“Baby brain”: Examining the link between sleep, information processing speed and executive functioning during late stage pregnancy

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Abstract

'Baby brain' is a term given to the phenomenon experienced by many pregnant women who feel that they have some pregnancy induced cognitive disadvantage. Traditionally the investigation of cognitive deficits during pregnancy has focussed on various subtypes of memory, but researchers have broadened their scope in recent years to include a wide range of cognitive functions.

This thesis considers and expands on the conclusions of recent meta-analyses which suggest that deficits occur in the domains of information processing speed and executive functioning. The current study analyses reported findings in respect of these two cognitive domains, which have been inconsistent across individual studies. Further, the thesis seeks to explore the possible inter-relationship between information processing speed and the planning facet of executive functioning. This additional analysis is based on research with other populations indicating that perceived impairments in executive functioning can be more accurately understood as secondary consequences of impairments in processing speed.

Participants were 133 women from within the Wellington region who were either in the late stages of pregnancy with their first child, or who were not pregnant and had not previously had a child.

Scores on the reaction time measure of processing speed showed an impairment in simple reaction times for pregnant women when compared to non-pregnant controls. The more complex 'choice reaction time measure' also showed a trend indicative of impairment during pregnancy, but this did not meet the threshold for statistical significance. There was no measurable difference between pregnant and non-pregnant women on the planning measure of executive functioning.

Deficits in sleep quality and altered mood during pregnancy were considered as potential moderating variables when reviewing scores on cognitive tasks. It was found that while pregnant women had significantly poorer self-reported sleep quality than controls, this did not correlate with cognitive scores. However, anxiety was shown to impact on planning time during the executive functioning task, and on performance during that task.

The results of this research will help to clarify the current inconsistencies in results published in extant literature. It also provides recommendations for further exploration of these cognitive domains during pregnancy.

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CHAPTER ONE

Introduction

Women who are pregnant with their first child enter a period of life where they undergo a lot of physical change. But on top of the many physical changes taking place, there is evidence to suggest that women also face cognitive changes. These cognitive changes are colloquially referred to as ‘baby brain’, and there is growing support in literature that structural brain changes occur at this time (Hoekzema et al., 2017), as well as behavioural cognitive deficits.

When it comes to understanding what cognitive changes actually take place during pregnancy, it can become difficult to find agreement in extant research. Traditionally, research has focussed on memory problems experienced at this time, but recent evidence suggests that there may be more widespread cognitive effects on domains such as processing speed and various facets of executive function. Additionally, we know that women have poorer sleep quality in the late stages of pregnancy (Ladyman & Signal, 2018), but there has been limited investigation focussed on what role, if any, this has on cognitive change.

The contradictory findings in the research become important when considering the day-to-day implications for pregnant women. For example, if significant impairment is present during pregnancy, this may impact their performance at work, their ability to adequately plan and prepare to welcome a new family member, and perhaps even on functions such as driving where the ability to react quickly is vital.

The current study is one part of the endeavours of a wider research team to address gaps in the literature pertaining to ‘baby brain’. The specific focus of this study is to add to the emerging evidence of possible deficits in information processing speed and executive function. These two domains have been suggested through meta-analyses to be impaired during pregnancy, however when looking at individual studies in this area, coherent conclusions are difficult to draw.

Possible reasons for contradictory findings in the extant literature include that studies lack the statistical power to detect change due to small sample sizes, that participants have been assessed too broadly in pregnancy without enough consideration given to stage of pregnancy, that studies investigating executive function have varied in their definition of this as a construct, and that the fragmented approach to measure executive functioning has meant that the comparison between studies must be done with caution.

Additionally, extant studies have not specifically sought to investigate the relationship between processing speed and executive function. This leaves open the possibility that reports of impairments in the realm of executive function might be better explained as a secondary consequence of slower processing speed. While the possible interrelationship between these two cognitive domains has not yet been explored in studies with pregnant women, it has been investigated in relation to the cognitive impact of Multiple Sclerosis (MS), and the current study has drawn upon that research as an interesting possible parallel.

The literature relating to the impact of MS on cognitive function has often mentioned deficits in both processing speed and executive function in patients afflicted with this disease, but neuropsychologists at the University of Kansas have challenged this assertion, stating that patients' poor performance on measures of executive function may simply derive from their difficulties with processing speed (Owens, Denney, & Lynch, 2013).

This thesis begins in chapter two with an overview of the literature pertaining to cognitive change during pregnancy. This includes a summary of the three most recent meta-analyses in this area, as well as an exploration of specific studies that are important in informing the current research. Chapter three outlines the gaps and inconsistences in that literature in a more concise way, and poses the specific research questions that the current study seeks to address. The methodological considerations and overall approach to the research is detailed in chapter four. Chapter five outlines the results from the study and these are then discussed in relation to existing research in chapter six. This final discussion chapter includes a summary of the implications of the study's findings, recognised limitations and future research opportunities in this area.

CHAPTER TWO

Summary of Background Literature

The research literature relating to cognitive change during pregnancy primarily relates to memory decline. It is likely that this focus on memory function is linked to a desire to objectively test the well documented subjective memory difficulties experienced by the majority of women during pregnancy, a phenomenon commonly termed ‘baby brain’ (Casey, Huntsdale, Angus, & Janes, 1999; Cuttler, Graf, Pawluski, & Galea, 2011; Janes, Casey, Huntsdale, & Angus, 1999; Logan, Hill, Jones, Holt-Lunstad, & Larson, 2014). More recently, researchers have begun to expand on the cognitive functions tested in pregnancy by looking at areas such as processing speed, executive function, and attention (Christensen, Leach, & Mackinnon, 2010; Crawley, Grant, & Hinshaw, 2008). Consequently, knowledge regarding cognitive change during pregnancy is expanding, yet results remain in some cases fairly equivocal.

There have been three published meta-analyses (Anderson & Rutherford, 2012; Davies, Lum, Skouteris, Byrne, & Hayden, 2018; Henry & Rendell, 2007) that seek to combine relevant research and resolve the ambiguities in understanding arising from the conflicting results published in independent studies. Henry and Rendell’s (2007) review focussed on memory function during pregnancy and included 14 studies that spanned the 17 years prior to publication. They noted inconsistencies in that some studies supported the view that memory is adversely affected during pregnancy, while others failed to identify any measurable objective impairment at all. Henry and Rendell concluded that pregnant women were impaired on some but not all measures of memory. They report that statistically significant impairment could be found by focussing on memory measures that placed high demand on effortful processing, such as free and delayed recall and the executive component of working memory.

Anderson and Rutherford (2012) updated the 2007 review to examine whether more recent studies supported Henry and Rendell's conclusions. Anderson and Rutherford also broadened the criteria for inclusion by including studies that measured general cognition and processing speed. That this review had a wider cognitive scope meant that it was able to compare pregnant women with non-pregnant controls and report statistically significant results in a range of areas. The results published by Anderson and Rutherford that met the threshold for statistical significance are shown in table 1.

Table 1. Summary statistics from the 2012 meta-analysis comparing pregnant and non-pregnant women

Cognitive domain	Mean effect size	Lower 95% CI	Upper 95% CI	Total N
Working memory	-.07**	-.13	.00	1042
Free recall	-.14***	-.23	-.04	1621
Delayed free recall	-.20***	-.32	-.07	1037
Naturalistic prospective memory	-.25**	-.46	-.01	214
Processing speed	-.33***	-.53	-.09	949
Subjective memory	-.33***	-.41	-.24	636
General cognition	-.13*	-.27	.02	272

Note: * $p < .10$, ** $p < .05$, *** $p < .01$ (Anderson & Rutherford, 2012)

Laboratory testing of prospective memory yielded no difference between pregnant and non-pregnant women, but there was a difference when looking at naturalistic tasks.

A negative sign is an indication of pregnant women performing worse than non-pregnant control participants.

These results support the earlier review in some areas that are important to the current study. For example, Henry and Rendell (2007) suggested that tasks requiring more effortful processing are most likely to be negatively impacted during pregnancy, and Anderson and Rutherford (2012) also found that pregnancy had small to moderate effect on free and delayed recall as well as working memory. These are tasks that can be considered to involve effortful processing and sit under the broad umbrella of executive functioning. Processing speed was not a target variable of the 2007 review, but in 2012 it was found to have a larger negative impact during pregnancy than any of the memory measures. Anderson and Rutherford (2012) suggested that this might have been an important feature driving subjective reports of cognitive impairment from pregnant women. This idea is supported by the fact that the effect sizes for subjective memory and processing speed measures mapped very closely in their results. If processing speed deficits do directly impact other cognitive areas during pregnancy, a better understanding of this may alter the rhetoric around 'baby brain' and what that really describes from a cognitive perspective.

The most recent meta-analysis that addresses cognitive change during pregnancy (Davies et al., 2018) also seeks to update Henry and Rendell's 2007 review by testing their finding that memory is impacted in pregnancy. Additionally, Davies et al. (2018) sought to broaden the scope of their review to include overall cognitive function, executive function, and attention. This meta-analysis does not acknowledge or make reference to the 2012 review for reasons unknown. Similar to Anderson and Rutherford's (2012) review, Davies et al. also reported cognitive results that were consistent with Henry and Rendell (2007) to the extent that there were measurable differences in memory performance between pregnant women and non-pregnant controls.

It is difficult to directly compare memory findings with previous reviews because Davies et al. have aggregated the subdomains of working memory, recognition, and recall, to publish results for overall memory performance (SMD = 0.48 [95% CI, 0.04–0.92], p = .033). However, it is important to the current study that the difference in memory performance between pregnant and non-pregnant participants was greater when just looking at trimester three results (SMD = 1.47 [95% CI, 0.27–2.68], p = .017). Additionally, Davies et al. identified impairments in general cognitive function (SMD = 1.28 [95% CI, 0.26–2.30], p = .014) and in executive function (SMD = 0.46 [95% CI, 0.03–0.89], p = .036) only in trimester three of pregnancy.

When looking at cognitive differences that may be present during pregnancy, the phenomena whereby women in ‘late stage’ pregnancy perform differently when compared to women in the earlier stages of pregnancy seems to be a common feature of the literature. For the purposes of their review, Davies et al. (2018) described general cognitive function as a construct which encompassed memory, attention, executive function, processing speed, and verbal and visuospatial abilities. Executive functioning was described as including attention, planning, shifting between ideas, fluency, problem solving, abstraction, and ability to inhibit inappropriate responses.

However, the studies that informed the 2018 meta-analysis did not necessarily share the same definition of executive functioning for the purposes of those specific research goals. This is an important consideration when assessing the possibility that there is an impairment in this cognitive function during pregnancy. The authors of the 2018 meta-analysis note that executive functioning performance was calculated based on a limited sample, and that further research would be required to form more confident conclusions. The current study will aid in this endeavour by testing executive functioning performance during late stage pregnancy.

Information Processing Speed

Information processing speed definition

Information processing speed can be most simply defined as a measure of the efficiency of cognitive function (DeLuca & Kalmar, 2007). It can be considered a basic resource of the cognitive system and has been shown in the aging population to mediate declines in other cognitive areas (Salthouse, 1996). Operationally, information processing speed can be described as the time it takes for an individual to perceive information, process that information, and enact a response (DeLuca & Kalmar, 2007).

Extant literature on processing speed during pregnancy

As noted earlier, Anderson and Rutherford's 2012 review found that the highest pregnancy-induced deficits in cognitive performance were found when looking at processing speed. This was the only one of the three meta-analyses of cognitive function in pregnancy to report separately on processing speed differences. Interestingly, the deficit in processing speed most closely matched subjective memory complaints in the pregnant population. It was therefore suggested that processing speed deficit is a component that impacts how pregnant women perceive their memory difficulties (Anderson & Rutherford, 2012).

Six studies contributed to the processing speed results published in the 2012 meta-analysis. These studies used a range of measures to investigate processing speed, including digit symbol coding, the symbol digit modalities test (SDMT), the letter digit substitution test (LDST), and the speed of comprehension task of the SCOLP. One study that aimed to investigate whether the phenomenon of 'baby brain' reflected measurable cognitive decline, or the impact of social stereotypes (Crawley et al., 2008), found that there were significant group differences between pregnant and non-pregnant women on the speed of comprehension task of the SCOLP. Women who were not pregnant completed more items in this task than women in both the second and third trimester of pregnancy (*p* = <.001), and this difference was most evident in the third trimester. Women in their third trimester were also slower at attentional switching in the visual elevator task than women in the second trimester (*p* <.05) and non-pregnant women (*p* = <.001).

Another study looking at cognition in pregnancy was conducted in the Netherlands and measured processing speed using various tasks such as concept shifting, the Stroop test, and LDST (De Groot, Hornstra, Roozendaal, & Jolles, 2003). This study recruited one of the largest samples included in the 2007 and 2012 meta-analyses, with 71 pregnant women and 57 non-pregnant controls. They found no difference between those groups in any of the three tasks measuring processing speed. This finding is at odds with the overall findings of Anderson and Rutherford (2012) who, when including five other studies, reported an overall decrease in processing speed when comparing pregnant women with non-pregnant control participants.

There are some potentially meaningful participant characteristics in DeGroot et al's (2003) study however. For example, unlike any other studies that included processing speed as a measure, all pregnant women in DeGroot et al's study were in the early stages of pregnancy (less than 14 weeks). It may therefore be the case that pregnancy does induce some deficit in processing speed, but that this does not become evident until later in pregnancy. This is an idea which, as mentioned prior, is supported by other research (Crawley et al., 2008).

In another study looking at cognition during late stage pregnancy, as compared to the same women in the postpartum, pregnant women showed lower performance on tasks requiring speed of cognitive processing (Buckwater, 1999). This lends further support to the idea that gestational stage may play a role in pregnancy induced processing speed deficits.

Another study that found no difference in processing speed between pregnant and control women was conducted in the United Kingdom by taking a subset of women who had already contributed to a larger survey on personality and total health (Christensen et al., 2010). Data collected for this study was done initially in 1999, with follow-up assessments in 2003 and 2007. The authors were able to identify women who reported to be pregnant for the first time at either of the follow-up assessments, comparing their scores during pregnancy with their earlier scores before they were pregnant. This study used the SDMT to measure processing speed and reported overall that there was no difference between scores during or prior to pregnancy. Interestingly however, when the authors undertook some secondary analyses, examining whether the stage (or gestation) of the pregnancy impacted performance on the SDMT, they did find that women in late stage pregnancy showed some decline in scores compared to those when they were not pregnant. This finding was significant (t = 2.138, p = .033), however the authors noted in their limitations that the participant group size for this late stage pregnancy effect may be an issue, and that the phenomena therefore required replication.

One of the benefits of Christensen et al's (2010) study was that the same women were tested pre and during pregnancy, so they could measure effects on a particular person. The current study is unable to replicate that aspect of the research, however it does aim to restrict testing to a group of women who are all in the late stages of their pregnancies, to test the theory that this might be the crucial time for cognitive change taking place.

Possible effect of mood on processing speed

Harris, Deary, Harris, Lees, & Wilson (1996) used Digit Symbol Coding and the Paced Auditory Serial Addition Test to show that there was a pregnancy related decline in information processing speed. However, through further analysis, the authors found that this result was confounded with depression and that differences between pregnant and control women were no longer significant when depression was controlled for. Logan et al. (2014) have also suggested that increased levels of depression in the pregnant women who participated in their study provided a potential explanation for the processing speed deficits recorded in this group when compared to non-pregnant controls. Pregnancy is often a time of mental well-being, but it can sometimes be a great stressor in a woman's life which can increase the likelihood of developing a mood or anxiety disorder (Byrnes, 2018). This will be an important consideration for the current research, both for the well-being of participants, and for the possibility that cognitive results may be skewed by mood related features.

