EXAMINING MOTHERHOOD AS A FORCE FOR

COGNITIVE PLASTICITY

by

ALIA MOWERY

A THESIS

Presented to the Department of Psychology
and the Robert D. Clark Honors College
in partial fulfillment of the requirements for the degree of
Bachelor of Science

June 2015

An Abstract of the Thesis of

Alia Mowery for the degree of Bachelor of Arts
in the Department of Psychology to be taken June 2015

Title: Examining Motherhood as a Force for Cognitive Plasticity

Approved: _____

Dare A. Baldwin

New mothers face significant learning requirements, and must develop skills necessary for their infant's survival. Perhaps the hormonal changes that presage birth, and are maintained by breastfeeding, enhance mothers' cognitive preparation to cope with the learning challenges of motherhood. We propose a study with several aims: to examine the extent to which motherhood facilitates women's ability to learn across a variety of tasks; to investigate whether breastfeeding might extend a potential period of heightened cognitive plasticity in new mothers; and to see if greater learning ability predicts better acquisition of skills central to motherhood, such as breastfeeding. We anticipate that mothers will outperform non-mothers on learning tasks, that breastfeeding mothers will show a slower decline in learning performance after giving birth than non-breastfeeding mothers, and that those showing strong learning performance will display higher levels of breastfeeding success. Should our findings confirm these predictions, this information will broaden perceptions about what motherhood potentiates, and may provide a frame to study learning enhancement in adults.

Acknowledgements

First and foremost, I would like to extend my utmost gratitude to Professor Dare Baldwin, without whom this thesis would certainly not exist. I have enjoyed every one of our meetings over the last several years, and I greatly appreciate your guidance, kindness, and remarkable insight throughout this thesis project. It has been truly wonderful to have your mentorship and friendship, and I am so indebted to you. I would also like to thank Professor Heidemarie Laurent for being willing to join Dare and me on this project. Talking over our ideas with you, and hearing your suggestions for additions to the study, certainly contributed a great deal to this thesis. I am eager to continue working together as this research progresses. Additionally, I am so grateful to Professor Roxann Prazniak for agreeing to serve on my thesis committee. I have very much enjoyed sharing my project with you, and I look forward to hearing your thoughts on the final work. It would be an oversight not to thank the University of Oregon at large, and the many wonderful members of the faculty, staff, and students who have made my college career productive, illuminating, and highly enjoyable. Finally, I would like to thank all of my family and friends who have contributed to my work in direct and indirect ways. Your support and care has made it possible for me to work towards my dreams.

Table of Contents

Introduction

Imagine yourself as a new mother. You've just given birth, and your world is suddenly in upheaval. Even with months of forethought and preparation, caring for a new baby is an immense amount of work, and you will have to acquire myriad skills - how to calm a crying baby, how to read your infant's body language, how to manage a child's eating and sleeping schedules, and how to breastfeed effectively. Each of these tasks is extremely important to your child's well-being in the present day, but let's go back in time and imagine what your circumstances would be like if you lived 1000 years ago, or 100,000 years ago. Then, learning how to successfully care for a child was literally a matter of life or death. There were no support groups for new mothers, lactation consultants, breastpumps, infant formula, baby monitors, nor a large body of research about how to best care for one's baby. Without the resources we take for granted today, mothers had to find everything they needed to give their child a healthy start in life within themselves. Learning how to care for a new infant presented a major life challenge, and one's baby's survival depended on you meeting it.

Given the clear importance of learning how to become a competent parent, evolutionary changes over millennia seem likely to have equipped women to cope with a new child effectively. During pregnancy, women experience a cascade of hormonal and physiological changes, which prepare the body and mind for birth. At the time of childbirth, more changes take place that allow for a shift to motherhood. Post-birth, breastfeeding and other mothering behaviors impact hormone levels, which may enhance cognitive abilities that help women learn how to care for their babies. In preparation for and after birth, then, there are physical mechanisms in mothers -

hormonal and neurological changes - that enhance women's ability to help their child survive. We posit that such developments may serve to enhance new mothers' learning ability. After all, the essence of any major life transition is learning. To be a successful mother, in particular, requires facing novel challenges and learning how to surmount them.

Learning

When we say that an effective transition to motherhood requires learning, what precisely do we mean by that? Perhaps it would be useful to step back and think about what learning entails in the first place - what happens in the brain when a novel skill is being learned? Learning is the process by which behavior, knowledge, and skills are shaped; it is the human response to experience and novelty. Learning, essentially, has to do with making connections between concepts represented in your brain, strengthening those connections, and pruning them when necessary; any learning is represented by changes in the neurons in your brain. When humans develop a skill or gain knowledge, they stimulate neurons related to that skill or piece of information, which primes those neurons to function more efficiently upon further stimulation. Over time, practicing a task will lead to the brain developing efficient neural pathways to facilitate the performance of that task (Galván, 2010). If we think about new mothers, we could imagine that repeatedly attempting to discern what your infant is crying about, or consistently trying to breastfeed your baby, would over time lead to neural changes in the pathways facilitating such tasks. These neurological changes would result in your brain gaining the ability to complete those tasks more easily - you would learn how to better interpret your infant's cries, or breastfeed more effectively.

