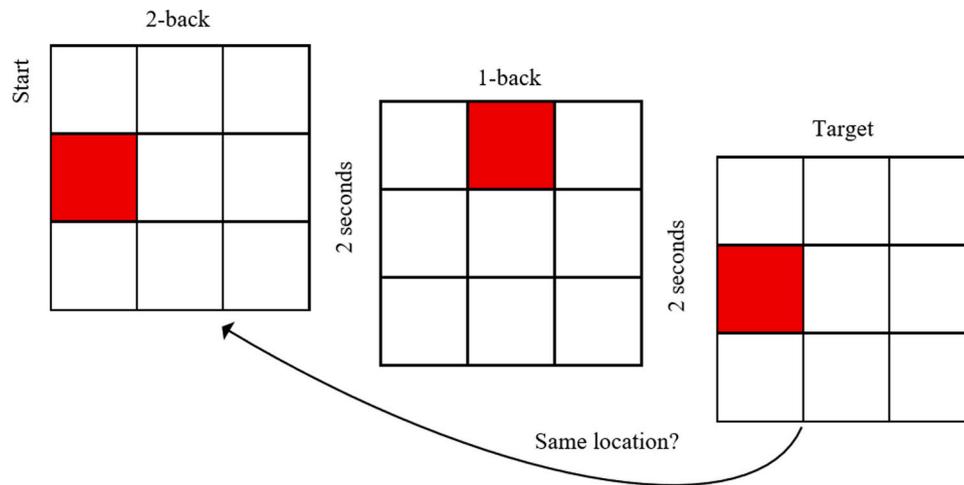


Fig. 1. Schematic of the 2-back version of the N-back task.

subtracted from each maternal difference score. Fourth, the standard error of difference was calculated using the formula of Iverson (2001):  $SE_{diff} = \sqrt{SEM_1^2 + SEM_2^2}$ .  $SEM_1$  was calculated by multiplying the standard deviation of the scores of fathers at T1 ( $SD_1$ ) with the square root of 1 minus  $r_{12}$ , where  $r_{12}$  stands for the test-retest reliability of the scores of fathers (i.e.,  $SEM_1 = SD_1 * \sqrt{(1-r_{12})}$ ).  $SEM_2$  was calculated accordingly, but the standard deviation of the scores of fathers at T2 ( $SD_2$ ) was used (i.e.,  $SEM_2 = SD_2 * \sqrt{(1-r_{12})}$ ). Last, the difference scores calculated in step three were divided by  $SD_{diff}$  to generate a RCI for every mother. RCI scores greater than or equal to 1.645 indicated improved WM, whereas RCI scores lower than  $-1.645$  indicated deteriorated WM. Most mothers ( $N = 69$ ; 92%) did not change in WM from T1 to T2: four mothers (5.33%) improved and two mothers (2.67%) deteriorated.

### 3.4. Sensitivity analysis

Following Crockford et al. (2018), a regression-based approach was used to determine whether mothers performed as expected based on the performance of the reference group, that is, the fathers. First, because regression-based approaches can include covariates and moderators, bivariate correlations with potential covariates (age and education) were examined. Neither age ( $r = 0.10$ ,  $p = .290$ ) nor education ( $r = 0.12$ ,  $p = .209$ ) were associated with T2 N-back scores. Next, a simple linear regression determined the intercept value ( $C$ ) and the beta coefficient ( $\beta$ ) for fathers T1 performance predicting their T2 performance. Then, mothers' expected T2 scores ( $\hat{X}$ ) were calculated using the equation:  $\hat{X} = \beta X + C$ ; where  $X$  is each mother's T1 score, and  $\beta$  and  $C$  are the values calculated using the control group. Then, mothers' expected T2 values were subtracted from their actual T2 values ( $X - \hat{X}$ ) and this value was divided by the standard error of the estimate gleaned from the regression equation with fathers. When the resultant value was  $\pm 1.645$ , a reliable deviation from the expected value was indicated. The majority of mothers did not show a deviation from their expected performance taking into account the practice effects of the fathers, indicating that most mothers performed similarly to fathers at T2. However, 15 mothers (20%) performed worse than expected.