Approaches to measuring processing speed

While most studies that consider processing speed during pregnancy typically use rapid serial processing measures such as Digit Symbol Coding, the SDMT, and the Stroop, simple reaction time tasks have also been used with pregnant populations and there is evidence to suggest that performance on these tasks at 36 weeks pregnant is significantly lower when compared to non-pregnant controls (Silber, Almkvist, Larsson, & UvnÄS-Moberg, 1990). Hughes, Denney, & Lynch (2011) examined both approaches to assessing information processing speed deficits in patients with MS, and while they concluded that rapid serial processing measures were slightly better than reaction time measures, both approaches differentiated patients from controls and were highly significant (*p* values <.001). Furthermore, in this study, the correlation between SDMT scores and choice reaction time score was .401, indicating that both options can be assumed to be good measures.

One of the benefits of using reaction time tasks to measure processing speed is that tasks are often easy to use, and can be delivered using computer-based administration. Such administrations have been shown to be sensitive to detecting processing speed deficits, for example in clinical evaluations of traumatic brain injury (TBI) (Tombaugh, Rees, Stormer, Harrison, & Smith, 2007). Whilst TBI patients may be viewed as being different in many respects to healthy pregnant women, both populations would benefit from the administration of brief, simple tasks. For TBI patients this may be important because of an inability to concentrate for long periods, and for women in the late stages of pregnancy, they may be burdened with physical discomfort when sitting for long periods.

Further literature relating to reaction time measures suggests that the sensitivity of these measures relies on the reaction time tasks becoming more difficult. Reicker, Tombaugh, Walker, & Freedman (2007) found that as the reaction time tasks became more difficult, differences in performances between study groups increased. This finding implies that the current study might be best informed by including a more complicated measure of reaction time, requiring participants to respond to one of a number of stimuli.

Executive Functioning

Executive functioning definition

Executive function is a complex attribute encompassing a lot of different, higher order cognitive functions. At least 30 constructs such as planning, working memory, attention, inhibition, and self-monitoring exist under the umbrella term of executive functioning, and this makes it operationally hard to define (Goldstein & Naglieri, 2014). While there is great variation in how executive function is defined, there is reasonable agreement that planning is one of its core components (Barkley, 2012). Essentially, executive function is carried out in the pre-frontal areas of the frontal lobes and refers to the ‘executive system’ that is involved in controlling and managing other systems and processes required for individuals to function effectively (Barkley, 2012). In considering the planning and strategizing that women employ during their first pregnancies, to ready their families and households for a new addition, it is clear that at least in the case of planning, impairments in executive functioning may have important implications. If planning impairments in late stage pregnancy do exist, it would be valuable to understand the magnitude and impacts of those impairments on everyday life.

Extant literature on executive functioning during pregnancy

Due in part to the broad definitional nature of executive functioning, it is a difficult construct to discuss in an aggregated fashion as Davies et al. (2018) have done. It is therefore important to understand the studies that inform the published findings of that meta-analysis, which to reiterate, were that executive functioning is significantly poorer in women in the third trimester of pregnancy when compared to non-pregnant controls. Barkley (2012) suggests that there is an ongoing inability to operationally define executive functioning, which leads to extensive problems with regards to measurement. Given that there are more than 30 constructs that have been categorised as relating to executive functioning, virtually any cognitive measure aligned to one or more of those can claim to be executive in nature (Barkley, 2012).

Davies et al. (2018) base their findings, (that there is impairment in executive functioning in the late stages of pregnancy) on the results published in two independent studies (Crawley et al., 2008; Raz, 2014). Raz sought to investigate the behavioural and neural correlates of cognitive and emotional processing during pregnancy. To do this she compared the performance of women who were between 26 and 36 weeks pregnant with non-pregnant women matched on age and education. The measures used were an online continuous performance test (OCPT) and a visual emotional oddball task. These are both measures of sustained attention and response inhibition. The visual emotional oddball task in this study was developed based on the oddball paradigm which has been used extensively to identify the behavioural and neural correlates of cognitive processing by measuring electrophysiological responses (Näätänen, 1990). Whilst the term 'executive function' was not mentioned at any stage throughout the journal article, attention and inhibition do fit under the umbrella of executive function (Goldstein & Naglieri, 2014) and so can be considered to be measuring this, albeit quite differently to tasks that engage with mental planning ability.

Raz (2014) found that pregnant women had lower performance than controls on most indices of the OCPT and the oddball task. It seems important to the current study that the reaction times to the OCPT task were significantly slower for pregnant women than for controls ($F = 5.75$, $p = .022$), which creates the possibility that while the results of this study may be indicative of deficits in executive functioning, these might be linked to deficits in processing speed.

Role of processing speed in performance on executive functioning tasks

Adding to the complexity of including executive functioning in the current study is that authors have previously noted that measures of executive functioning can be influenced by problems in the realm of processing speed. This phenomenon has been noted in work with children (Willoughby, Blair, Kuhn, & Magnus, 2018) and as previously stated, in work with adults with MS (Owens et al., 2013). Owens et al. (2013) concluded that apparent differences in executive function between MS patients and healthy individuals observed in other studies were probably due to the fact that these other studies tended to use timed measures and therefore confounded the assessment of executive function with the very real deficits that MS patients have in processing speed. In other healthy populations such as older adults, declines in processing speed have also been found to account for a significant portion of other cognitive problems (Salthouse, 1996).

The findings of studies such as these, when considered alongside the evidence of there being some pregnancy-induced effects on processing speed, raise the question of whether processing speed has a role to play in the emerging idea that executive functioning is impacted in the late stages of pregnancy. This is a key consideration of the current study. The relationship between executive function and processing speed has been extensively explored in MS research (Blair et al., 2016; Drew, Starkey, & Isler, 2009; Leavitt et al., 2014), which is why this seemingly very different population is referred to a number of times throughout this thesis.

Stage of pregnancy related to performance on executive functioning tasks

As noted above, Crawley et al. (2008) suggested (in relation to processing speed) that ‘stage’ of pregnancy plays an important role in the presence of measurable cognitive impairment. Notably, the authors of this study also explored executive function in a much more explicit way than Raz (2014). Crawley et al. (2008) used 13 well known cognitive tests and found that significant group differences between pregnant women and non-pregnant controls existed only in the Speed of Comprehension task of the SCOLP, and in the timing score of the Visual Elevator task. They note in their post hoc analyses that women in the third trimester were also slower at attentional switching in the Visual Elevator task.

These results have two key implications for the current research. Firstly, that women in late stage pregnancy may be more prone to cognitive impairments compared to those earlier in their pregnancies. And secondly, that whilst the tests for which there were significant group differences may be considered measures of executive functioning, these were all tasks with a timed element, which leaves the interpretation open to imply that processing speed deficits might be more relevant to this study than problems with executive functioning.

Sleep quality related to performance on executive functioning tasks

Onyper et al. (2010) looked at executive functioning as part of their study examining cognition in pregnancy, primarily using the COWAT and Wisconsin Card Sorting Task (WCST). Pregnant women were found to generate significantly fewer words than control women in the COWAT ($t(44) = 1.81$, $p = <.04$), however there were no group differences on the WCST with respect to either the number of errors made, or the number of categories completed. The authors concluded that only limited support could be given to their hypothesis that women would be impaired on tasks of executive functioning. It was noted that there was some covariation between the scores on the COWAT and perceived sleep quality. This suggested that problems with verbal fluency may relate at least in part, to a lack of sleep.

Literature related to 'planning' ability during pregnancy

Despite the recent literature published in the area of executive function during pregnancy, research becomes more difficult to find if this is narrowed to measures relating to planning. This is despite consensus that planning is a core feature of executive functioning. Crawley et al. (2008) included both the Zoo Map task and the Modified Six Elements test from the Behavioral Assessment of Dysexecutive Syndrome (B. Wilson, Alderman, Burgess, Elmslie, & Evans, 1996) as measures of planning and prospective memory. There was no identifiable difference between pregnant women and non-pregnant controls on either of these tasks. A much earlier study that was not included in the 2018 meta-analysis used the Porteus Maze test in their study and found that pregnant women did have a mean difference from controls ($p = <.05$). Authors concluded that this indicated that there was a pregnancy-induced deficit in planning (Jarrahi-Zadeh, Kane, Van De Castle, Lachenbruch, & Ewing, 1969). Similar to Anderson and Rutherford's (2012) suggestion that processing speed deficits may be linked in some way to subjective memory complaints, Jarrahi-Zadeh et al. found that planning deficits closely matched subjective memory reports, and indicated that this may imply that poor test performance may relate to emotional factors, rather than to genuine issues with planning. It is therefore important that the current study measures participant mood, to be able to conduct an analysis on whether this accounts for some or all of any possible cognitive impairment.

Sleep Quality

Sleep quality definition

Sleep quality can be defined in relation to the current study as the subjective assessment of good or poor sleep. It differs from other aspects of sleep that might be considered in research such as the physiological architecture of sleep or the neural activation and deactivation of specific brain structures (Buysse, 2014).

Extant literature on sleep quality during pregnancy

It has been reported that more than three quarters of pregnant women report poor sleep during pregnancy (Chang, Pien, Duntley, & Macones, 2010; Hertz et al., 1992; Hutchison et al., 2012; Neau, Texier, & Ingrand, 2009) and that sleep quality worsens progressively throughout pregnancy (Ross, Murray, & Steiner, 2005). Reduced sleep quality is one of the most reported changes in pregnancy (Ladyman & Signal, 2018) and yet very few pregnant women are educated about its prevalence and therefore are not aware of the dangers sleep loss brings (Dixon, 2014). Sleep dysfunction is a known contributor to serious impairment in daytime performance (Shekleton et al., 2014). The significance of the link between sleep and cognitive processes is put into context by considering that one night of total sleep deprivation causes neurobehavioral impairment equivalent to a 0.10% bloodalcohol concentration (Dawson & Reid, 1997). Although sleep disturbance in pregnancy usually doesn't meet the threshold for sleep deprivation, the cumulative effect of fragmented sleep across consecutive nights leads to impairments equivalent to those following one night of total sleep deprivation (Insana, Williams, & Montgomery-Downs, 2013).

A recent review into sleep health during pregnancy provides confirmatory evidence for reduced sleep quality during this time, and that sleep may be most disturbed during the third trimester (Ladyman & Signal, 2018). However, this review cautions that there are limited studies available from which to draw such conclusions, and that these studies are additionally limited by geographical bias given that most originate in Taiwan or the United States, with none considered from New Zealand (Ladyman & Signal, 2018). The current review of literature in the area of sleep and cognitive performance in obstetric populations confirms that it is sparse. Most cognitive studies that include a sleep measure have been specifically focused on particular domains of memory such as working memory (Hampson et al., 2015), and verbal memory retention (D. Wilson et al., 2013). When targeting these specific domains, authors of the research have been unable to find a link between memory deficits and sleep disturbance, although small correlations between memory and sleep meant they were unable to rule out sleep as a contributing factor. Onyper et al. (2010) measured sleep quality in their pregnancy study and found a significant difference between pregnant women and non-pregnant controls ($t(44) = 1.87$, $p = .035$). This finding triggered some post-hoc analysis to re-examine cognitive differences between study groups while controlling for reduced sleep quality. It was concluded that although the effect of pregnancy remained significant for some cognitive measures, the groups no longer differed in the number of words generated on the COWAT. This suggests that sleep quality may be an important feature in the observed scores on this measure.

Effect of reduced sleep quality on processing speed

Rather than looking at memory specific domains, a study by Insana et al. (2013) aimed to measure reaction time performance in women in the 12 weeks following childbirth. Results from this study have provided evidence to suggest that the cumulative effects of sleep disturbance in the postpartum period may have negatively influenced their performance on the reaction time task used. This lends support to the idea that similar effects might be seen in the pregnant population, given that sleep, particularly in the later stages of pregnancy, is impaired in a similar way.

The relationship between sleep quality and cognition during pregnancy has not been extensively investigated in extant literature, however a study by Henry & Sherwin (2012) that has reported finding impaired processing speed in pregnancy, also included the PSQI as a measure of sleep quality. They reported no significant relationship between sleep quality and processing speed, however they also noted that the pregnant participants in their study reported only minor sleep difficulties. Studies on other populations such as adolescents, have shown that processing speed is particularly vulnerable to sleep loss (Cohen-Zion, Shabi, Levy, Glasner, & Wiener, 2016).

Sleep quality as related to memory deficits

A related study that may be considered to be closely aligned to the pregnant population is that which was conducted by McBean & Schlosnagle (2016) to investigate the relationship between sleep disturbance and general health of parents of children with special health needs. Participants in this study were predominantly female, and due to the health needs of their children they reported poor sleep quality. Sleep quality in this population could be considered similar to that experienced in pregnancy (such as taking longer to fall asleep at night, shorter overall sleep duration and worse subjective sleep quality). The study found that poor sleep quality was associated with worse prospective and retrospective memory among parents.

Summary

In summary, evidence suggests that a large proportion of women report sleep disturbances in pregnancy. This sits alongside a growing body of evidence to suggest cognitive changes occur in pregnancy. Two areas that have shown to be significantly impacted in pregnancy are processing speed and executive functioning. It is important to understand how sleep disturbances in this population are related to performance on measures of these two cognitive domains. It might be the case that compromised sleep quality causes impairment rather than pregnancy itself. This knowledge could be used to better inform women of the various components underlying cognitive change, and perhaps empower them to prioritize sleep and make some beneficial changes to sleep habits.

If pregnancy-induced reduction in sleep quality is found to be linked with cognitive deficits in this study, the results will contribute to an evidence base that highlights the importance of sleep in the obstetric population. This may inform treatment for women at the more severe end of the spectrum in regard to sleep quality. In addition to the direct benefits for pregnant women, this research would contribute to the existing literature published regarding cognitive changes during pregnancy which is currently burdened with confounding evidence either for or against the existence of cognitive difficulties during pregnancy. If reduced sleep quality is found to contribute to cognitive change in pregnancy, it may then be considered to be a factor explaining these mixed results.

General Issues Pertaining to Research with Pregnant Women

A review of the extant literature relating to cognitive performance during pregnancy has raised some additional considerations that are important to the current study. Firstly, there is some evidence to suggest that adverse effects on cognitive function, at least with respect to memory, are compounded with successive pregnancies (Glynn, 2012). This evidence raises the possibility that parity, or the number of pregnancies that a woman has experienced, might impact their performance on cognitive tasks.

Secondly, Cuttler et al. (2011) flagged the possibility that the physical symptoms of pregnancy, which were measured explicitly in their study, accounted for at least a portion of the pregnancy related deficits in prospective memory. This is interesting information to be considered in the current study because pregnant women are all in their third trimester, therefore possibly feeling discomforts more acutely after sitting for an hour in front of a computer.

CHAPTER THREE

The Current Research

Research Context

Through conversations with the team already working on 'baby brain' research, it became evident that there were several aspects of this phenomena that required further investigation. There were many benefits to working within a team structure. Firstly, the task of participant recruitment was shared. This was a great advantage to both research projects, as recruitment of pregnant women in Wellington has been found to be both difficult and time consuming in the past (Sweeney, 2013). Additionally, the team was able to take a joint approach to data collection, thereby doubling the number of participants they were able to meet with through shared test administration as well as shared budgets for participant koha. This therefore avoided the previously identified limitations of some existing studies in this area having small sample sizes.

The current research was conducted (by researcher C) as part of a wider study that was being investigated by a doctoral student at Massey University (researcher P).

Current Research

Because subjective cognitive complaints in pregnancy are common, there can be benefits from the expansion of existing research in this area by helping to clarify the measurable objective difficulties women may experience at this time. Whilst traditionally focussed on memory complaints, a review of the literature relating to cognition during pregnancy indicates that research in this area is broadening in scope to include the investigation of a range of cognitive functions. Meta-analyses appear to agree that women experience impairment during pregnancy in some but not all areas of memory, processing speed, and executive function.