The mechanism of physical changes in the brain, particularly changes in neural connections, is termed plasticity. Plasticity is essentially evolution's mechanism for humans to respond to change in the world and diverse environments. When people encounter novel information or physical or mental challenges, their brain is reconfigured to take whatever novel thing they've come across into account - plasticity is at work. All learning, then, requires some degree of plasticity. Evolutionarily speaking, plasticity is necessary for survival, because humans need a mechanism in the brain that allows for adaptation to a diverse range of environments, or changing habitats (Pascual-Leone, Amedi, Fregni, and Merabet, 2005). Over millennia, then, as humans had to adapt to environmental pressures and experiences, the human brain evolved an extraordinary level of plasticity. The human brain is most plastic in childhood and adolescence, (when vast amounts of knowledge and information have to be represented in the brain, and connections between stimuli and actions must be made to function effectively in the world. More than at any other point in life, childhood is full of novelty. Every skill is yet to be learned, every fact yet to be memorized. Children face an extreme challenge: to learn how to function effectively in a completely new world. The brain responds to these heavy demands by behaving in a malleable way; the young brain is able to change dramatically, and is perfectly suited for effective learning. It seems likely that the brain exhibits enhanced plasticity in times when learning is an urgent need - while childhood is the most obvious example, perhaps the transition to motherhood is also a period in which learning becomes a matter of survival, which could indicate it is also a time of increased plasticity.

Unfortunately, as humans age into adulthood, the brain becomes less plastic. While learning can still occur, of course, adults are not as suited to sponge up skills as children are. Most of the crucial elements for survival have been learned already - most adults know how to navigate the world, care for themselves, and interact with others. The evolutionary need for abundant learning is not as high, so energy previously invested in making the brain plastic and adaptable is likely put to use elsewhere. Neurogenesis and creating neural connections becomes more difficult, the brain's ability to change decreases, and with it the capacity to learn declines (Sowell et al, 2003; Casteron, 2014, Raz et al, 2005). Old age is often associated with general cognitive deterioration, but many changes to cognitive function and plasticity actually begin much earlier - adults in their 20s show reduction in regional brain volume, binding of neuroreceptors, and other areas (Salthouse, 2009). It seems that overall degeneration in some areas of cognitive ability - and in particular, learning - begins in early adulthood and continues into old age. However, age-related declines in plasticity do not happen in the same way or at the same rate for everyone, so there is a significant range in learning ability among the post-adolescent population - some individuals may maintain a higher level of cognitive function and plasticity across their lifespan, while others may see a sharp decrease in their mental abilities (Raz et al, 2005). Thus, among new mothers, we would expect to see some women who have retained a relatively high ability to learn novel skills, while others would possess lesser capacity for learning, which would impact individual's ability to transition to motherhood.

Even in adolescence, plasticity is not universally at high levels throughout the brain. Different brain areas and cognitive pathways are primed to be more or less plastic

- receptive to learning - during distinct time periods. In some cases, there is a brief temporal window to learn a skill; once past, the ability to learn is lost (or at least significantly diminished) forever. This is called a critical period. Many domains of human learning display critical period effects. Generally, critical periods are found in experience-dependent systems - that is, the human brain is evolutionarily ready to support learning of essential abilities (such as the development of vision, learning to speak, and other important skills), and builds circuits in preparation for input from such crucial domains. Learning will readily occur in response to input in these domains, because the scaffolding of neural connections seems to be to some degree already in place. However, if input does not come during a temporal window, then the brain loses its preparedness and learning will not occur readily, if at all. Thus, the learning is experience-dependent - if humans are exposed to particular stimuli during a specific time frame, then the skill will reliably develop; if not, it will not (Desai et al, 2002; Werker & Hensch, 2015). For example, for proper development of the visual system, humans need extensive visual input in early childhood. If children are deprived of this vital sensory information (they do not receive visual input), then they are left with permanent visual impairment (Mitchell, 2004). Language learning is a another example - individuals are much more able to attain native fluency or accent in a second language when they begin learning it at a younger age; typically, individuals who try to learn a new language later in life find it much more difficult, because they have passed the critical period for language learning (Hensch, 2004). It is important to note, however, that our understanding of critical periods is still evolving. Recent evidence has shown that even in areas thought to have a clearly delineated critical period, experiences may

have an impact on learning after the critical period has passed (Werker & Hensch, 2015; Levi, 2005). Generally, critical periods indicate a time of enhanced plasticity - a temporal window during which the brain is prepared for learning. Often, these periods occur early in life, which contributes to our understanding of children's prodigious capacity for learning, but it is not true that such periods are completely exclusive to childhood.