## 4. Discussion

Results revealed that mothers and fathers performed equally well on a WM task and improved across time at a statistically equivalent rate in contention with our hypothesis that fathers would outperform mothers. Moreover, taking into account practice effects, we found that overall mothers did not improve or decline in WM capacity from pre- to postpartum. This does not support our hypotheses that we would see a

decline in mothers' WM performance in the RCI analysis. This is, however, in line with previous findings that women have similar levels of WM at pregnancy and postpartum (e.g., Anderson and Rutherford, 2012; Henry and Rendell, 2007) and provides stronger evidence than previous work by also accounting for practice effects. Interestingly, a regression-based sensitivity analysis indicated that, taking into account fathers' practice effects, a subset of mothers (20%) performed worse than expected. Future studies replicating this effect could also aim to identify factors that may place some mothers at risk for cognitive declines in the postpartum, such as family structures or sleep schedules.

Contrary to our expectations of fathers outperforming mothers, mothers and fathers had comparable mean scores at both time points and showed similar improvements in WM. A possible explanation for this is that although men don't undergo women's extreme physical changes and hormonal variations during their partner's pregnancy, they can experience hormonal fluctuations, such as decreased testosterone (e.g., Sim et al., 2020) and even physical symptoms similar to those of pregnant women (e.g., Couvade symptoms; Mrayan et al., 2019). Future work could address whether having a pregnant partner influences men's WM by testing couples pre-conception and again during pregnancy, or by adding non-pregnant adults as a third control group.

Importantly, we note two limitations. First, we acknowledge our relatively small sample size and encourage replication in larger groups. In addition, we note that there was limited variability in our WM measure, potentially due to the small number of trials or task difficulty, which may have masked effects. In particular, we note that many participants had scores at or close to ceiling, potentially indicating that the task was not difficult enough for this highly educated sample. A meta-analysis examining pregnancy effects on memory found that pregnancy in most detrimental to memory tasks "that place relatively high demands on effortful processing and, specifically, measures of free recall and the executive component of WM" (Henry and Rendell, 2007). While the 2-back task does tap the executive component of WM by requiring continuous memory updating, it is possible that a more extended or difficult version of the task may have revealed stronger effects (e.g., by using a 3-back task). However, a recent study by Bak et al. (2020) on working memory capacity in postpartum women also used a 2-back working memory paradigm with an average accuracy of 92%, which is highly comparable to our findings. Still, the restricted range of scores in the current study limits the generalizability of this work. Future studies should endeavor to replicate the current findings using WM tasks with varying lengths and difficulties.

#### 4.1. Conclusions

This study extends the literature by employing a novel and practically matched control group and a sophisticated statistical analysis (RCI) to examine whether women differ in WM from pregnancy to postpartum while accounting for practice effects. This study provided additional, strong, evidence that maternal cognitive capacities remain constant from late pregnancy to the early postpartum in a majority of mothers, but indicated that a subset of mothers may indeed show cognitive decline in the postpartum period. This is also the first study to show that fathers perform similarly to mothers on a test of WM in this time period. This was a surprising finding and opens an interesting line of inquiry. Might it be that fathers also experience declines in WM around the birth of their child? Future studies could compare cohabiting and non-cohabiting expectant fathers, or add a third reference group – non-expectant adults. In addition, future work should endeavor to discover not only the cognitive changes associated with early parenthood, but also the hormonal mechanisms that underlie such changes and the behaviors associated with them.

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#### CRedit authorship contribution statement

Authors took on the following CRediT roles: **Sara Pieters**: conceptualization, formal analysis, writing – original draft, review, and editing; **Bonnie E. Brett**: formal analysis, writing – original draft, review, and editing, visualization; **Roseriet Beijers**: conceptualization, writing – review & editing, supervision, project administration; **Roy P.C. Kessels**: methodology, writing – review & editing; **Carolina de Weerth**: conceptualization, writing – review & editing, supervision, project administration.

#### Declarations of interest

None.

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