Looking at the independent studies that inform these meta-analyses creates a somewhat ambiguous view of the impact of pregnancy on cognitive function. Some studies report no difference at all between pregnant women and non-pregnant controls, whereas others have found measurable cognitive impairments. One of the possible contributing causes of equivocal findings is that many of the sample sizes in studies are limited, making the detection of small differences difficult. For example, of the six studies that informed the 2012 meta-analysis in regards to processing speed deficits, only one (De Groot et al., 2003) had more than 64 participants (the number Cohen (1992) suggests is required to find medium sized effects between groups).

Research suggests that structural brain changes that occur during pregnancy are long lasting, enduring for at least two years post-pregnancy (Hoekzema et al., 2017). And while it is not known whether these structural changes have any behavioural impact, it does raise the possibility that control women who are already biological mothers and whose brains may have undergone structural change, may bias results. The literature review revealed evidence that suggest cognitive performance is differentially impacted depending on the number of successive pregnancies a woman has had (Glynn, 2012). Despite this, very few studies have accounted for whether control women had previously had a child, and nor have many stipulated in respect of women in the pregnant group that it must be the woman's first pregnancy. This is deemed to be important for this study, not only due to the possibility that neurological change is pervasive, but also because the demands on a pregnant mother with older children are different to a woman pregnant with her first child. For example, sleep may be more severely restricted or disrupted if a mother is needing to get up to a toddler during the night.

Additionally, prior research has often not placed emphasis on the gestation of the pregnancy at the time of testing. It appears that differences in cognitive performance are more pronounced in late pregnancy, yet many studies have tested women at all stages of pregnancy without controlling for gestation at the time of testing. This may have contributed to the inability to detect effects that are perhaps genuinely experienced in the later stages of pregnancy.

The current research seeks to minimise the possibility that cognitive deficits that might be characteristic of pregnancy remain undetected using a number of methods. Firstly, by ensuring the sample sizes for the pregnant and non-pregnant control groups are large enough and recruiting at least 64 women per group. Secondly, by only testing with women who are pregnant with their first child. Thirdly, by only testing with women in the late stages of their pregnancy – which for the purposes of this study is 33-40 weeks.

Constructs

Research that investigates problems with memory is comparatively extensive in this field, however studies that relate to executive function are more limited in numbers. It has been suggested that executive functioning is one of the cognitive areas most effected during late-stage pregnancy, however the literature that informs this idea takes inconsistent approaches to defining and measuring the construct itself. This makes those studies difficult to compare. Researchers have noted that there is a need for further investigation into the changes that may take place in executive functioning ability during pregnancy.

One important study that has measured executive function using a range of tests has found pregnant women to be differentiated from controls in one but not all facets of executive functioning (Crawley et al., 2008). This would imply that it is possible that deficits may be specific to certain elements of executive function, and if this is the case, it would be important to know which functions may be compromised during pregnancy. In thinking about the changes taking place for an expectant new mother, and the preparations she and her family must make leading up to the birth of her first child, it seems that planning is a crucial competency in pregnancy. If this was significantly impaired, that would create problems for women that would be important to understand. For this reason, planning is the facet of executive function that will be explored in the current study.

Processing speed is another cognitive area that meta-analyses have identified as being compromised during late stage pregnancy. However, looking at the independent studies that inform this finding, we can see that there is ambiguity in results. It would therefore be beneficial to replicate a study of processing speed with a comparatively large sample of pregnant women to add to the literature pertaining to processing speed during pregnancy and help to understand whether there are problems in this facet of cognition.

The benefit of looking at both executive function and processing speed is that it enables the assessment and consideration of whether problems in the realm of executive function are more likely to be a reflection of deficits in processing speed. This has been shown to be the case in other populations such as older adults and patients with MS and it therefore seems an important consideration.

Aims

The main aim of the study was to investigate women's cognition during pregnancy. Specifically, this study seeks to investigate the relationship between information processing speed and executive functioning – both of which have been shown by meta-analysis to be negatively impacted in pregnancy. The study also seeks to ascertain whether there is any possibility that deficits in these areas are moderated by reduced sleep quality or mood in the late stages of pregnancy.

Research Questions and Hypotheses

Do women in late stages of pregnancy show deficits in either or both of executive functioning and information processing speed? Based on meta-analyses published in 2012 and 2018, it is hypothesised that both of these domains will be negatively effected in the late stages of pregnancy.

Might any pregnancy induced decline in executive functioning be more accurately described as a secondary consequence of difficulties in information processing speed in pregnancy? It is hypothesised that relatively poor information processing speed will determine at least a proportion of the decline in executive functioning.

Does a reduction in sleep quality account for deficits in either or both of executive functioning and information processing speed? Despite previous studies finding that sleep quality was not a contributing variable to cognitive difference between pregnant and non-pregnant research groups, it is hypothesised that relatively poor sleep quality will play some role in predicting scores on cognitive tasks.

Study Implications

Both processing speed and executive functioning have fundamental importance to daily life, and the evidence to suggest that pregnancy-induced objective deficits exist in these domains warrants further investigation. Pregnant women, on top of needing to function in their everyday lives, may have additional planning pressures such as organising the necessary material items required to prepare the home for the arrival of a baby, planning how to share parenting responsibility, negotiating maternity leave, etc.

If a pregnancy-induced reduction in sleep quality is found to be linked with cognitive deficits in this study, our results will contribute to an evidence base for highlighting the importance of sleep in the obstetric population. This may inform treatment for women at the more severe end of the spectrum in regards to sleep quality.

In addition to the benefits for pregnant women, this research would contribute to the existing body of literature in this field which is currently burdened with mixed research outcomes. If sleep is found to contribute to cognitive change in pregnancy, it may then be considered to be a factor explaining the mixed results of previous studies that have omitted sleep quality as a measure.

CHAPTER FOUR

Method

The study design is a cross-sectional between groups design comparing the cognitive performance of women in late stages of pregnancy with their first child with that of women who are not pregnant and have not yet had a child. Whilst the meta-analyses published in 2012 (Anderson & Rutherford) and 2018 (Davies et al.) support the main study hypothesis, that women in the late stages of pregnancy show deficits in both executive functioning and information processing speed hypothesis, there are no suitable studies included in these analyses to use in sample size estimations. For this reason, sample sizes were based on Cohen's (1992) calculations to find a medium sized mean difference when $\alpha = .05$. This translates to at least 64 participants for the late stage pregnant group, and at least 64 comparable control women. The reported difference in information processing speed in the 2012 meta-analysis and the reported difference for executive functioning in the 2018 meta-analysis both support the rationale for a sample size suited to medium sized mean differences.

Participants

The participants in the current study were 68 women pregnant with their first child, and 65 women of a similar age who were not pregnant and who had not previously had a child at the time of testing. Pregnant women were asked to meet for testing during the late stages of their pregnancy. The current study defined late stage pregnancy as >33 weeks gestation. The importance of including this gestation criteria has been based on numerous prior studies that found this to be a factor contributing to cognitive impairment (Buckwater, 1999; Christensen et al., 2010; Crawley et al., 2008). Additionally, the 2018 meta-analysis

(Davies et al., 2018) found that the statistically significant effects of pregnancy on executive functioning were only present during the third trimester. Given that one of the main objectives of this study was to test this finding, it was important to include gestation in the criteria for testing.

Further rationale for focussing on late stage pregnancy is found in the 2018 review of maternal sleep (Ladyman & Signal) where sleep quality was shown to be most affected in the third trimester of pregnancy. Gestation of pregnant women at the time of testing varied between 33.0 and 39.3 weeks (M = 35.6, SD = 1.81). Figure 1 shows the gestation of the 68 pregnant women in this study.

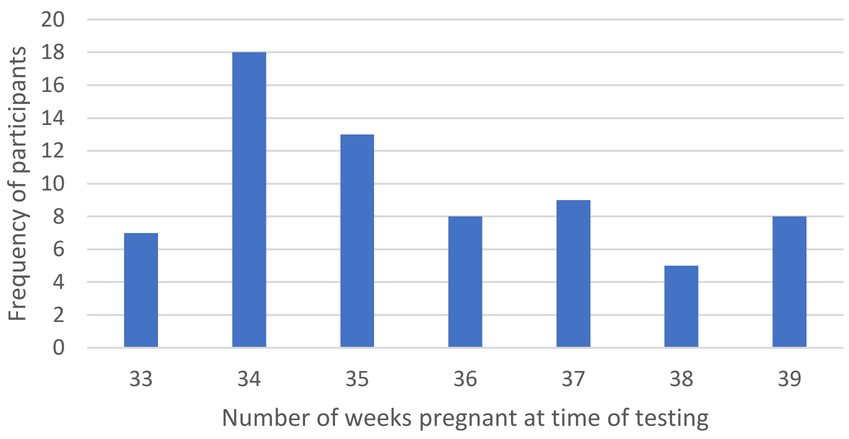

Figure 1. Chart showing gestation of pregnant women at time of testing.

The participants' ages ranged from 19 – 42 years with the average age of pregnant participants being 31.78 (*SD = 4.15*), and the average age of non-pregnant participants being 30.42 (*SD = 4.89*). An independent samples t test revealed no significant difference between these groups in terms of age, $t(131) = 1.74$, $p = .085$.

Level of education was scored from zero (no formal education) through to seven (doctoral level degree). Compared to Wellington women overall, participants in this study were well educated[1]. Over 80% of study participants held an undergraduate, postgraduate, or doctoral degree compared with only 43% of women in the Wellington region. Although the study participants were more highly educated than the population from which they were drawn, the pregnant and non-pregnant groups are very similar in level of education and so any differences in cognitive scores between these two groups are unlikely to relate to any disparity in education. Because scores assigned to the level of education variable represent ordinal rather than interval or ratio data, they were analysed with nonparametric statistical tests. The median level of education for both pregnant and non-pregnant participants was 5 which translates to the median qualification being an undergraduate degree. The interquartile range for both sample groups was 1. A Mann Whitney test found that there was no statistically significant difference in level of education between pregnant and non-pregnant groups (z = .689, p = .490). Figure 2 shows the highest level of education presented as a percentage of women in each of the study groups, as well as regional percentages for women aged between 20 and 44 years.

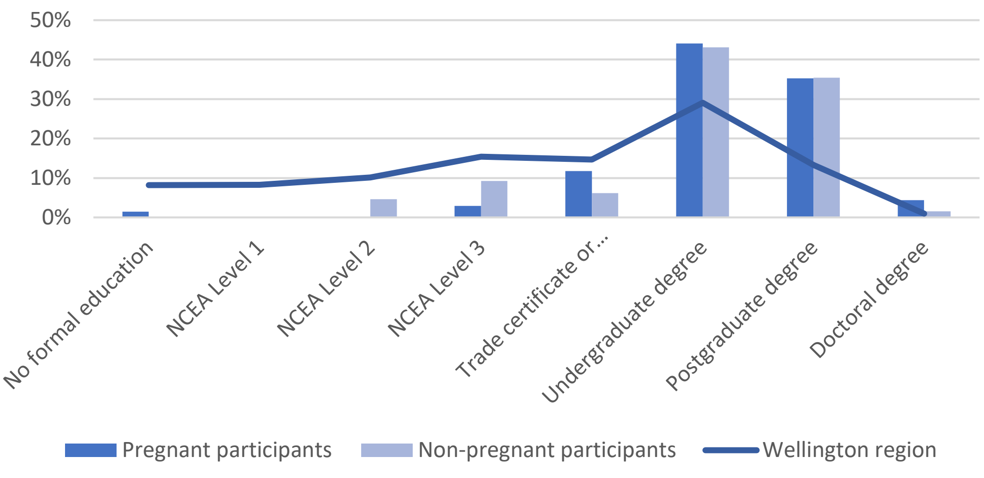

Figure 2. Highest level of education

Regional data sourced from Statistics New Zealand

[1] Under the agreement they have with The Council of New Zealand University Librarians, Statistics New Zealand have provided a customised table for comparison with participants in this study. The comparative data provides a subset of the 2013 Census data that is specifically focussed on women aged between 20-44.

When enquiring about participant ethnicity, the current research took the approach recommended to researchers by Statistics New Zealand, allowing participants to identify with multiple ethnicities, and deriving proportions based on total ethnic counts. Historically it has been more common to use methods of ethnic prioritisation which assign people with multiple ethnicity to one ethnic category. This prioritisation method has the advantage of ethnic counts being equal to population counts, meaning that data is mathematically more straightforward to analyse, but it comes at the cost of drawing potentially misleading conclusions about participant ethnicity (Didham & Callister, 2012). The use of total ethnic counts provides a more accurate description of research populations, despite adding some complexity to statistical analysis because of the overlapping of ethnic categories. It is important to understand that under this approach, the sum of ethnic categories exceeds the total population count, and so the sum of all published ethnic proportions will be > 100%.

The pregnant and non-pregnant groups show similarities in the percentages of women identifying with each ethnic group. These distributions matched reasonably well to the wider Wellington and New Zealand populations that were provided to the author by Statistics New Zealand. Unfortunately, despite efforts to recruit Māori women as participants in this study, proportionally Māori were under-represented. Only 7% of pregnant participants and 12% of non-pregnant participants identified as Māori, whereas at the national level Māori represent 15% of the population. Table 2 more clearly shows the percentage of women in each ethnic category.

Table 2.

Ethnic composition (%'s) of sample groups with comparative national statistics

Ethnic group	Pregnant (n=68)	Non-pregnant (n=65)	Wellington (n=86,157)	New Zealand (n=715,758)
NZ European	63	72	63	59
Māori	7	12	13	15
Samoan	3	2	5	3
Cook Island Māori	3	0	1	1
Tongan	0	0	1	1
Niuean	1	2	0	1
Chinese	1	5	4	6
Indian	6	5	4	5
Other	26	22	23	22

Some participants have reported multiple ethnicity meaning that ethnic categories overlap. Percentages have been calculated using population counts as the denominator, hence sample group percentages total > 100%. Source of regional and national data: Statistics New Zealand

The group size of at least 64 participants per group was based on Cohen's (1992) calculations to find a medium sized mean difference when $\alpha = .05$. Estimating sample size based on the effect sizes reported in previously published studies that assess executive functioning and processing speed during pregnancy was considered flawed due to the variation and inconsistencies in results between those studies. Cohen's recommendations were therefore considered to be the most realistic approach in proving a sample size sensitive enough to detect meaningful differences between study groups in the realm of both executive function and processing speed.

To be able to statistically test whether impairments lying within the realm of executive function were due to underlying problems with processing speed, participants were randomly assigned to complete the executive functioning measure under either timed or untimed conditions. Of the pregnant participants, 35 were given a timed version of the Tower test and 33 an untimed version. Of the control participants, 32 were given a timed version of the Tower test and 33 an untimed version.

It is recognised that because these subgroups exist for the executive function measure, Cohen's threshold of 64 per group was no longer met for the purposes of this cognitive domain. However, this reduced sample size still exceeds those used in the 2018 meta-analysis to evidence significant differences in executive functioning during pregnancy. The results of these studies were based on late stage pregnancy group sizes of 25 (Crawley et al., 2008) and 17 (Raz, 2014). In each case these compared with similar sized control groups.

Because of the requirement to meet with participants face-to-face, recruitment was limited to women in the greater Wellington region. Research participants were offered a koha of a $20 grocery voucher to thank them for the time required for participation in the study. Women were recruited through a range of different avenues. A Facebook page was created which outlined the purpose of the research and provided information to women about what would be required of them if they chose to participate. This was a useful marketing tool for the study because it made it easy to share with women in the wider Wellington community. The Facebook page was linked to social networking pages used by antenatal groups across the region, and the success of this meant that the majority of participants signed up to the study via Facebook. This same page was also able to be promoted and shared with women who were eligible to sign up as non-pregnant control participants, with specific posts and advertisements aimed at recruiting these women.

Other recruitment methods included contacting and visiting antenatal groups and breastfeeding classes directly. On some occasions the researcher presented to these classes in person, and on other occasions printed information sheets were provided to group coordinators who could then disseminate those to pregnant women. Advertising was also done through pregnancy yoga classes, hydrotherapy classes for pregnant women, hypnobirthing classes, and an acupuncture clinic specialising in pregnancy. Direct contact was made with obstetricians and midwives, who despite being very busy, were often happy to at least display some study brochures in waiting rooms.