Interestingly, a few recent studies have found evidence for a resurgence in plasticity - and the re-emergence of critical periods - in adults (Casteron, 2014; Hensch et al., 2013). Several studies in mammals have found that histone-deacetylase (HDAC), a type of protein that modifies genetic expression through epigenetics (the experience-dependent control of genes), contribute to the decline in plasticity with age. So, HDAC inhibitors have been found to enhance plasticity later in life (Vecsey et al, 2007; Guan et al, 2009; Miller, Campbell, & Sweatt, 2008). Of course, the relationship is very complex, and a number of other proteins are involved, but this research shows a clear link between molecules present in the brain and changes in plasticity. It also shows that increased plasticity is possible later in life under certain circumstances. More specifically, research has been done on what treatments might contribute to plasticity renewal in adults. In one study, adults taking Valproate - a HDAC inhibitor - were able to learn absolute pitch late in life (Hensch et al, 2013). Absolute pitch is a skill linked to an early-life critical period, so it seems that with certain brain chemistry conditions, critical periods can be re-opened. Beyond just HDAC inhibitors, other neuromodulators can enhance plasticity. With focused, consistent attention, as well, higher-than-usual levels of learning can occur, which indicates that behavior can also contribute to

plasticity enhancement (Werker & Hensch, 2015). Researchers have concluded that the human brain retains the ability to exhibit a great deal of plasticity throughout life, but this ability is stabilized and controlled by behavioral, chemical, and epigenetic 'brakes'. In some situations, then, the brakes may be released to an extent and a renewal of plasticity or opening of a critical period can occur (Werker & Hensch, 2015).

Perhaps most relevant to the present study is research on the impacts of hormones on plasticity, as hormonal changes are one of the most distinctive factors in pregnancy and early motherhood. For example, researchers have found that thyroid hormone deficiencies are linked to memory impairment (Rivas & Naranjo, 2007). Hormones often administered to women in the form of contraceptives, such as estrogens, have also been shown to impact cognitive function. Pretzer and colleagues (2010) found significant differences in the brains of women who were taking hormonal contraceptives vs. women who were not - they exhibited significantly larger prefrontal cortices, pre- and postcentral gyri, parahippocampal and fusiform gyri and temporal regions. It's also been found that women using hormonal contraceptives show better performance on certain memory tasks (Pletzer & Kerschbaum, 2014). If hormonal administration via contraceptives can induce changes in the brain - plasticity - then there's reason to think that naturally occurring changes in hormone levels, such as during pregnancy, childbirth, and early motherhood, would have similarly profound effects on neuroplasticity.

Breastfeeding

With a better understanding of plasticity and factors affecting learning, we can now turn our attention back to new mothers. While there are many learning challenges

facing women in the postpartum period, one important skill to acquire is effective breastfeeding. Evolutionarily speaking, there has been almost nothing more crucial for the survival of new infants than access to breastmilk. We may think of it is a natural, essential, intuitive task, yet it is something that many mothers struggle with - initiating and maintaining breastfeeding can be arduous for women. Interestingly, breastfeeding bears one of the hallmarks of a task requiring plasticity - a critical period for learning. It also generates hormonal changes in women, which could facilitate the development of neural pathways that help women learn how to breastfeed or gain other skills important in new motherhood. Taken holistically, it seems plausible to suggest that changes inherent to new motherhood - particularly, hormonal changes - potentiate a period of enhanced plasticity in new mothers, which facilitates the learning of skills necessary to care for one's child. Because of the range of tasks mothers are required to learn, it is unlikely such enhancement would be restricted to learning a select few skills; rather, it is probable that learning would be heightened across a range of domains. If learning is crucial to an effective transition to motherhood, individual differences in learning ability should predict differences in the development of mothering skills, like breastfeeding. Breastfeeding is an especially important task for new mothers to learn, and may have a role in maintaining the hormonal changes that facilitate plasticity; breastfeeding, then, may predict the extent and temporal frame of learning enhancement. Overall, we believe that a better understanding of the links between breastfeeding and learning could help us both understand what plasticity enhancement motherhood might potentiate, and why individual differences in breastfeeding ability exist.

To begin our discussion of breastfeeding, we should think about why it is important in the first place. It is generally accepted that breastfeeding positively impacts infant health and development. In recent years, several large-scale reviews have found that breastfeeding reduces the risk of myriad health problems in infants, including such severe conditions as leukemia, various respiratory diseases, SIDS, and diabetes. Additionally, mothers who breastfeed their infants see reduced instance of breast and ovarian cancer (Chung et al., 2007; U.S. Dept. of Health, 2011). The impact of breastfeeding is not limited to physical health; extensive, long-term studies have linked breastfeeding, particularly long-term and exclusive breastfeeding, to greater academic success and higher scores on intelligence tests later in life. In general, there is strong evidence that breastfeeding consistently improves cognitive development (Horwood and Fergusson, 1998; Kramer et al, 2008). Moreover, the benefits from breastfeeding seem to function in a dose-responsive manner; the more one breastfeeds – both in terms of duration and exclusivity - the greater the benefit in outcome for one's child.