Recruitment for the control group women was driven largely through the Facebook marketing efforts, and through word of mouth. Pregnant participants were invited to nominate a control participant, and additionally the personal contacts of the researcher were utilised to spread word of the project. On some occasions, when visiting a workplace to meet with a control participant, that participant would recommend colleagues who could meet directly following the testing session.

Data Collection Context

As previously mentioned, data collection was conducted in conjunction with ‘researcher P’ whose research focus was concerned with changes in social cognition during pregnancy. The projects were aligned because the participant groups that each of the researchers were recruiting was the same. However, the studies themselves, and most of the measures used to investigate each study, were distinct from each other. Prior to testing with any study participants, the researchers familiarised themselves with materials and manuals, and practised administration at home with friends and family. For the first four participants, both researchers went to testing sessions together to get a good understanding of how tasks could be consistently administered. For all other participants, researchers went to testing sessions alone. When administering computer-based reaction time tasks, reported response times can vary depending on the mouse or keyboard being used (Plant & Turner, 2009).

Because the computer based cognitive tests were conducted on two different laptops, there was a need to consider timing errors caused by the use of different hardware. The goal was that each researcher would meet with equal numbers of pregnant and non-pregnant participants to control for the potential that each would measure reaction times differently. Unfortunately, there was some difficulty in achieving this goal due to the availability of the researchers, and as such, this even split did not occur. Table 3 details the number of participants tested by each researcher. Possible implications for the integrity of the research findings are discussed in the results and discussion chapters.

Table 3.

Numbers of participants tested per examiner

Examiner	Pregnant		Not pregnant	
	Timed Tower	Untimed Tower	Timed Tower	Untimed Tower
Researcher C	21	15	18	21
Researcher P	14	18	14	12

Measures

Demographic and general information

Demographic data for this research was collected at the beginning of the testing session and comprised five questions relating to age, level of education, the number of hours spent with children, ethnicity, and the due date of pregnant women. The number of hours spent with children was not a variable of interest for the current study but was asked in relation to the social cognition aspects of the wider study.

Deary-Liewald reaction time task (Deary, Liewald, & Nissan, 2011)

In this task, information processing speed is derived through recorded reaction times using both a simple reaction time (SRT) task, and a choice reaction time (CRT) task. Previous studies with pregnant populations have tended toward measuring information processing speed by adopting a rapid serial processing approach, such as the digit symbol coding test or the stroop. Hughes, Denney & Lynch (2011) examined both the reaction time approach and the rapid serial processing approach to assessing information processing speed deficits in Multiple Sclerosis (MS) patients. Based on that research, rapid serial processing approaches were seen to be slightly better than reaction time approaches to measuring processing speed deficits in MS patients. However, all differences between MS patients and healthy controls on these measures were highly significant (all p's $< .001$), and so using a reaction time test like the Deary-Liewald was deemed to be appropriate.

The Deary-Liewald reaction time task was selected for the current study because of its ease of use and because its computer-based administration fitted with the rest of the test battery for the study. Late stage pregnancy is often accompanied by discomfort with sitting for long periods of time and so the brief nature of this test was also a determining factor in its selection.

The administration of the Deary-Liewald reaction time task begins with the SRT test. In this test a single white box appears in the center of the screen. Participants are told that a cross will appear eight times during a practice session of the task, and that each time it appears they should press and release any key as quickly as they can. At the end of the practice participants are asked if they understand what to do. Once this is confirmed, the cross will appear another 20 times, and as in the practice phase, participants must press any key as quickly as they can upon seeing the cross. At the end of the SRT test a message reads “Test Completed Thank You!”, at this point participants move on to the CRT test.

In the CRT test, there are also eight practice trials. The premise is similar to the SRT test, however there are now four white squares presented horizontally in the center of the computer screen. The same cross as the one that appeared in the SRT test will appear in one of the four boxes and participants must press the correct key for that box as quickly as they can. The squares in the CRT test correspond to specific keys on the keyboard, which for this study was ‘z’ for the far left box, ‘x’ for the box one from the left, ‘full stop’ for the far right box, and ‘comma’ for the box second from the right. Participants are reminded that a cross can appear in any of the four boxes, and when they are ready, they start the practice. If the participant understands what to do following the practice trials, they begin the recorded trials where the cross will appear another 40 times.

Computerised Tower of London. (Krikorian, Bartok, & Gay, 1994)

The Tower of London test is a measure that is used in the assessment of executive functioning, specifically to detect deficits in planning ability. Executive function is a complex attribute encompassing a lot of different, higher order cognitive functions, but there is reasonably good consensus that one of these is "planning"(Barkley, 2012; Goldstein & Naglieri, 2014). The Tower task has an added benefit of yielding a measure of the speed with which this mental planning is taking place, which provides a useful comparison with the reaction time data derived from the Deary-Liewald reaction time task.

The computerised version of the Tower task that is used in this study was designed at the University of Kansas for the purpose of challenging evidence that Multiple Sclerosis patients have impairments lying within the realm of executive function (Owens et al., 2013). Studies with these patients found that what sometimes appeared to be poor executive functioning was really a secondary consequence of their difficulties in processing speed. Given that these are the same two cognitive constructs that the current study is researching in late stages of pregnancy, this version of the Tower was an appropriate one.

This specific Tower task presents a display of three coloured discs arranged on three pegs in the upper portion of the computer screen. In the lower portion of the screen are the same three pegs, with the same three discs, presented in a different arrangement. The participant's task is to move the discs in the lower portion of the screen to match the arrangement in the upper portion of the screen. Three practice problems were worked through by participants so that they were comfortable with what was being asked of them. These practice problems also gave participants the opportunity to become comfortable operating the mouse to make the required moves to solve each problem.

Once participants had completed the practice problems, they were given 16 further problems graduated in difficulty from those that could be solved in two moves, to those requiring five moves. The number of moves permitted for each problem was presented to them prior to the discs pertaining to that problem appearing. This was so that once the problem was displayed, participants could focus their full attention on solving that problem in the allotted number of moves. The computer measured and recorded planning time as length of time between the display of the problem and the first move. Executive functioning performance was measured as the total points scored from the 16 problems participants were asked to complete.

Participants were randomly assigned to complete this task under either timed or untimed conditions. Those in the untimed condition were told they could take as much time as they required to solve each problem. Those in the timed condition were restricted to a set amount of time per problem, which varied depending on the number of moves. Table 4 details the time allowed for each problem.

Table 4.

Time allowed for participants assigned to the timed condition of the Tower task

Problem difficulty	Time allowed (seconds)
Two-move	7
Three-move	12
Four-move	17
Five-move	22

The timed condition included some differences from the untimed condition. As well as the number of moves permitted for each problem being presented to participants prior to the discs appearing on screen, those in the timed condition were also shown the time allowed for each forthcoming problem. In addition, once the participant had commenced each problem, the seconds remaining counted down in a box at the top left side of the screen in the timed condition. If the time expired prior to the participant solving a problem, a text box appeared on screen to indicate that the current problem had timed out, and to move participant along to the next problem. Figure 3 shows the layout of this task on screen for both the timed and untimed conditions.

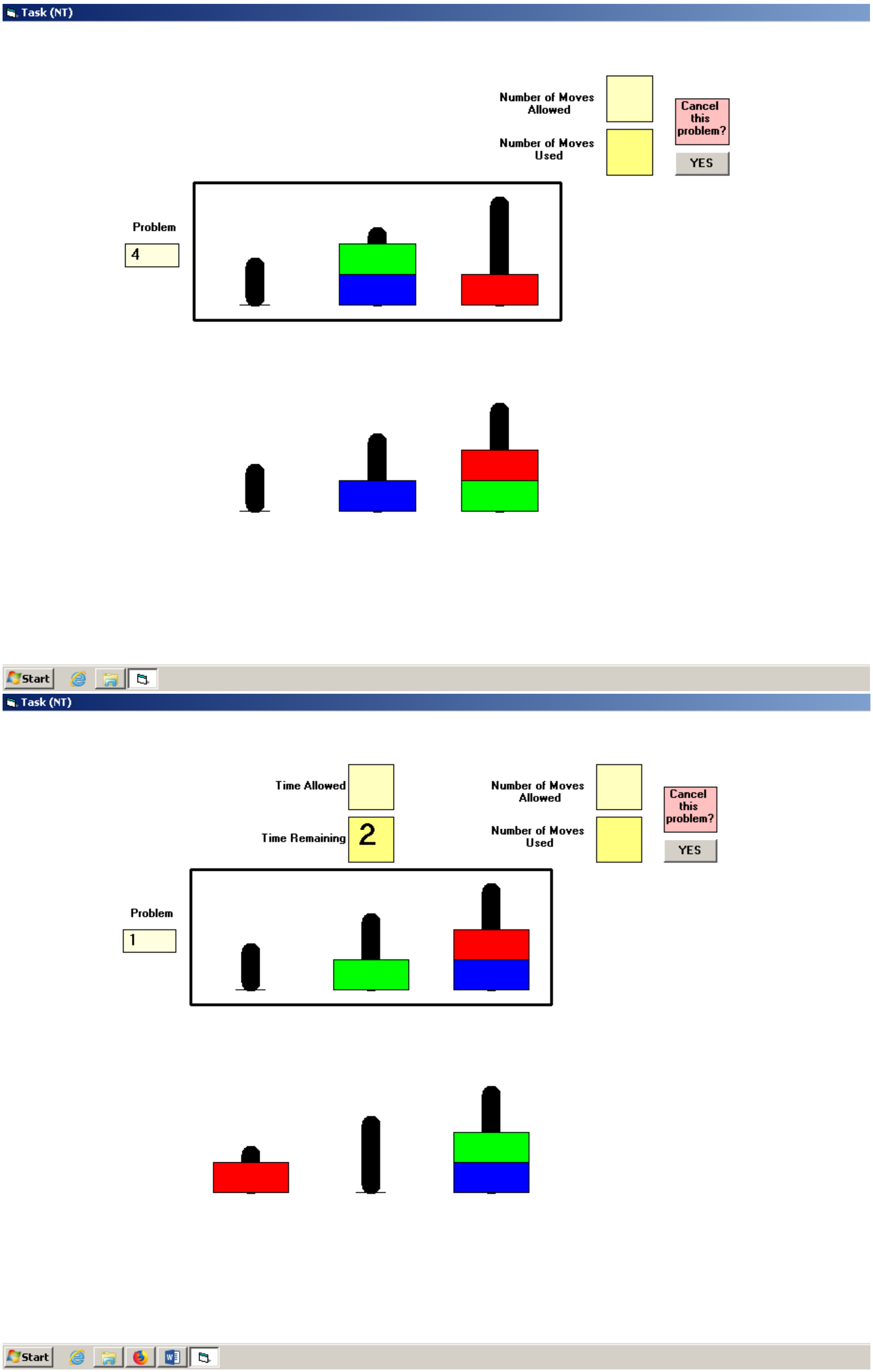

Figure 3. Screen layout for the Tower task

Pittsburgh Sleep Quality Index (PSQI)

The Pittsburgh Sleep Quality Index is a self-rated standardised measure of subjective sleep quality (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The questionnaire is comprised of 19 items which assess a variety of factors relating to sleep quality during the previous month. Participants are asked to estimate sleep duration, sleep latency, use of medications, daytime sleepiness that may impede functions such as driving or socialising, and also the presence and frequency of specific sleep related problems such as difficulty falling asleep and waking throughout the night. These items generate seven equally weighted component scores relating to subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction due to sleepiness. Component scores are totalled to yield a global PSQI score between 0 and 21, where higher scores relate to poorer sleep quality.

The PSQI was favoured as a measure of sleep quality in pregnancy because it is easy for participants to understand and can be completed within 5-10 minutes. The brief nature of the measure is useful with participants who are in the later stages of pregnancy and who may therefore become uncomfortable sitting for long periods. The PSQI has been widely used in a number of studies that consider sleep quality as an important feature of cognitive performance (Ahrberg, Dresler, Niedermaier, Steiger, & Genzel, 2012; Kazemi et al., 2016). It has also been shown to have good construct validity and reliability for assessing sleep quality among pregnant women (Zhong, Gelaye, Sánchez, & Williams, 2015).

Depression, Anxiety, Stress Scale (DASS-21).

The DASS-21 is the short form of the DASS-42 (Lovibond & Lovibond, 1995). The scale consists of 21 items that relate to three subscales for depression, anxiety and stress. Each subscale is informed by seven items for which participants are asked to indicate how much a particular statement applied to them over the past week from 0 (did not apply to me at all) to 3 (applied to me very much, or most of the time).

The DASS-21 has been shown to be reliable and valid with non-clinical samples (J. Henry & Crawford, 2005). It is also highly correlated to other validated measures of depression and anxiety, indicating a high convergent validity. The DASS-21 has been used successfully in existing research with pregnant populations (Saeideh, Hossein, Leila, & Akram Sadat, 2018; Shafaie, Mirghafourvand, Rahmati, Nouri, & Bagherinia, 2018; Zhong et al., 2015).

Procedure

Women who registered their interest in the study were sent a follow up email or Facebook message that included information sheets for both studies. Once they had read through relevant information, they would then confirm their interest in participating and individual meetings were arranged at a time and place that was most suitable for them. It was explained to participants that the location needed to be one that was quiet and free from distraction. In most cases, women opted for meeting rooms at their work places, in quiet areas of public libraries, in study rooms at Massey University Library, or in their own homes. In the initial stages of the meetings, participants were encouraged to ask any questions they had regarding the information they had been sent. Once any questions and concerns had been addressed, they signed consent forms and testing could begin. Copies of the study information sheets and consent form are provided in Appendix A.

The testing itself was done in three stages which are outlined in figure 4. The first stage involved participants working through an online Qualtrics survey at their own pace, and without any input from the researcher. During this time, the researcher sat across from the participant, usually doing some reading, whilst being available for any procedural questions that the participant might have.

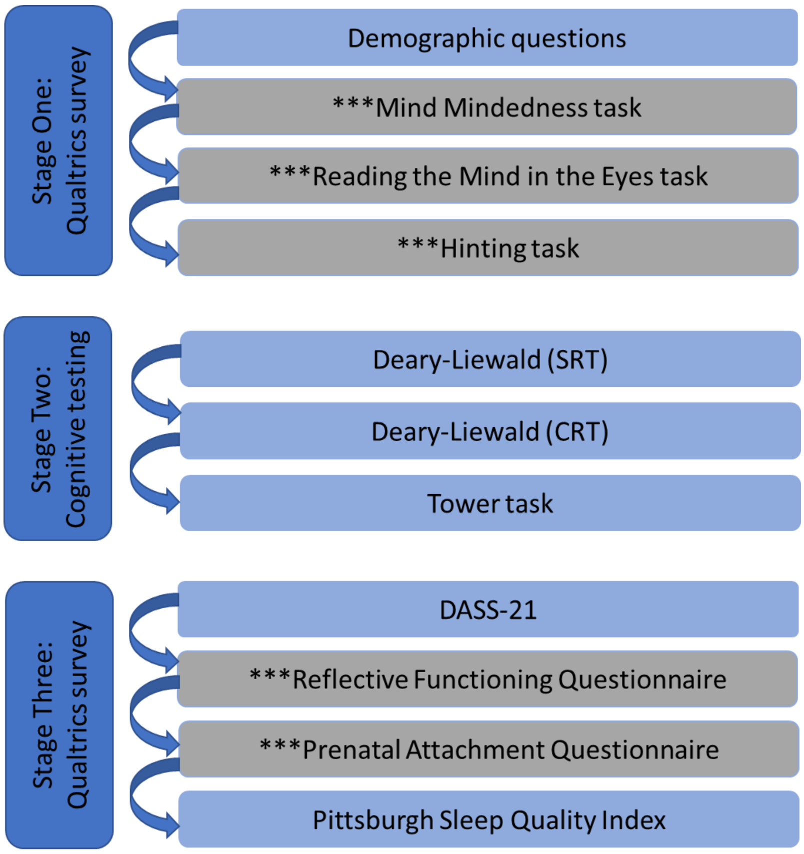

Figure 4. Testing schedule for research participants
(*** these tasks relate only to examiner P's study)

As previously mentioned, despite best efforts, researcher C and researcher P met with an uneven number of participants. Additionally, there was an uneven split between timed and untimed Tower test administrations between examiners. This is important to understand when considering the current study results, and potential role of examiner effects.

Stage two of the testing required more direct guidance by the researcher as the computer based cognitive tasks were explained. In the case of the Deary-Liewald tasks, a script was followed that gave participants clear instructions of how to complete both the simple and choice reaction time tasks. Participants were given verbal instruction and were then asked to complete a practice trial where the target stimulus appeared eight times. Both tasks are straight-forward to understand and all participants were comfortable moving into the recorded test phase.

The Tower task was a somewhat more complex to explain to participants, as the task itself is more difficult. A script was followed to ensure that all participants were given the same instructions prior to testing. Participants where then stepped through three practice problems with the researcher observing and available to answer questions. It was during this practice phase that participants seemed to properly grasp what was involved in this task. Once they were comfortable with what was required, and how to move discs, the researcher moved away from the participant to enable them to begin the 16 scored problems without interference. Scripts used for both the Deary-Liewald and the Tower task are located in Appendix B.

The final stage of testing involved questionnaire-based measures which were embedded in the Qualtrics survey that participants had been working through in stage one. Again, participants worked on the computer on their own, while the researcher sat at a reasonable distance so as not to interfere with responses.

If participants asked questions relating to question interpretation, the researcher was careful not to bias responses. In most cases, participants were encouraged to answer questions in the way that they best understood them. Generally speaking, participants had no problems interpreting questions and task instructions, however some questions were raised in regards to sleep items in the PSQI that were difficult to respond to by participants who worked shift work (nurses and meteorologists for example). The specific difficulties here were based on questions relating to the time at which participants had gone to bed and subsequently woken. The nature of shift work is such that these times may vary greatly over the course of a month.

Ultimately, interpretation of these items was left up to individuals in these cases, and women were encouraged to give their best estimate.

The DASS-21 contains some questions that may cause discomfort for participants and this was addressed in information sheets and discussed with women in the introductory period of testing meetings. DASS-21 scores were calculated soon after meetings took place, and participants with elevated scores on one or more of the scales were contacted to offer some support. This was done using a telephone script provided in appendix C.

Data Management

Participant data was stored on two locked, password protected, computers. Personal information was only obtained in so far as it related directly to the research questions and identifying information such as names and addresses were stored separately from the data in locked filing cabinets at Massey University. The data collected during this research will be securely kept for ten years after which time it will be destroyed.

Ethical Approval

Prior to the commencing the current study, researcher P had prepared an application for ethical approval. The current study could not be granted ethical approval under that same application because the Massey University Human Ethics Committee (MUHEC) required that participants could consent to either or both studies independently from each other. Therefore, an independent application was drafted and approval was granted from MUHEC (Application NOR 18/11) in April 2018. The study procedure specified in the ethics application was adhered to throughout the research process. Notably, prior to meeting with participants, they were informed regarding the nature and purpose of the study. Participants were advised that their involvement in the study was voluntary and that they could decline from answering any specific question. Participants could withdraw from the study during their meeting or up to two weeks after, in which case the data collected from them would not be used in data analysis and would be destroyed.

Because some meetings took place in participants' own homes, risk was managed for the researcher by ensuring she would notify someone upon entering a home, and again after leaving.

CHAPTER FIVE

Results

The overall aim of the current study was to investigate reported differences in executive functioning and processing speed between women in the late stages of pregnancy and control women who were not pregnant and had not previously had a child. Additionally, the study sought to test whether differences in performance on a test of executive functioning are due to any extent to differences in performance on a test of processing speed. And finally, the study aimed to investigate whether differences in sleep quality or mood contribute to a decline in performance on either or both cognitive tasks.

To assist in the readability of this chapter, results will be presented in the same sequential order as the specific research questions posed earlier in the thesis. Given that the data collected for the current study was done as part of a wider research team, the chapter will conclude with some statistical consideration of inter-rater reliability.

Analyses of Cognitive Performance: Processing Speed and Executive Functioning

The results in this section relate to the main objective of this study; to test the findings of prior research that reported statistically significant declines in processing speed and executive functioning in pregnant women. Summary scores relating to cognitive performance are shown in table 5.

Table 5.

Cognitive test scores

	Pregnant Mean	Not pregnant Mean
Simple Reaction Time Task (SRT)	305.29 (36.83)	282.27** (26.86)
Choice Reaction Time Task (CRT)	467.96 (55.62)	451.87 (61.56)
Tower: Total Points Scored all	11.49 (2.42)	11.84 (1.99)
Tower: Total Points Scored timed	10.51 (2.25)	10.81 (1.86)
Tower: Total Points Scored untimed	12.52 (2.17)	12.88 (1.56)
Tower: Planning Time timed	2.98 (0.70)	3.03 (0.17)
Tower: Planning Time untimed	6.70 (3.49)	6.51 (2.77)

***Significant at $p < .01$ level*

Processing speed

The only cognitive test that met the threshold of a statistically significant difference between the pregnant and non-pregnant group was the Deary-Liewald SRT measure. Because the distribution of reaction times to any item on a test such as this will typically be skewed, comparison was based on the mean of the median values for pregnant participants (M = 305.29, *SD* = 36.83) versus the mean of the median values for non-pregnant participants (M = 282.27, *SD* = 26.86). An independent samples t test revealed that this difference in the mean reaction times was statistically significant ($t(130) = 4.082$, $p = <.001$, Cohen's d = .711). The choice reaction time task on the Deary-Liewald test also showed a trend indicative of slower processing speed on the CRT for pregnant participants (M = 467.96 milliseconds, SD = 55.62) compared with non-pregnant participants (M = 451.87 milliseconds, SD = 61.56). However this difference in mean scores for the CRT task did not reach the threshold for statistical significance ($t(130) = 1.578$, $p = .117$).

Processing speed was also considered using a more covert measure, initial planning time for participants who completed the computerised Tower test under the untimed condition. Results for this were shown in table 5 and show no statistically significant difference between the pregnant and non-pregnant groups.

Executive function

To test whether there was any between group differences in performance on the executive functioning task, an independent sample t test was conducted to compare total points scored across all 16 problems of the Tower task. This found no significant difference between the mean score for pregnant participants (M = 11.49, *SD* = 2.42) and non-pregnant participants (M = 11.84, *SD* = 1.99).

Analyses of the Relationship between Processing Speed and Executive Function

Another objective of the current study was to test whether any decline in executive functioning was caused at least in part by a decline in processing speed. Before beginning these analyses of cognitive performance, further analyses of demographic variables were conducted to investigate whether participants randomly assigned to the Timed and Untimed condition of the Tower test differed in age or level of education. The average age of Timed participants was 30.36 (*SD* = 4.56), and the average age of Untimed participants was 31.88 (*SD* = 4.47). An independent samples t test revealed no significant difference between these groups in terms of age, $t(131) = 1.94$, $p = .054$. The median level of education for participants in both the Timed and Untimed condition was 5 (equal to the medians of the pregnant and non-pregnant groups) which translates as the median qualification being an undergraduate degree. The interquartile range for both sample groups was 1. A Mann

Whitney test found that there was no statistically significant difference in level of education between participants assigned to the Timed or Untimed Tower groups (z = 1.41, *p* = .159).

A two-way between-groups analysis of variance was conducted to explore the impact of pregnancy status and time conditions on total Tower scores. The main effect for pregnancy status (F(1,128) = 0.90, *p* = .344) was not significant. There was a statistically significant main effect for time conditions (F = 34.46, p = <.001, partial eta squared = .212) indicating that the performance of participants who completed the Tower task under time constraints was adversely impacted relative to those in the untimed condition. However, this adverse impact was virtually the same for the pregnant group and the non-pregnant group; the interaction effect between pregnancy status and time conditions was not statistically significant (F(1,128) = .008, *p* = .929). Figure 5 presents the mean scores used in the factorial analysis.

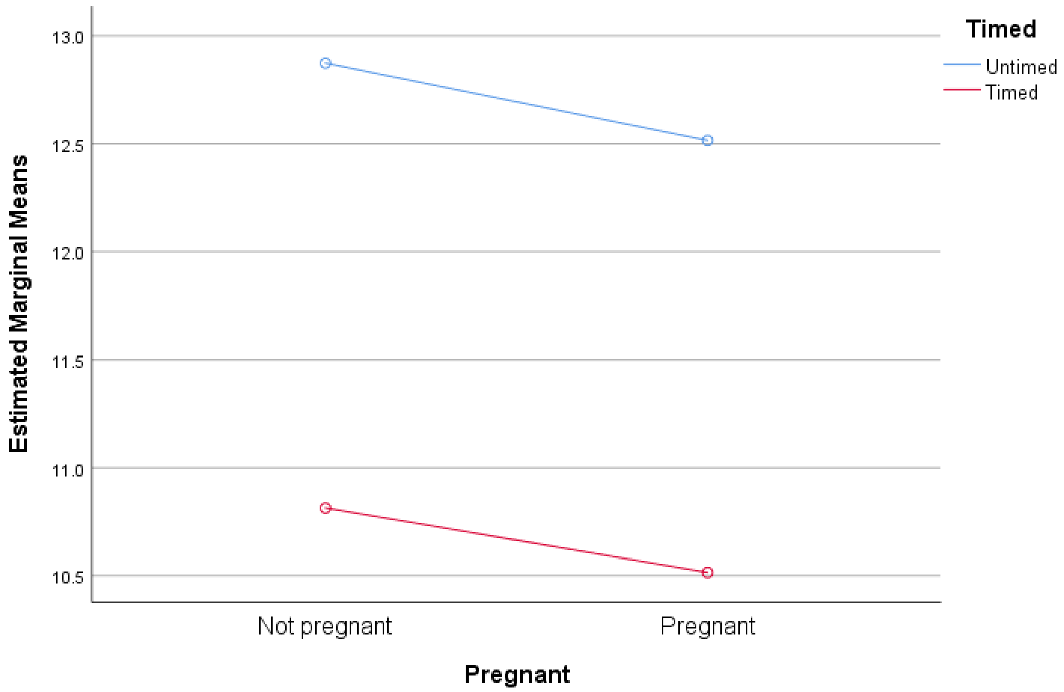

Figure 5. Interaction between pregnancy status and time condition on Tower task

Analyses of Sleep Quality and Mood

Descriptive statistics pertaining to sleep quality (as measured by the PSQI) and mood (as measured by the DASS-21) for the samples of pregnant and non-pregnant women are presented in Table 6.

Table 6.

Sleep Quality and Mood Scores

	Pregnant Mean	**Not pregnant Mean**
Sleep quality total score	8.31 (3.13)	5.99** (3.59)
DASS-21 depression score	2.64 (3.54)	2.69 (3.05)
DASS-21 anxiety score	3.71 (2.93)	2.72* (2.45)
DASS-21 stress score	6.62 (4.11)	5.97 (3.90)

***Significant at $p < .01$ level, *Significant at $p < .05$ level*

On the PSQI, data was missing for six pregnant and two non-pregnant participants. The instructions provided with the PSQI were clear about how to address missing data on one item of the index, but not others. To clarify the most appropriate way of dealing with remaining missing data, contact was made with the authors of the measure at the University of Pittsburgh, although the response was not completely clear as to how missing data was to be treated (D. Buysse, personal communication, September 25, 2018).

Although the most common practice employed for missing data is to substitute means, imputation methods based on multiple regression have been shown to be preferable from a statistical standpoint (Gelman & Hill, 2007; Graham, 2009; Horton & Kleinman, 2007). To ensure that a total score could be calculated for all participants, multiple linear regression was used to impute values for the missing item data. PSQI total scores were regressed on the following seven predictor variables: pregnancy status, age, highest education level, total hours spent with children, DASS depression subscale, DASS anxiety subscale, and DASS stress subscale. The results of this multiple regression indicated that the constellation of these seven predictor variables when assigned appropriate weights, constituted a reasonably good model for predicting the participants' scores on the PSQI total. The multiple regression coefficient was R = .511, multiple R-squared = .261, and the test of the model was highly significant (F = 5.893, df = 7 & 117, $p < .001$.) About 25% of the variability in the PSQI total scores is accounted for by this 7-predictor model. Therefore, it provides a more effective way of determining the PSQI total scores for the eight missing participants than the alternative of filling missing item data with group means.

Larger scores on the PSQI indicate lower sleep quality, and lower scores indicate higher sleep quality. The average score of pregnant participants was 8.31 (*SD* = 3.13), and the average score of non-pregnant participants was 5.99 (*SD* = 3.59). An independent sample t test revealed that this difference in the mean PSQI scores was statistically significant (t = 3.747, p = <.001). The magnitude of the differences in the means (mean difference = 2.32, 95% *CI*: 1.17 to 3.47) was medium (Cohen's d = .695).

As mentioned previously, the PSQI total score is determined by seven separate subscales. A comparison of mean scores on these subscales provides further insight into what contributes to poorer sleep quality during the late stages of pregnancy. These analyses indicated that the poorer sleep quality of pregnant participants resulted from significantly poor scores on sleep efficiency ($t(130) = 3.972$, p = <.001), sleep disturbance ($t(126) = 8.827$, p = <.001), overall sleep quality ($t(131) = 3.160$, p =.002), and daytime disfunction due to sleepiness ($t(130) = 2.294$, p =.026).

Mood was measured using the DASS-21. Overall scores on this measure show that pregnant women have higher scores (Mean = 12.97, *SD* = 9.07) than non-pregnant women

(Mean = 11.38, *SD* = 8.16), but that this difference is not statistically significant *t*(131) = 1.06, *p* = .291.

Further analysis of the three subscales included in the DASS-21 showed that pregnant participants had significantly higher scores on the anxiety scale (M = 3.71, *SD* = 2.93) than non-pregnant participants (M = 2.72, *SD* = 2.45, *t*(131) = 2.110, *p* = .037, Cohens d = .369). There was a significant difference in anxiety, but not in depression or stress. Subscale mean score comparisons for all three subscales are shown previously in table 6.

Correlational analyses of sleep quality and mood

The relationship between the total score on the Pittsburgh Sleep Quality Index and cognitive performance as measured by the Deary-Liewald Reaction Time task and the computerised Tower task was investigated using Pearson product-moment correlation coefficients. The same correlation coefficients were calculated to understand the possible relationship of the DASS-21 subscales to these same cognitive measures. Results of these analyses are shown in table 7.

Table 7.

Correlation analyses between cognitive performance and sleep and mood

Pregnant		PSQI	DASS-D	DASS-A	DASS-S
(*n* = 68)	Simple Reaction Time	-.089	.030	-.052	-.211
	Choice Reaction Time	-.009	-.075	.042	-.120
(*n* = 33)	Tower (initial planning time)	-.338	.154	-.398 *	.029
	Tower (total points scored)	-.056	-.150	-.372 *	-.072
Not pregnant					
(*n* = 64)	Simple Reaction Time	-.136	.047	-.056	.012
	Choice Reaction Time	.054	.087	-.024	.006
(*n* = 33)	Tower (initial planning time)	.105	.265	.141	.338
	Tower (total points scored)	.144	-.124	-.017	-.119

**Significant at p < .05 level. Only participants who were randomly assigned to the untimed condition of the Tower task have been included in correlation analyses of the relationship between mood and Tower task scores.*

Although none of the correlations between sleep quality and cognitive scores are significant, the correlation between pregnant participants' sleep quality and their initial planning times on the Tower (untimed condition) was close to significant (r = -.338, p = .055). The direction of this correlation is opposite to what was expected though, since higher scores on the PSQI (poorer sleep quality) is associated with shorter planning times (faster processing speed).