There also doesn't seem to be any fully equivalent substitute for breastmilk. Despite the development of infant formula, researchers remain unable to replicate complex hormones, enzymes, anti-bodies, long-chain fatty acids, and other valuable substances found in breastmilk, and there is no replacement for the physical connection between mother and child during breastfeeding (Léon-Carva, Lutter, Ross, and Martin, 2002; UNICEF, 2014). Of course, there are some self-selection issues at play in the discussion of breastfeeding benefits; perhaps, children who are breastfed have better outcomes because of other factors, like socioeconomic status. Indeed, some recent studies have found that the health benefits of breastfeeding are diminished when

effective controls are put in place - however, these studies did not take into account exclusivity or success of breastfeeding. Even in studies questioning the impact of breastfeeding, researchers still found significant positive effect on cognitive development and reduction in leukemia in children (Evenhouse and Reilly, 2005; Colen and Ramey, 2014). It is important to note the amount of literature speaking to the positive impact of breastfeeding, compared to a relatively small body of work questioning its benefit, and the fact that cognitive benefits and leukemia reduction related to breastfeeding are relatively uncontested.

When we move our investigative scope to the developing world, the costs of not breastfeeding are even greater. Infant mortality rates are particularly high in developing nations, and one of the most effective interventions is breastfeeding. UNICEF reports that implementing optimal breastfeeding practices would be the single best way to improve infant survival, and potentially prevent over 800,000 deaths (or 13% of current yearly deaths) of children under the age of five (UNICEF, 2014). In developing nations in particular, infant formula is not a viable alternative. The high prevalence of contaminated water provides a grave danger, as formula is mixed with water and given to infants without well-developed immune systems. Overall, then, it seems breastfeeding is still a vital need in the contemporary world, and has the potential to save or improve many lives.

In terms of evolution, lactation developed as a crucial process for the continuation of the human line. Thousands of years ago, as mammals evolved, food supply was limited and not reliable. While adults can go days without a substantial meal, fragile infants would have died quickly without access to adequate nutrition. To

overcome this environmental challenge, the adaptation for breastfeeding slowly developed (Dall, 2004). When lactating, women can draw on energy stores (fat, muscle) to produce breastmilk - it is not as dependent on the immediate availability of food. Thus, breastfeeding provided the consistent nourishment babies needed to survive. This adaptation was critical for mammals, and lactation has been central to infant's well-being ever since it evolved (Volk, 2009; Pond, 1977). Now, we have developments that somewhat diminish the essentialness of breastfeeding - infant formula and donated breastmilk, for example - but there is no denying that without lactation, humans would not have survived historically.

Since breastfeeding was essential in the evolutionary past, and given the wealth of evidence detailing the positive results from breastfeeding, we would expect virtually everyone to breastfeed exclusively for a relatively long period of time, as an easy and economical way to improve their child's physical and cognitive outcomes. However, this is not the case. According to the CDC, for infants born in 2011 in the US, 79% of mothers started to breastfeed, but most did not continue for the recommended length of time; only 49% were still breastfeeding when infants reached 6 months and only 27% at 12 months. In developing nations, only 39% of infants younger than 6 months are exclusively breastfed (UNICEF, 2014). Clearly, the well-being of a considerable segment of the global population could be improved by increased breastfeeding. However, there are a variety of reasons why mothers may not initiate or maintain breastfeeding. Lack of knowledge, social norms that discourage breastfeeding, mothers who need to work, unsupportive family members, and health issues (both physical and mental) can all function as barriers against effective breastfeeding (US Dept. of Health,

2011). It seems that even if women want to breastfeed, there may be obstacles that make it prohibitively difficult for them to do so.

When considering factors that influence a mother's ability to breastfeed her child, something that may not come to mind is her capacity for learning. However, as previously discussed, breastfeeding is a skill that requires development. As with any other novel task, it requires learning - the maternal brain has to engage in plasticity to set up the neural networks dedicated to breastfeeding. How well a woman is able to learn how to breastfeed has a significant impact on how long, effectively, and exclusively she will maintain lactation (Volk, 2009). Given the immense importance of breastfeeding for infant survival and health, particularly before the development of infant formula, this learning process is crucial. In the scope of human history, it seems likely that evolutionary processes would result in humans being equipped to learn the important skill of breastfeeding quickly and successfully. Why breastfeeding presents a difficult learning challenge is a matter still up for debate - perhaps it has to do with human learning styles, breast shape, or infant's lack of motor development (Volk, 2009). Whatever the reason, it is clear that such a challenge does exist, and women are differentially equipped to meet it. The question at hand is: what neural frameworks might exist to facilitate this learning process? Is the maternal brain particularly plastic during the early postpartum period?

Hormones may play a significant role in a woman's adjustment to motherhood. During pregnancy, levels of progesterone and estrogen (produced by the placenta) increase consistently. The placenta also produces human chorionic gonadotropin (hCG, which mediates progesterone levels) and human chorionic somatolactotropin (hCS).