Pregnant participants' scores on the anxiety scale of the DASS were significantly correlated with their planning time (r = -.398, p = .022) and point scores on the Tower (r = -.372, p = .033). This indicates that higher anxiety scores were related to shorter planning times (faster processing speed) on the Tower, but also to lower point scores on this measure.

Inter-rater Reliability

To assess whether the results from the cognitive tasks were subject to any examiner effects 2 (Group) x 2 (Examiner) ANOVA's were calculated on the Deary-Liewald SRT and CRT. These analyses found significant main effects for Group (F = 14.80, *p* = <.001, partial eta squared = .104) and for Examiner (F = 18.85, *p* = <.001, partial eta squared = .128) on the SRT and a significant main effect for Examiner (F = 5.48, *p* = <.021, partial eta squared = .041) on the CRT. However, on neither measure is there a significant interaction between group and examiner. This is important because it implies that the examiner effects are consistent in that participants tested by examiner P had longer reaction times across both Deary-Liewald tasks. Considering that the main effect for the examiner had a smaller p-value in the case of the CRT than in the SRT, the idea that the differences may relate to processor speed variations between laptops is supported. This is because a difference in processor speed is more likely to have an impact on measures involving a very short reaction time such as the SRT than on the relatively longer reaction times involved on the CRT.

Given that there was a significant main effect for examiner on the SRT task, the value for Cohen's d associated with the significant main effect for Group is .670. This effect size is smaller than the earlier reported Cohen's d .711 due to the fact that a proportion of the effect size attributed to Pregnant vs Non-pregnant groups in the former t test was actually attributable to Examiner effects. In the 2 X 2 analysis, the Examiner effect is segregated out of the Group effect and so this smaller value is a more accurate rendition of the effect size for Group.

The same 2x2 ANOVA was performed on the processing speed measure on the Tower task. This found no significant main effects and no significant interaction. This lends further support for the idea that computer processor speed differences were the likely cause of examiner differences in processing speed tasks because when we consider the much longer response times entailed in the case of TOL planning times (4-5 seconds, instead of 200-500 milliseconds), there is virtually no evidence of a main effect difference between Examiners.

To further examine the influence of possible examiner effects on cognitive results, a 2 (Group) x 2 (Time Condition) x 2 (Examiner) ANOVA was performer on the Tower task total point scores. The results of this analysis show a significant 3-way interaction. Examiner P's results show that under the added time pressure of the Timed Condition, pregnant subjects performed a lot more poorly than in the Untimed Condition whereas the time pressure had less of a deleterious effect on the performance of the non-pregnant subjects. The opposite occurred in the case of the results from examiner C's participants'. Here the added time pressure had a more deleterious effect on the non-pregnant participants' performance than on the pregnant subjects' performance. To follow up on this 3-way interaction a Group x Time Condition ANOVA was performed on point scores for the examiner P-run participants and same 2-way ANOVA was performed on the examiner C-run participants. The results of these ANOVAs show that both of these interactions are significant or nearly so (examiner P: p = .046; examiner C: p = .058) but run in different directions. That they run in different directions is the reason that the 3-way interaction turned out to be significant.

CHAPTER SIX

Discussion

The main purpose of the current study was to provide confirmatory evidence for the previously published suggestion that there is a pregnancy induced deficit in executive functioning and information processing speed by focussing on women in the late stages of pregnancy. Testing was carried out in a format similar to that used by Owens et al. (2013) in their research with MS patients. Conducting research using this study design allowed measurement of executive functioning and information processing speed to occur independently, as well as facilitating the investigation of a possible inter-relationship whereby lower executive functioning scores might occur only in timed versions of the Tower task, because of slowed processing speed.

The current study also included measures of sleep quality and mood in order to test the hypotheses that these may play a predictive role in the presence of cognitive impairment during pregnancy.

This chapter examines the results presented in the previous chapter, considering them in respect of the hypotheses of the current study, and the previously published research in the area of cognition during pregnancy.

Findings in Relation to Processing Speed

Analyses of the data collected has provided some support for a pregnancy related decline in information processing speed on the Deary-Liewald task. These results showed a statistically significant difference in SRT scores between pregnant and non-pregnant participants. Whilst not meeting the threshold for statistical significance, the trend in CRT scores also indicated that pregnant women had slower reaction times than non-pregnant controls. That pregnant women have lower scores on the reaction time tasks support Anderson & Rutherford's (2012) conclusions that pregnant woman possess a moderate deficit in processing speed.

The computerised Tower task allowed processing speed to be considered using a more covert measure, comparing initial planning times on correctly solved problems in this task. Analyses of differences between the performance of pregnant women and non-pregnant controls did not support that there was a difference between these groups in processing speed. This outcome appears to be at odds with reaction time task scores and forces the consideration of why there is this discrepancy.

The biggest material difference between the two measures of processing speed that have been considered for the current study is the period of time being measured. The response times involved in the Tower task are about 4-5 seconds, whereas the reaction time measures in the Deary-Liewald sit between 200 and 500 milliseconds. It is therefore possible that the fractions of seconds that separate the pregnant and non-pregnant women in the reaction time tasks in the current study do also exist in the Tower task, but are subsumed in the much longer duration of time that elapses when planning is taking place.

Another potential explanation is that pregnant women are less inhibited than non-pregnant controls. They may be more inclined to 'just get on with it" rather than thinking the whole problem through before clicking. The correlational analyses between sleep quality and initial planning time on the Tower task offered some support to this theory. It was found to be the case that higher scores on the PSQI were associated with shorter planning times. It is unclear what factors underlie this, however it might suggest that women who were tired just wanted to get their tests done and go home. If this was the case, the planning time data from the Tower task is not a comparable measure of information processing speed.

Findings in Relation to Executive Functioning

As far as the author was able to establish, the current study is one of a small number of studies that has considered executive functioning using a 'planning' measure. There was no significant difference between pregnant women and non-pregnant controls on performance in this task. This suggests that, during pregnancy, the planning facet of executive function remains intact. This finding is consistent with Crawley et al.'s (2008) study which found no difference in planning tasks between pregnant women and non-pregnant controls.

However, Jarrahi-Zadeh et al. (1969) that found that there was a pregnancy induced deficit in planning using the Porteous maze task. This leaves some ambiguity in whether planning is negatively impacted during pregnancy or not. Jarrahi-Zadeh et al. (1969) suggested that the comparatively lower test performance by pregnant women on the Porteous maze task might relate to emotional factors rather than being reflective of true deficits in planning. This might explain the inconsistency in the results found in the current study as well as in that conducted by Crawley et al. (2008). That emotional factors may be relevant to the current research provided rationale for including a mood measure, and the implications of outcomes from correlational analyses between scores on the cognitive tasks and score on the DASS-21 subscales are discussed later in this chapter.

Another potential explanation for the lack of any between group differences in executive function is that whilst pregnant women performed as well as non-pregnant women in laboratory tasks, they were not as strong in naturalistic tasks. Cuttler et al. (2011) found in their study that pregnant women experienced measurable impairments in cognitive tasks carried out in field tests that were meant to reflect their everyday lives. However, these impairments were not detected in laboratory settings. The implication here is that while pregnant women show no measurable deficit in laboratory tasks that they are motivated to complete, they are more susceptible to the inherent distractions that exist in everyday situations (Henry & Rendell, 2007; Cuttler et al., 2011).

Anderson and Rutherford's (2012) meta-analysis also found evidence of disparate findings between laboratory and naturalistic prospective memory tasks, concluding that this is an important consideration. It perhaps indicates that the problem is not with executive function, but more related to the overall cognitive load of pregnant women, and to the priority that they assign to tasks in everyday life. Whether they are able to function at the same cognitive capacity as they previously could in their everyday lives could be a different question than whether they can perform well during one hour of dedicated cognitive testing that they can put their full focus on.

Interrelationship between Information Processing Speed and Executive Functioning

The second objective of the current study was to investigate whether any decline in executive functioning could be better understood as a secondary consequence of difficulties in information processing speed. This was a difficult concept to test given that there were no differences in executive functioning performance between pregnant and non-pregnant women. However, figure 5 in the previous chapter shows that the groups were equally impacted by the time constraints placed on those randomly assigned to the timed condition. This suggests that while performance is adversely effected by imposing time constraints, there is no obvious additional disadvantage attributable to pregnancy.

Moderating role of Sleep

The third objective of the current study was to explore the role of compromised sleep quality in cognitive change during pregnancy. The higher PSQI scores for pregnant women in relation to non-pregnant controls was expected, as this is an area in previous literature with a high level of agreement (Ladyman & Signal, 2018). However, the hypothesis that reduced sleep quality would impact cognitive scores was not supported for either executive functioning or information processing speed measure.

Interestingly, in relation to sleep quality, the only correlation coefficient that was close to statistical significance was in the opposite direction to what was expected. This showed that lower sleep quality was associated with faster information processing speed as measured by initial planning time in the Tower task. This was not supported by similar results in the Deary-Liewald measures of processing speed, and could therefore perhaps be better explained as a motivational difference between pregnant and non-pregnant women. It could be the case that pregnant women whose sleep quality was compromised were more uncomfortable by this stage of testing and just wanted to get it over and done with.

Moderating role of Mood

One of the more interesting findings of the current study was found when correlating cognitive scores with the subscales of the DASS-21. Anxiety in pregnant women appears to have led them to reduce the time they allow themselves to plan their solutions to the problems, thus detracting from the success of their solutions. This raises the possibility that previous indications of impairment in executive functioning among pregnant women may be a by-product of anxiety that some of these women may feel over the impending changes that will arise from the birth of their first child.

Experimenter Effects

The computer used by researcher C appears to have been slightly slower in reaction time recording than research P's was. This casts some doubt on the validity of differences that were found in the reaction time task scores. However, the 2x2 group x examiner ANOVA was able to segregate the variance attributable to this "examiner" effect from that attributable to the group effect. In other words, the ANOVA was able to determine that the difference between pregnant and nonpregnant women in SRT reaction time is significant even after accounting for the variance stemming from examiner differences. It would raise more serious concerns if the Group x Examiner interactions were significant in these ANOVAs because then it would be telling us that the difference in reaction time between the two groups depended on whether they were tested by researcher C or by researcher P. The fact that these interactions aren't significant indicates that the examiner difference was a constant difference and did not depend upon who was being tested. This makes it more likely that differences were due to some difference in the processing speed of the computers used to administer the DL).

When performing the same 2x2 ANOVA on planning time in the Tower, there are no significant effects. Therefore, the "examiner" effect probably shows up on the Deary-Liewald reaction times, but not on the processing speed measure of the Tower because the Tower measure of processing speed is much longer in duration. The relatively small difference in the speed of the two laptops makes very little difference on planning time in the Tower, but because the Deary-Liewald reaction times are much shorter, the difference between laptops had a more noticeable impact.

Limitations to the Current Study

To allow for testing the inter-relationship between executive functioning and information processing speed, the study was designed to split participants equally into either a timed or untimed administration of the Tower task. This had advantages in terms of the measurement of the relationship between the constructs, however it simultaneously disadvantaged the study by cutting the group sizes in half on this measure, and reducing the statistical power. It therefore remains a possibility that the current study failed to find a significant difference between study groups in this task due to sample sizes being too small.

As much of the extant research relating to cognition during pregnancy has found that the most pronounced cognitive deficits are found in the third trimester of pregnancy, this was deemed to be an important restriction in scheduling testing for women in the pregnant group. However, these later stages of pregnancy are often when women are most physically uncomfortable. Previous research has been able to show that some cognitive impairments are attributable to physical symptoms (Cuttler et al., 2011), and so comfort during testing over the course of an hour is an important consideration when considering results. It should be considered that physical limitations may impact results in this study, particularly given that both the Deary-Liewald and Tower tasks were presented n the latter stages of the hour.

Another limitation to the current study is that recruitment relied on women voluntarily opting in to participate. Christensen et al. (2010) had previously compared the cognitive scores of women before they knew they were pregnant, with those from when they were pregnant. This is a unique approach in literature in this area. Results in that study were equivocal between pregnant and non-pregnant women suggesting that inconsistencies between their findings, and those stated in other research, might relate to specific biases due to the recruitment of volunteer women.

Christensen et al. (2010) believed that women who volunteer for studies such as these may differ in significant ways from the women in their study who were recruited from a population based electoral role sample. For example, they believed that women may be more inclined to partake if they are particularly anxious about cognitive change that they believed was taking place for them personally, whereas those who don't feel affected by any changes may not opt in to such a study. Anecdotally, the women who volunteered for this study did seem to reflect this with many reporting after testing that they felt that they were cognitively impaired. Participants were keen to learn the outcomes of this study because they felt this might provide some evidence that their pregnancy was what was causing this impairment.

Christensen et al. (2010) also suggested that control participants who volunteer for a study such as this might also differ in significant ways to pregnant volunteers other than just non-gravid status. They proposed for example that the motivation to be included in such a study of cognition during pregnancy might suggest that they have a greater investment than most in their own cognitive performance.

In a similar vein, women who are more severely impacted by sleep problems or low mood may also use research opportunities more readily to help with their understanding of what was going on for them.

Future Research Opportunities

Accepting that the planning facet of executive functioning remains intact during pregnancy does not rule out the possibility that other facets of executive function are impaired, such as verbal fluency. Future research could focus on further exploration of executive function and aim to investigate whether other specific facets are impaired at this time.

The cognitive tasks used in the current study could be replicated with pregnant women in a shortened testing session. The Deary-Liewald and Tower task together could be completed in little more than 15 minutes. Trimming back the time spent on test administration might help to eliminate the potential impact of physical discomfort.

In respect of the comments made by Christensen et al. (2010) regarding biases introduced by the volunteer status of participants, future studies could benefit from enacting recruitment strategies that place less emphasis on cognitive deficit. A study with more broad objectives may generate interest from a cross-section of pregnant women that is more representative of the general population.

The findings relating to planning in the current study were based on a computerised measure of the Tower test which was designed for the purposes of testing this facet of executive functioning in MS patients. To contribute further to evidence pertaining to planning deficits in pregnancy (or lack thereof), future researchers might benefit from including other measures which may be more sensitive to subtle differences in this domain.

Conclusions

There are many ways in which researchers have approached the measurement of impairments in processing speed and executive functioning, and these have implications in how successfully studies can be compared, or aggregated through meta-analyses. This study explicitly measured processing speed through reaction time measures, and narrowed the focus of executive functioning to pertain only to ‘planning’. In so far as the author could ascertain, it is the only study in this area which has been designed to explore the inter-relationship of these two constructs.

Findings from the current study support the extant literature that evidences the presence of some impairment in processing speed during late pregnancy. While no difference between pregnant and non-pregnant women was found relating to planning the findings do not discount the possibility that there are impairments in other facets of executive function, and this is an area that could be explored in future research.

As expected, sleep quality is significantly worse in late pregnancy when compared to non-pregnant controls. However, the hypothesis that this would be a contributing variable to negative cognitive results, was not supported.

Heightened anxiety during late stage pregnancy did correlate with scores on the Tower task, with results suggesting that compared to non-pregnant controls, pregnant women spent less time planning, and that this impacted the number of correct problems solved in this task.

References

Ahrberg, K., Dresler, M., Niedermaier, S., Steiger, A., & Genzel, L. (2012). The interaction between sleep quality and academic performance. *Journal of Psychiatric Research, 46*, 1618-1622. doi:10.1016/j.jpsychires.2012.09.008

Anderson, M., & Rutherford, M. (2012). Cognitive reorganization during pregnancy and the postpartum period: An evolutionary perspective. *Evolutionary Psychology, 10*(4), 659-687. doi:10.1177/147470491201000402

Barkley, R. A. (2012). *Executive functions: What they are, how they work, and why they evolved*: New York, NY, Guilford Publications.