12

These four hormones - progesterone, estrogen, hCG, and hCS - are produced in the greatest quantity during pregnancy. However, other important hormonal changes occur as well. In preparation for lactation, levels of prolactin increase - indeed, the pituitary gland, which secretes prolactin, increases in size by 50%. Parathyroid hormone and adrenal hormones - like cortisol and aldosterone - levels also increase throughout pregnancy. Finally, human placental lactogen (HPL, which conserves glucose stores for fetal use) is produced by the placenta. These changes culminate in a radically different hormone profile in pregnant women, which becomes more extreme until childbirth. During labor and birth, another hormone reordering takes place. Late in gestation, oxytocin levels rise in preparation for labor - it is released in greater amounts during labor and post-birth lactation. Progesterone, estrogen, and HPL levels, which have risen throughout pregnancy, drop sharply after birth and remain low for some time, which allows for lactation to begin. Temporarily, during labor, melatonin and endorphin levels, as well as adrenaline, also increase. Of greatest concern for the question of postpartum learning are the hormones at play after birth. In this period, lactation is the primary force that generates and maintains differential hormonal levels.

During lactation, women are flooded with a variety of hormones, some of which influence brain chemistry and function. Perhaps the most important are prolactin, which influences the development of breast duct structures and alveoli; and oxytocin, which contracts the muscles surrounding alveoli to move milk into ducts; both of which are produced at high levels during breastfeeding. Many other hormones play a substantial role, though; growth hormone, adreno-cortico-tropic hormone (ACTH), glucocorticoids, thyroid stimulating hormone (TSH), follicle stimulating hormone (FSH), and luteinizing

hormone (LH) are all present at elevated levels. During the act of breastfeeding, other hormones such as insulin, thyroxine, and cortisol are involved, but their exact role is not yet well understood.

In considering the role of hormones in the postpartum period, it is important to question what effects they may have on cognitive ability - in particular, what role they might play in plasticity. Some of the hormones present at elevated levels after childbirth, including prolactin and oxytocin, have been linked to enhanced learning ability (Shingo et al, 2003; Hurlemann et al, 2010; Pletzer et al, 2010; Larsen & Grattan, 2012). For example, studies have shown that prolactin can affect neurogenesis - a significant component of plasticity - in various brain areas (Shingo et al, 2003; Torner et al, 2009; Larsen & Grattan, 2012). One study, by Shingo and colleagues (2003), found specifically that hormones active during pregnancy can contribute to significant neural development, and that such plasticity is modulated by prolactin. Larsen and Grattan (2012) discovered that low prolactin levels can cause impairment in maternal behavior in the postpartum period, which suggests that normal levels of prolactin are crucial for typical adjustments to motherhood – perhaps including the acquisition of new skills - to develop. Perhaps the most compelling piece of evidence to suggest that hormones present during the postpartum period affect learning and plasticity is a study conducted by Tomizawa and colleagues in 2003 that showed that oxytocin improved spatial memory in new mothers. Further research has indicated that hormonal changes potentiate spatial and working memory enhancement (Pawluski et al, 2006). Overall, it appears that hormones present at elevated levels during pregnancy and

postpartum can have significant effects on plasticity in new mothers and provide the framework for learning.

As an additional note on breastfeeding's link to plasticity, there appear to be critical period effects at play in breastfeeding initiation and maintenance. This idea is reinforced anecdotally, but there may be real evidence for it. Though research on the topic is minimal, a few studies suggest that the first several weeks post-birth are crucial for establishing long-term breastfeeding success- and vulnerable to factors negatively affecting breastfeeding. Essentially, this early period of time appears to be a window of opportunity where setting up good breastfeeding practices can result in long-term success (Gross et al., 2011). The existence of a critical period would indicate strongly that the brain is primed for learning skills during the early postpartum period.

The Present Study

In sum, the cumulative evidence seems to suggest a likely link between plasticity and recent childbirth. Evolution has equipped humans with mechanisms to enhance plasticity during times when a high level of learning is required. Generally, this means plasticity is greatest during childhood, but becoming a mother requires a great deal of learning as well - women need to quickly develop skills necessary for their new infant's survival. Given the immense importance of transitioning to motherhood effectively, humans have adapted in ways to make that transition easier. Perhaps such adaptations include a period of increased plasticity in women following childbirth. The critical period associated with learning to lactate, for example, certainly suggests that a short, temporal span of high potential for learning is present. Moreover, as we've discussed, studies have found that hormones associated with pregnancy, childbirth, and

most strikingly, breastfeeding, are also linked to elevated learning and neuroplasticity in some domains. Likely, hormonal changes in the prepartum period establish a framework for learning, and hormones increased by breastfeeding serve to maintain and enhance that framework. Taken holistically, it seems very likely that a special period of enhanced plasticity is brought about during a woman's transition to motherhood, particularly during lactation. Interestingly, despite the evidence strongly suggesting new mothers experience a change in learning potential, almost no previous research has been undertaken in this realm. The few studies that provide the best evidence for our hypothesis - linking new mothers and hormones increased by lactation with improvements in spatial and working memory (Tomizawa et al, 2003; Pawluski et al, 2006) - were conducted in rodents, and have not been extensively followed up on. It seems that a window of potential for research is available, then. Given how crucial effective transition to motherhood is, as well as the importance of better understanding learning and plasticity in adults, this is a topic that should not go unexplored.

The amount and variety of research that could - and should - be conducted on the topic of new motherhood and learning is vast, but here we propose a single study to investigate the plausibility of our hypothesis - that learning has a significant role in the transition to motherhood, and particularly, lactation; and changes brought about by this transition contribute to a time of enhanced plasticity. In this study, we will assess plasticity using learning tasks, gather information on mother's level of success at transitioning to motherhood, and measure other potentially confounding factors known to influence learning and lactation. We expect that this research will shed light on what direction further investigation into motherhood and plasticity should take. Our study has

already been fully developed, and we have begun collecting data from participants, but at the present we do not have enough data for a thorough analysis of our results. Thus, at this phase it is not yet possible to provide extensive presentation or discussion of findings. Rather, the focus will be on providing a full explanation of how the study was developed and what we hope to learn from it.

The present study has two primary goals: first, to assess learning ability on a number of tasks in a range of women, from recent mothers to women who have never given birth; and second, to evaluate the lactation successes and challenges of women who have attempted to breastfeed their children, in order to examine such successes in relation to learning ability. With those aims in mind, we began to develop our research plan.

The first and most important step was to identify measures of learning plasticity. Some researchers study plasticity using brain imaging, but we decided to use behavioral methods instead. A range of tasks to assess various aspects of learning ability exists, so we had to make careful judgments about which measures to use. One consideration was our desired participants; we knew we needed new mothers to be able to complete our study in a way that was not too intrusive to their busy lives, so it was important that we select tasks that could be done quickly and without too much bother. For this reason, we decided to mount the study online so that participants would be able to complete the study online in a location of their choice rather than having to schedule an appointment and come in to the lab. This meant that all learning measures needed to be relatively quick to complete and computer-based. A second consideration was domain. Learning is a broad term which encompasses many perceptual and cognitive components across a

diverse range of domains. While we believe that becoming a mother opens up a window of learning potential, we don't know whether this potential is domain-general (e.g., many types of learning are possible) or domain-specific (e.g., learning is only enhanced in select areas, such as learning to breastfeed). As an initial probe, without knowing what domain or domains in which plasticity might be at work, we decided to cast a wider net and include a range of cognitive and learning tasks in multiple domains, to see which might show an effect. With these two considerations - ease of access, and selecting several different types of measure - we sifted through research on learning to unearth tasks that might show effects of plasticity. Our selections and reasoning for each are discussed in the Methods section of this paper. Perhaps all of the plasticity measures included will show enhanced learning in new mothers, or perhaps none will, but the variety of tasks we utilized will provide an opportunity to see how broadly childbearing affects learning and cognitive functioning.

While the cognitive tasks we included will address the question of whether the transition to motherhood coincides with a period of enhanced plasticity, another question remains; whether women who possess a higher level of plasticity will also be more effective at breastfeeding. To this end, we developed a self-report questionnaire to evaluate breastfeeding success; the Breastfeeding Experiences Questionnaire (BEQ). The BEQ asks mothers about their experiences initiating and maintaining breastfeeding; their challenges, successes, obstacles, and goals. Besides simply evaluating lactation success, the BEQ (among other questionnaires included) attempts to measure other factors, besides learning ability, which could potentially affect breastfeeding. In this study, there are elements beyond the obvious which could significantly impact our data

– variables that could explain trends in new mothers' skill development, as well as patterns we see in performance on learning tasks.

We know from previous research that many factors can impact women's capacity for learning, as well as one's transition to motherhood. Learning ability is not the only variable that accounts for differences in breastfeeding success, and becoming a mother is not the only factor that determines level of plasticity. The issue of confounds and covariates is a serious one, especially in this study, as breastfeeding and learning are both realms with many factors known to have influence functioning. Thus, we have included several questionnaires that could give insight into other causes of variation in learning and breastfeeding ability. As previously mentioned, several major obstacles to successful breastfeeding have been established. These need to be considered as potentially confounding variables when investigating a possible connection between plasticity and breastfeeding. While we will assess a variety of conceivable differences between women that could impact breastfeeding success - and all measures are discussed further in the Methods section of this paper - there are several that deserve greater focus and discussion. One important factor is social support, or the degree to which family and friends are present and encouraging. Women who lack a supportive social network, particularly a supportive partner, are likely to have greater difficulty in breastfeeding initiation or maintenance (Raj and Plichta, 1998); thus we have included a measure of social support. Another influential factor is socioeconomic status. Studies have found a very strong link between maternal education and employment and breastfeeding duration (Flacking, Nyqvist, and Ewald, 2007). Our demographics questionnaire assesses socioeconomic status, making it possible for us to assess the

19

extent to which socioeconomic status might be influencing both learning ability and breastfeeding success in our sample, as well as any potential links that may emerge between them. There is also considerable evidence that mindfulness affects both mother's transition to parenting (Hughes et al., 2009; Duncan & Bardacke, 2010), as well as impacting individual's learning ability (Salomon & Globerson, 1987; Langer, 2000). For this reason, we have included two measures of mindfulness; one related to the general population, and one targeted at new mothers. Finally, subjective feelings of stress and depression can also impact breastfeeding; in particular, increased stress or depression predicts less successful breastfeeding (Field, 2010). Thus, we have included an assessment of stress as well as a postpartum depression inventory.