Blair, M., Gill, S., Gutmanis, I., Smolewska, K., Warriner, E., & Morrow, S. A. (2016). The mediating role of processing speed in the relationship between depressive symptoms and cognitive function in multiple sclerosis. *Journal of Clinical and Experimental Neuropsychology, 38*(7), 782-794. doi:10.1080/13803395.2016.1164124

Buckwater, J. G. (1999). Pregnancy, the postpartum, and steroid hormones: Effects on cognition and mood. *Psychneuroendocrinology, 24*(1), 69-84.

Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter? *Sleep: Journal of Sleep and Sleep Disorders Research, 37*(1), 9–17. doi: 10.5665/sleep.3298.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193–213. doi: 10.1016/0165-1781(89)90047-4.

Byrnes, L. (2018). Perinatal mood and anxiety disorders. *Journal for Nurse Practitioners, 14*(7), 507–513. doi: 10.1016/j.nurpra.2018.03.010

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 and Gynaecology, 20*(3), 158-164.

Chang, J. J., Pien, G. W., Duntley, S. P., & Macones, G. A. (2010). Clinical review: Sleep deprivation during pregnancy and maternal and fetal outcomes: Is there a relationship? *Sleep Medicine Reviews, 14*, 107-114. doi:10.1016/j.smrv.2009.05.001

Christensen, H., Leach, L. S., & Mackinnon, A. (2010). Cognition in pregnancy and motherhood: Prospective cohort study. *British Journal of Psychiatry, 196*(2), 126-132. doi: 10.1192/bjp.bp.109.068635

Cohen-Zion, M., Shabi, A., Levy, S., Glasner, L., & Wiener, A. (2016). Effects of partial sleep deprivation on information processing speed in adolescence. *Journal of the International Neuropsychological Society, 22*(4), 388-398. doi:10.1017/S1355617716000072

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159. doi:10.1037/0033-2909.112.1.155

Crawley, R., Grant, S., & Hinshaw, K. (2008). Cognitive changes in pregnancy: mild decline or societal stereotype? *Applied Cognitive Psychology, 22*(8), 1142. Retrieved from http://ezproxy.massey.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=35200138&site=eds-live&scope=site.

Cuttler, C., Graf, P., Pawluski, J. L., & Galea, L. A. M. (2011). Everyday life memory deficits in pregnant women. *Canadian Journal of Experimental Psychology, 65*(1), 27-37.

Davies, S., Lum, J., Skouteris, H., Byrne, L., & Hayden, M. (2018). Cognitive impairment during pregnancy: A meta-analysis. *The Medical Journal of Australia*, *208*(1), 35–40. doi:10.5694/mja17.00131

Dawson, D., & Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature* (6639), 235. Retrieved from http://ezproxy.massey.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edsovi&AN=edsovi.00006056.199707170.00010&site=eds-live&scope=site.

De Groot, R. H. M., Hornstra, G., Roozendaal, N., & Jolles, J. (2003). Memory performance, but not information processing speed, may be reduced during early pregnancy. *Neuropsychology, Development, and Cognition. Section A, Journal of Clinical and Experimental Neuropsychology, 25*(4), 482-488.

Deary, I. J., Liewald, D., & Nissan, J. (2011). A free, easy-to-use, computer-based simple and four-choice reaction time programme: The Deary-Liewald reaction time task. *Behavior Research Methods, 43*(1), 258-268. doi:10.3758/s13428-010-0024-1

DeLuca, J., & Kalmar, J. (2007). *Information Processing Speed in Clinical Populations* (1 ed.). New York, NY: Psychology Press.

Didham, R., & Callister, P. (2012). The effect of ethnic prioritisation on ethnic health analysis: A research note. *New Zealand Medical Journal, 125*(1359), 1.

Dixon, C. L. (2014). Sleep deprivation & pregnancy related risks. *International Journal of Childbirth Education*, *29*(3), 62-65.

Drew, M. A., Starkey, N. J., & Isler, R. B. (2009). Examining the link between information processing speed and executive functioning in multiple sclerosis. *Archives of Clinical Neuropsychology, 24*(1), 47-58.

Gelman, A., & Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*: Cambridge ; New York, NY: Cambridge University Press, 2007.

Glynn, L. M. (2012). Increasing parity is associated with cumulative effects on memory. *Journal of Women's Health, 21*(10), 1038-1045. doi:10.1089/jwh.2011.3206

Goldstein, S., & Naglieri, J. A. (2014). *Handbook of executive functioning*: New York, NY: Springer, 2014.

Graham, J. W. (2009). Missing data analysis : Making it work in the real world. *Annual Review of Psychology, 549*. Retrieved from http://ezproxy.massey.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edsfra&AN=edsfra.21168107&site=eds-live&scope=site.

Hampson, E., Phillips, S.-D., Duff-Canning, S. J., Evans, K. L., Merrill, M., Pinsonneault, J. K., . . . Steiner, M. (2015). Working memory in pregnant women: Relation to estrogen and antepartum depression. *Hormones and Behavior, 74*, 218-227. doi:10.1016/j.yhbeh.2015.07.006

Harris, N. D., Deary, I. J., Harris, M. B., Lees, M. M., & Wilson, J. A. (1996). Peripartal cognitive impairment: Secondary to depression? *British Journal of Health Psychology, 1* (2), 127-136. doi:doi.org/10.1111/j.2044-8287.1996.tb00497.x

Henry, J., & Crawford, J. (2005). The short-form version of the Depression Anxiety Stress Scales (DASS-21): Construct validity and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 44*, 227-239.

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

Henry, J., & Sherwin, B. (2012). Hormones and cognitive functioning during late pregnancy and postpartum: A longitudinal study. *Behavioral Neuroscience, 126*(1), 73-85.

Hertz, G., Fast, A., Feinsilver, S. H., Albertario, C. L., Schulman, H., & Fein, A. M. (1992). Sleep in normal late pregnancy. *Sleep, 15*(3), 246-251.

Hoekzema, E., Barba-Muller, E., Pozzobon, C., Picado, M., Lucco, F., Garcia-Garcia, D., . . . Vilarroya, O. (2017). Pregnancy leads to long-lasting changes in human brain structure. *Nature Neuroscience, 20*(2), 287-296.

Horton, N. J., & Kleinman, K. P. (2007). Much ado about nothing: A comparison of missing data methods and software to fit incomplete data regression models. *The American Statistician, 61*(1), 79-90, doi: 10.1198/000313007X172556

Hughes, A. J., Denney, D. R., & Lynch, S. G. (2011). Reaction time and rapid serial processing measures of information processing speed in multiple sclerosis: Complexity, compounding, and augmentation. *Journal of the International Neuropsychological Society, 17*(6), 1113-1121. doi:10.1017/S1355617711001135

Hutchison, B. L., Stone, P. R., McCowan, L. M. E., Stewart, A. W., Thompson, J. M. D., & Mitchell, E. A. (n.d.). A postal survey of maternal sleep in late pregnancy. *BMC Pregnacy and Childbirth, 12*(1), 144. https://doi-org.ezproxy.massey.ac.nz/10.1186/1471-2393-12-144

Insana, S. P., Williams, K. B., & Montgomery-Downs, H. E. (2013). Sleep disturbance and neurobehavioral performance among postpartum women. *Sleep, 36*(1), 73-81.

Janes, C., Casey, P., Huntsdale, C., & Angus, G. (1999). Memory in pregnancy. I : Subjective experiences and objective assessment of implicit, explicit and working memory in primigravid and primiparous women. *Journal of Psychosomatic Obstetrics and Gynaecology, 20*(2), 80-87.

Jarrahi-Zadeh, A., Kane, F. J., Van De Castle, R. L., Lachenbruch, P. A., & Ewing, J. A. (1969). Emotional and cognitive changes in pregnancy and early puerperium. *The British Journal of Psychiatry, 115*(524), 797-805. doi:10.1192/bjp.115.524.797

Kazemi, R., Haidarimoghadam, R., Motamedzadeh, M., Golmohamadi, R., Soltanian, A., & Zoghipaydar M. R. (2016). Effects of shift work on cognitive performance, sleep quality, and sleepiness among petrochemical control room operators. *Journal of Circadian Rhythms, 14*(1), 1-8. doi:10.5334/jcr.134

Krikorian, R., Bartok, J., & Gay, N. (1994). Tower of london procedure: A standard method and developmental data. *Journal of Clinical and Experimental Neuropsychology, 16*, 840-850.

Ladyman, C., & Signal, T. L. (2018). Sleep health in pregnancy. A scoping review. *Sleep Medicine Clinics, 13,* 307-333. doi:10.1016/j.jsmc.2018.04.004

Leavitt, V. M., Wylie, G., Krch, D., Chiaravalloti, N., DeLuca, J., & Sumowski, J. F. (2014). Does slowed processing speed account for executive deficits in multiple sclerosis? Evidence from neuropsychological performance and structural neuroimaging. *Rehabilitation Psychology, 59*(4), 422-428. doi:10.1037/a0037517

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. *Neuropsychology, Development, and Cognition. Section A, Journal of Clinical and Experimental Neuropsychology, 36*(5), 528-539.

Lovibond, S.H. & Lovibond, P.F. (1995). *Manual for the Depression Anxiety Stress Scales*. (2nd. Ed.) Sydney: Psychology Foundation.

McBean, A. L., & Schlosnagle, L. (2016). Sleep, health and memory: Comparing parents of typically developing children and parents of children with special health-care needs. *Journal of Sleep Research, 25*(1), 78-87.

Näätänen, R. (1990). The role of attention in auditory information processing as revealed by event-related potentials and other brain measures of cognitive function. *Behavioral and Brain Sciences, 13*(2), 201-288. doi:10.1017/S0140525X00078407

Neau, J., Texier, B., & Ingrand, P. (2009). Sleep and vigilance disorders in pregnancy. *European Neurology, 62*(1), 23–29. doi:doi.org/10.1159/000215877

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. *Neuropsychology, Development, and Cognition. Section A: Journal of Clinical and Experimental Neuropsychology*, *32*(9), 986-995.

Owens, E. M., Denney, D. R., & Lynch, S. G. (2013). Difficulties in planning among patients with multiple sclerosis: A relative consequence of deficits in information processing speed. *Journal of the International Neuropsychological Society, 19*(5), 613-620.

Plant, R., & Turner, G. (2009). Millisecond precision psychological research in a world of commodity computers: New hardware, new problems? *Behavior Research Methods, 41*(3), 598–614. doi: 10.3758/BRM.41.3.598

Raz, S. (2014). Research report: Behavioral and neural correlates of cognitive–affective function during late pregnancy: An event-related potentials study. *Behavioural Brain Research, 267*, 17-25. doi:10.1016/j.bbr.2014.03.021

Reicker, L. I., Tombaugh, T. N., Walker, L., & Freedman, M. S. (2007). Reaction time : An alternative method for assessing the effects of multiple sclerosis on information processing speed. *Archives of Clinical Neuropsychology*, *22*(5), 655-664.

Ross, L. E., Murray, B. J., & Steiner, M. (2005). Sleep and perinatal mood disorders: a critical review. *Journal of Psychiatry and Neuroscience, 30*(4), 247-256.

Saeideh, N., Hossein, A., Leila, T., & Akram Sadat, T. (2018). The effect of progressive muscle relaxation and guided imagery on stress, anxiety, and depression of pregnant women referred to health centers. *Journal of Education and Health Promotion, 7*(1), 41-41. doi:10.4103/jehp.jehp_158_16

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*(3), 403-428. doi:10.1037/0033-295X.103.3.403

Shafaie, F. S., Mirghafourvand, M., Rahmati, M., Nouri, P., & Bagherinia, M. (2018). Association between psychological status with perceived social support in pregnant women referring to Tabriz health centers. *The Journal Of Maternal-Fetal & Neonatal Medicine: The Official Journal Of The European Association Of Perinatal Medicine, The Federation Of Asia And Oceania Perinatal Societies, The International Society Of Perinatal Obstetricians, 31*(12), 1554-1560. doi:10.1080/14767058.2017.1319934

Shekleton, J. A., Flynn-Evans, E. E., Miller, B., Epstein, L. J., Kirsch, D., Brogna, L. A., . . . Rajaratnam, S. M. W. (2014). Neurobehavioral performance impairment in insomnia: Relationships with self-reported sleep and daytime functioning. *Sleep, 37*(1), 107-116.

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.

Sweeney, B. M. J. (2013). *Perinatal sleep and postnatal mood in New Zealand women : an investigation of the relationship and trial of a sleep education intervention : a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Public Health at Massey University, Sleep/wake Research Centre, Wellington campus, New Zealand*: Massey University.

Tombaugh, T. N., Rees, L., Stormer, P., Harrison, A. G., & Smith, A. (2007). The effects of mild and severe traumatic brain injury on speed of information processing as measured by the computerized tests of information processing (CTIP). *Archives of Clinical Neuropsychology, 22*(1), 25-36.

Willoughby, M. T., Blair, C. B., Kuhn, L. J., & Magnus, B. E. (2018). The benefits of adding a brief measure of simple reaction time to the assessment of executive function skills in early childhood. *Journal of Experimental Child Psychology, 170*, 30-44. doi:10.1016/j.jecp.2018.01.003

Wilson, B., Alderman, N., Burgess, P. W., Elmslie, H., & Evans, J. J. (1996). Behavioural Assessment of the Dysexecutive Syndrome. In R. C. D'Amato & S. D. Haynes (Eds.), *BADS*.

Wilson, D., Barnes, M., Ellett, L., Permezel, M., Jackson, M., & Crowe, S. F. (2013). Reduced verbal memory retention is unrelated to sleep disturbance during pregnancy. *Australian Psychologist, 48*(3), 196-208. doi:10.1111/j.1742-9544.2012.00076.x

Zhong, Q.-Y., Gelaye, B., Sánchez, S. E., & Williams, M. A. (2015). Psychometric properties of the Pittsburgh sleep quality index (PSQI) in a cohort of Peruvian pregnant women. *Journal of Clinical Sleep Medicine, 11*(8), 869-877. doi:10.5664/jcsm.4936

Appendix A

PARTICIPANT INFORMATION SHEET (FOR PREGNANT WOMEN)

Title of Project: "Baby Brain": Examining the link between sleep, information processing speed and executive functioning in the late stages of pregnancy.

An invitation

My name is Kate Connolly and I am a masters student in the School of Psychology at Massey University. I am inviting you to participate in a research project that I am leading to investigate whether pregnant women have different patterns of performance on some kinds of cognitive tasks compared to women who are not pregnant. Your agreement to take part in this study would be greatly appreciated.

What is the purpose of this research?

The purpose of this study is to expand what we know about the phenomenon commonly termed "baby brain". Many women report that they don't feel as 'mentally sharp' during pregnancy than they otherwise would. This has been supported in research that has been recently published showing that "baby brain" is more than a myth, and that on some mental tasks, pregnant women perform poorer than their non-pregnant counterparts. The focus of this study is based predominantly on investigating the relationship between women's performance on different tasks so as to better understand what drives poorer performance.

Who is eligible to take part?

We are looking for women who are pregnant with their first baby. Additionally, women should be 19 years of age or older, proficient in English, and living in the Greater Wellington Region. We will need to recruit a range of volunteers who represent the diversity of women in New Zealand. In other words, we are hoping to recruit participants who range in age, gender and ethnicity. Whatever your unique demographic combination, we would like to hear from you.

If you participate, what will you need to do?

If you agree to participate then you will be invited to meet with a researcher at a location that is convenient for you. The meeting will be around 60 minutes long and will involve answering a brief questionnaire, and a series of tasks that are similar to puzzles. The meeting will take place when you are in the third trimester of pregnancy (ideally during 33-36 weeks). Your comfort will be paramount throughout the meeting, and there is no physical component involved.

Because the measures are for research and not for a clinical assessment, the results of your performance on the measures will not be provided. However, we invite you to request a summary of the research findings by indicating so on the consent form. The summary will be posted or emailed to you at the conclusion of the project.