To sum up, while there is a deficit of research in our field of inquiry, we believe the cumulative evidence justifies an investigation into potential links between breastfeeding, maternal learning, and plasticity. Our proposed study has several objectives: to examine if new mothers display heightened learning ability and plasticity when contrasted to women their same age who have not recently had a child, to see if breastfeeding – through maintenance of hormonal changes – extends this period of enhanced learning, and to see if there is a correlation between learning ability and breastfeeding success within the population of breastfeeding mothers. Our prediction is that women transitioning into motherhood will exhibit markers of a window of enhanced plasticity, that new mothers who breastfeed will show a longer period of heightened learning, and that mothers with greater learning ability will show correspondingly higher success at breastfeeding.

Methods

Participants

Our sample, achieved thus far (data collection is ongoing), consists of 34 women between the ages of 18 and 34 (M=22, SD=3.8). Four were mothers, and 30 were not mothers. All of the mothers were currently breastfeeding. The time since their child's birth ranged from 7 months to 16 months (M= 11, SD=3.9). One non-mother participant's data was not used in analysis because in a question regarding honesty she indicated that she had not put forth a sincere effort in completing the study, so we were left with 33 participants.

Procedure

Recruitment

Participants were recruited through several channels. Some were given the option to sign up for the study through the University of Oregon's Human Subjects Pool, some were recruited through partnership with local organizations such as the Breastfeeding Coalition or Daisy C.H.A.I.N. (a non-profit group aiding breastfeeding women), and some were invited to complete the study through the University of Oregon's Developmental Database. Participants recruited through the Human Subjects Pool, who were University of Oregon students, were invited to participate via the Human Subjects Pool website and were reimbursed in the form of study participation credits. Participants recruited through other routes - generally, community members - were asked to participate via an invitational email and were paid in the form of a $10.50 check, which was mailed to them after completion of the study.

Data collection

Once women agreed to participate in the study, they were emailed a link to the study, which was in the form of an online survey developed and hosted on Qualtrics. Participants were asked to complete the study on their personal computer in a private place when they had enough free, uninterrupted time to complete the entire study at once - about 1 to 2 hours.

First, participants were shown a consent screen and agreed to participation in the study before proceeding. Next, participants completed a series of cognitive tasks (which are discussed at length in the next section). Then, all participants filled out a demographics questionnaire; a depression, anxiety, and stress scale; a scale measuring perceived social support; and a mindfulness measure. Participants indicating they had a child additionally completed several measures relevant to parenthood, and participants who had at some point breastfed a child also completed a measure of breastfeeding success. After all questionnaires were completed, participants were shown a debriefing form, and given information on how they would receive compensation for the study, either in the form of Human Subjects Pool participation credits or a $10.50 check.

Measures

All participants completed several cognitive tasks embedded within the Qualtrics survey. Three tasks - a Statistical Learning task (Fiser & Aslin, 2002), a Verbal Paired Associates task (VPA; Uttl, Graf, & Richter, 2002), and the Rey Auditory Verbal Learning Task (RAVLT; Schmidt, 1996) - were designed to examine learning ability. Two tasks - a Stroop task (Stroop, 1935) and Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002) - were included to measure executive

function, which relates to management and regulation of cognitive processes rather than strictly learning. We included executive function measures, in addition to more traditional learning tasks, out of interest in seeing if differences exist between new mothers and non-mothers in the realm of executive function, and if executive function might have some relationship with learning or breastfeeding success. All participants filled out a standard demographics questionnaire, with several questions modified for the purpose of this study. All participants also completed the Depression Anxiety Stress Scale short-form (DASS-21; Henry & Crawford, 2005); the Multidimensional Scale of Perceived Social Support (MSPSS; Zimet, Dahlem, Zimet, & Farley, 1988); and the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). Participants who indicated they had a child, whether or not they were breastfeeding, also completed the Interpersonal Mindfulness in Parenting scale (IM-P; Duncan, 2007), and the Edinburgh Postnatal Depression Scale (EPDS; Cox, Holden, & Sagovsky, 1987). Finally, all participants who indicated that they were currently breastfeeding completed the newly-developed Breastfeeding Experiences Questionnaire (BEQ), a measure developed for this study to evaluate breastfeeding success, which includes items from the Infant Behavior Questionnaire (IBQ; Rothbart, 1981).