If you participate, what are the benefits?

We will offer you a token of our appreciation (koha) at the conclusion of your testing session. This will be a $20 voucher of your choice from either New World or The Warehouse.

An added benefit of your participation is likely to be the knowledge that you have contributed to our understanding of the maternal brain, and to the important field of maternal mental health.

If you participate, what are the risks of being involved?

There is a possibility that some women may experience discomfort when responding to the self-report measures (e.g., around levels of depression or anxiety). We are always available to talk through any concerns with you in the first instance. Your lead maternity carer or GP would be helpful if you still have ongoing concerns.

Your rights

You are under no obligation to participate in this research, and if you decide to participate, you have the right to:

- Decline to answer any particular question;
- Withdraw from the study during our meeting or up to two weeks after;
- Ask any questions about the study at any time during participation;
- Provide information on the understanding that your name will not be used;
- Be given access to a summary of the project findings when it is concluded.

If you participate, how will your data be managed and stored?

Data will be stored securely in password protected electronic files or locked filing cabinets until such a time that it is destroyed.

Who else is involved in this research?

My research is being conducted under the supervision of Professor Janet Leathem at Massey University.

Who should you contact if you have concerns or require further information about the research?

If you have any questions or concerns please contact Project Leader, Kate Connolly via phone, email or text. Contact details are provided below.

Yours sincerely, Kate Connolly

Contact: Email: baby.brain.research@gmail.com	College of Humanities and Social Sciences Massey University Private Box 756 Wellington New Zealand

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application NOR 18/11. If you have any concerns about the conduct of this research, please contact Associate Professor David Tappin (Chair), Massey University Human Ethics Committee: Northern, email humanethicsnorth@massey.ac.nz

INFORMATION SHEET (FOR NOT PREGNANT CONTROL PARTICIPANTS)

Title of Project: "Baby Brain": Examining the link between sleep, information processing speed and executive functioning in the late stages of pregnancy.

An invitation

My name is Kate Connolly and I am a master's student in the School of Psychology at Massey University. I am inviting you to participate in a research project that I am leading to investigate whether pregnant women have different patterns of performance on some kinds of cognitive tasks compared to women who are not pregnant. Your agreement to take part in this study would be greatly appreciated.

What is the purpose of this research?

The purpose of this study is to expand what we know about the phenomenon commonly termed "baby brain". Many women report that they don't feel as 'mentally sharp' during pregnancy than they otherwise would. This has been supported in research that has been recently published showing that "baby brain" is more than a myth, and that on some mental tasks, pregnant women perform poorer than their non-pregnant counterparts. The focus of this study is based predominantly on investigating the relationship between women's performance on different tasks so as to better understand what drives poorer performance.

Who is eligible to take part?

We are looking for women who are not pregnant and have not previously had a child. Additionally, women should be 19 years of age or older, proficient in English, and living in the Greater Wellington Region. We will need to recruit a range of volunteers who represent the diversity of women in New Zealand. In other words, we are hoping to recruit participants who range in age, gender and ethnicity. Whatever your unique demographic combination, we would like to hear from you.

If you participate, what will you need to do?

If you agree to participate then you will be invited to meet with a researcher at a location that is convenient for you. The meeting will be around 60 minutes long and will involve answering a brief questionnaire, and a series of tasks that are similar to puzzles.

Because the measures are for research and not for a clinical assessment, the results of your performance on the measures will not be provided. However, we invite you to request a summary of the research findings by indicating so on the consent form. The summary will be posted or emailed to you at the conclusion of the project.

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There is a possibility that some women may experience discomfort when responding to the self-report measures (e.g., around levels of depression or anxiety). We are always available to talk through any concerns with you in the first instance. Your GP would be helpful if you still have ongoing concerns.

Your rights

You are under no obligation to participate in this research, and if you decide to participate, you have the right to:

- Decline to answer any particular question;
- Withdraw from the study during our meeting or up to two weeks after;
- Ask any questions about the study at any time during participation;
- Provide information on the understanding that your name will not be used;
- Be given access to a summary of the project findings when it is concluded.

If you participate, how will your data be managed and stored?

Data will be stored securely in password protected electronic files or locked filing cabinets until such a time that it is destroyed.

Who else is involved in this research?

My research is being conducted under the supervision of Professor Janet Leathem at Massey University.

Who should you contact if you have concerns or require further information about the research?

If you have any questions or concerns please contact Project Leader, Kate Connolly via email. Contact details are provided below.

Yours sincerely, Kate Connolly

Contact: Email: baby.brain.research@gmail.com	College of Humanities and Social Sciences Massey University Private Box 756 Wellington New Zealand

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application NOR 18/11. If you have any concerns about the conduct of this research, please contact Associate Professor David Tappin (Chair), Massey University Human Ethics Committee: Northern, email humanethicsnorth@massey.ac.nz

PARTICIPANT CONSENT FORM

"Baby brain": Examining the link between sleep, information processing speed and executive functioning

This consent form will be held for a period of ten (10) years

I have read the Information Sheet and understand the details of these studies. I have sought explanation about any details of the studies that I do not understand.

I have had time to consider my participation and my questions have been answered to my satisfaction. I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet and I understand that I can withdraw myself and any data that has been collected from the study at any time.

YES NO

I wish to receive a summary of the research when it is completed

YES NO

Postal Address for Summary:

....

....

....

.... Postal Code..................

Email address for research summary: ....

Contact phone number:

....

Signature: .... Date: ....

Full Name Printed ....

Appendix B

TOWER OF LONDON (Modified 5 May 2018)

INSTRUCTIONS

Introduce the test by saying:

OK, this is a sort of puzzle task that I need you to do. I will show you how it works, and then you can get familiar with it with some practise questions.

[Point to **lower** model] This model down here is the one we'll be working with.

I want you to think of these as three pegs that are numbered from left to right: one -- two -- and three. These are colored disks that can fit onto the pegs. So there's a green disk, a red disk and a blue disk. Do you have any problem seeing colours on the screen?

I'm going to begin by showing you how to move the disks from peg to peg (now demonstrate the following features):

1. You can only move a disk if it's on top -- not covered by another disk.
2. To move a disk, you click it with the mouse. You can then see that buttons appear above the pegs where the disk could be moved. To move a disk to a peg, you will click one of the available buttons
3. Each peg can only hold a certain number of disks. The first peg can only hold one disk, the second peg can only hold two disks, and the third peg can hold up to three disks. The button will therefore not appear above a peg if that peg is already full.

Another important thing to know is that when we move on to look at the actual task, you will be allocated a certain number of moves you have available to complete that task. [Point to 'NUMBER OF MOVES USED' box]. Notice up here. This box keeps track of the number of moves you've made.

Also, suppose you changed your mind and decided you didn't want to move the disk that you've selected: As long as you haven't actually moved the disk, you can cancel a move. Just click another disk that you do want to move.

Let's try a practice item. [click 'PRACTICE' and give participant the mouse] click 'next until the practise problem appears.

Notice the upper model now shows an arrangement of disks. Your job is to try and arrange the disks in the lower model so they match this arrangement in the upper model. Remember, you're always moving the disks in the lower model. The disks in the upper model don't move...It just shows the pattern you're trying to copy.

You are told the number of moves allowed for each problem. See, this is telling you that this first practice problem must be solved by making only a single move.

Want to give it a try? Remember, this is just a practice item to become familiar with the task.

[If the subject successfully completes the first sample item in 1 move, say] GOOD! OK, let's try another practice problem. [direct them to Click 'NEXT']

[If the subject doesn't solve the item, say] OK. You've used up the 1 move you were allowed, so let's just try another practice problem. [direct them to Click 'NEXT']

[point to 'NUMBER OF MOVES ALLOWED' box] Now for this second problem, you are allowed 2 moves of the disks in the lower display to solve the problem. So let's give this problem a try. [direct them to Click 'GO'. Be sure not to say anything after clicking 'GO' so that the subject begins to get in the habit of starting the problem when it appears, without having to be prompted to do so.]

[If the subject successfully completes the second sample item in 2 moves, say] GOOD! OK, let's try another practice problem. [direct them to Click 'NEXT']

[If the subject doesn't solve the item, say] OK. You've used up the 2 moves you were allowed, so let's just try another practice problem. [direct them to Click 'NEXT']

[point to 'NUMBER OF MOVES ALLOWED' box] This third practice problem is another 2-move problem. You're allowed 2 moves to solve this problem. Ready? [direct them to Click 'GO'. Again, be sure not to say anything after clicking 'GO'.]

[If the subject successfully completes the third sample problem in 2 moves, say] GOOD! OK. Now, let's work on some actual items. [direct them to Click 'CONTINUE']

[If the subject doesn't solve the third sample problem, say] OK. You've used up the 2 moves you were allowed, so let's try these practice problems again.

PROCEDURE FOR REPEATING THE PRACTICE PROBLEMS, IF NECESSARY

[Double-click anywhere on white space of the screen to reveal special navigation buttons. Then click on 'RETURN TO SUBJECT' button to expose the SET SUBJECT screen. On this screen, click on 'CONTINUE' to return to the INSTRUCTION/PRACTICE screen, and click on 'PRACTICE' to start the first of the three practice problems again.]

Let's try this first practice problem again. [direct them to Click 'NEXT', then point to 'NUMBER OF MOVES ALLOWED' box] See, this first practice problem is a 1-move problem. Ready?

[direct them to Click 'GO'] Now move a disk in the lower model so it matches the arrangement in the upper model.

[Repeat the other two practice items in a similar fashion. If the subject doesn't complete the last practice problem correctly this time through, you should probably terminate the test.]

CONTINUING ON TO THE ACTUAL PROBLEMS

[The Tower program also has two options concerning "TIMED PROBLEMS." Either the subject is allowed all the time she needs to complete each problem (Timed Problems = NO) or is allowed only a limited time to complete each problem (Timed Problems = YES). The instructions vary according to which Timed Problems option you are using. Since this condition varies in this study, both sets of instructions are included here.]

[TIMED PROBLEMS = NO]

For each problem, you'll first be told the number of moves allowed to solve the problem. Then you'll go ahead and try to solve the problem in the permitted number of moves. If you don't succeed we'll just go on to another problem. As you might expect, the problems get harder as you go along. There's no time limit for this task so take all the time you need. Start when you are ready.

[TIMED PROBLEMS = YES]

For each problem, you'll first be told the number of moves allowed to solve the problem. However, unlike the practice items, you will only be allowed a limited amount of time to complete each problem. The number of seconds allowed for the problem will appear in this box [Point to the Time Allowed box]. And this box [Point to the Time Remaining box] will show the time counting down as you work on the problem. Your job is to try to solve the problem in the permitted number of moves within the time allowed. If you don't succeed we'll just go on to another problem. As you might expect, the problems get harder as you go along, but the time limit also becomes longer. You can start when you are ready.

CANCELLING A PROBLEM

[When the subject fails to solve a particular problem, she is likely to realize ahead of time that she's made a mistake and is going to run out of moves. Subjects often just pause at this point and sometimes it is difficult to determine whether the subject is still trying out a way to salvage the sitation or is just wants to give up on the attempt and doesn't know how to do so. They often will say something like, "well I've messed this one up." When you're certain that she realizes she is not going to succeed on the particular problem, say....]

If you want to cancel this problem and go on to the next one, just say so. Do you want to just go on to another problem?

[The key is not to say this to the subject too soon, before she herself may realize that she's not going to be able to solve the problem on this one and only try. You don't want to be, in effect, telling the subject that she's failed the problem. However, if she realizes it, then it's good to use the 'CANCEL' option because it notes the fact that the subject elected to cancel the problem in the data record. The 'CANCEL' option is exercised by clicking the 'YES' button under the 'Cancel this problem?' message.]

QUITTING THE PROGRAM

[When the subject has attempted all of the problems in the test, a QUIT button appears at the bottom right hand corner of the screen. Clicking on this button will terminate the program.

<u>Deary-Liewald Reaction Time Task – Standard Procedure</u>

<u>Running the Test:</u>
First, make sure you have created a study and saved the settings.

Next, enter the Subject ID in the space provided. Make sure the participant is sitting comfortably with the computer and keyboard on a table in front of them.

(a) Simple Reaction Time

Click "Run SRT practice". Confirm "Test Start" in the following dialogue box. Say:
First of all you will have a practice session. A cross will appear in the box on the screen 8 times and each time it appears you should press any key as quickly as you can. Don't hold the key down, but press and release it when the cross appears. Use the index finger of your preferred hand to press the key throughout the test. When you are ready, press any key to start.

At the end of the practice a message will read "Test Completed Thank You!". Wait a few moments for the screen to disappear.

Check the participant understands what to do. Click "Run SRT Test". Confirm "Test Start" in the following dialogue box. Say:
Now a cross will appear another 20 times and you should press any key as quickly as you can, as in the practice. When you are ready, press any key to start.

At the end of the test a message will read "Test Completed Thank You!". Wait a few moments for the screen to disappear.

You can abort the experiment at any time by hitting the "Escape" key on the keyboard.

N.B. If a participant holds a key down instead of releasing it, the cross will remain on the screen and the next trial will not begin until the key is released. Also, if a response falls out of the response range, it will not be recorded and will be replaced by another trial.

(b) Four Choice Reaction Time

Say:
In this test there will be four boxes on the screen. A cross will appear in one of them and you have to press the correct key for that box as quickly as you can.

Click "Run CRT practice". Confirm "Test Start" in the following dialogue box. Say:
When the cross appears in the box on the far left press the "z" key (point to each)**, when it appears in the box one from the left press the "x" key** (point to each)**; when the cross appears in the box on the far right press the "full stop" key** (point to each) **and when it appears in the box one from the right press the "comma" key** (point to each)**.**

Place the middle and index fingers of your left hand over the "z" and "x" keys like this (indicate which keys) **and the index and middle fingers of your right hand over the "comma" and "full stop" keys like this** (indicate which keys)**.**
As before you will have a practice of 8 crosses first. Remember, a cross can appear in any of the four boxes. When you are ready, press any key to start.

At the end of the practice a message will read "Test Completed Thank You!". Wait a few moments for the screen to disappear.

Check the participant understands what to do. Click "Run CRT Test". Confirm "Test Start" in the following dialogue box. Say:
You will now see another 40 crosses appear one after another and you should respond as quickly as you can by pressing the correct key, as in the practice. When you are ready, press any key to start.

At the end of the test a message will read "Test Completed Thank You!". Wait a few moments for the screen to disappear.

You can abort the experiment at any time by hitting the "Escape" key on the keyboard.

N.B. If a participant holds a key down instead of releasing it, the cross will remain on the screen and the next trial will not begin until the key is released. Also, if a response falls out of the response range, it will not be recorded and will be replaced by another trial.

Appendix C

Guidelines for follow up with women with high scores on the DASS-21

If the participant meets the threshold for follow up, (scores that meet criteria for 'severe' in one or more of the DASS-21 subscales) they will receive a follow up phone call.

Phone script:

Hi [participant name], my name is _______ from Massey University. I am calling as a follow up from the maternal cognition testing we did together recently.

Purpose of call:

Within the questionnaire you answered, there were a series of questions about mood, stress, and anxiety. I was keen to follow up with you today because your score on these questions was elevated [specify on which scale stress/anxiety/depression]. This does not necessarily mean that you should be concerned – it may be quite understandable in the context of what has been going on for you around the time of our testing. Importantly, you are probably the best person to know how you have been generally feeling, and I wonder how this information relating to your score fits with how you have been feeling lately.

Allow the conversation to continue in a natural fashion.

If they are not concerned and you are comfortable: Thank them again for their time and terminate the call, letting them know they are able to contact us at any time if they do have any concerns.

If they are concerned: We recommend that you let your lead maternity carer, GP, or other health professional know and they can provide further assessment and advice if required. If it would be helpful for you, we can put this information in a letter for you to take along to show them. Alternatively, we can try and contact your lead maternity carer, GP, or other health professional directly so that they can follow up with you.