Statistical Learning Task

The Statistical Learning task was adapted from the materials and procedures used by Fiser and Aslin (2002). It consisted of a habituation video showing a continuous sequence of shapes, in which some shapes were shown together more frequently than others. This was followed by a test phase in which participants viewed short clips of shape sequences, some of which appeared more often in the habituation

video, and asked to judge which sequences seemed more familiar based on their previous viewing. It was used as a measure of participants' ability to learn statistical information about visual sequences. Individuals who are sensitive to statistical differences in sequence presentation should perform better than individuals who are less able to extract information from the order of sequence presentation. As Fiser and Aslin note, to learn about visual scenes, humans rely on spatiotemporal correlations; that is, changes (or lack of change) in objects and their positions over time. Being able to parse information about temporal correlations across scenes – in particular, learning what changes or sequences of changes are typical (e.g., statistically more likely) – is important for understanding the visual world. The Statistical Learning task aims to assess how well individuals are tracking these temporal correlations; for our study, it serves as a measure of plasticity in the spatiotemporal domain.

Participants were told that they would watch a 7-minute video and be asked questions about it afterwards, so they must remain focused and attentive. They were not told what the test would be, or anything about content of the video. Then, the habituation video of a continuous sequence of shapes was shown to participants. The twelve shapes were organized into four sets of three – base triplets (see Figure 1). Each base triplet was always presented in the same temporal order. That is, if shapes A, B, and C form a base triplet, when shape A was presented, it was always followed by shape B, then shape C. Shape A was considered the first shape of the ABC base triplet, and shape C was the last shape. Since there are twelve shapes, there were four base triplets: ABC, DEF, GHI, and JKL. After C, the first shape of one of the other three base triplets was shown; either shape D, G, or J.

24

Figure 1: The twelve shapes used in the Statistical Learning task arranged into four triplets. Taken from Fiser & Aslin (2002).
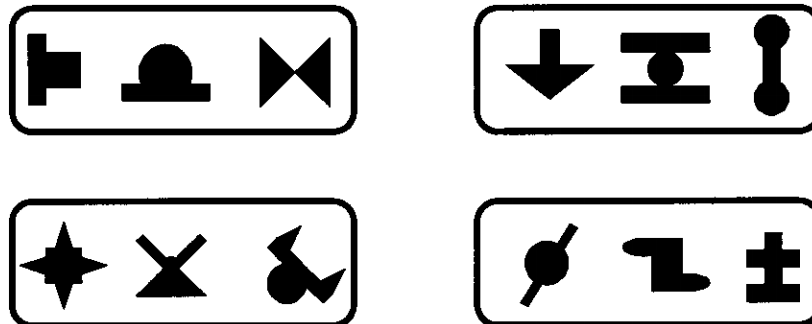
The continuous 7-minute video of shapes followed a strict order: the four base triplets were presented 24 times each, for a total of 96 triplets. The sequence was semi-random; no repetition of base triplets or triplet pairs occurred - e.g., no base triplets occurred twice in a row (e.g., ABC-ABC), and no two triplets appeared in series twice in a row (e.g., ABC-DEF-ABC-DEF). Since base triplets were always presented in order, shape B followed shape A 100% of the time, and shape C followed shape B 100% of the time. After shape C, though, it was approximately equally (33%) likely that shape D, G, or J would be shown. Thus, there was very high statistical probability that two shapes of a base triplet would be shown together – AB, BC, DE, or EF for example - and lower probability that two shapes which cross base triplet boundaries (the end of one base triplet and the start of the next) would be shown together – FA, IA, CD or CG, for example.

After the habituation video, participants entered the test phase. They were presented with 32 short (15-second) videos showing two triplets, separated temporally by a blank screen. In each case, one of the triplets shown was a base triplet (ABC, DEF,

GHI, or JKL) and the other was a 3-1-2 triplet – that is, it contained the last shape of a base triplet (C, F, I, or L) paired with the first two shapes of different base triplet (AB, DE, GH, or JK). Four 3-1-2 triplets were used: CDE, FGH, IJK, and LAB. To generate the 32 test videos, each of the four base triplets was paired with each of the four 3-1-2 triplets, and each triplet pair (base and 3-1-2) was shown twice: in half the test videos the base triplet was presented first, and in the other half the 3-1-2 triplet was shown first. After each test video, participants were instructed to select which of the two triplets was more familiar, based on the habituation video. Base triplets appeared far more often in the habituation video than 3-1-2 triplets. If the participant had successfully learned the statistical probability of the shape sequences, they should have always selected the base triplet rather than the less common 3-1-2 triplet. Participants were scored based on the number of triplets they correctly identified as more common.

Rey Auditory Verbal Learning Task

The Rey Auditory Verbal Learning Task was adapted from its description by Schmidt (1996). Participants were presented with five consecutive listen-recall trials. The first three trials were the same - an audio list of 15 words (see List 1 in Table 1, below) was played while the participant listened. Then, participants were presented with a text box in which to type in as many words from the list as they could recall - they could not, however, see what they were typing so they would not be able to visually rehearse the words. After three trials of listen-recall for List 1, the fourth listen-recall trial was an interference trial and used a different set of 15 words - List 2 (see Table 1). Finally, in the fifth trial, participants were asked to recall as many words from List 1 as they could without hearing the words again. Participants were scored based on the

26

number of words they correctly recalled in each trial. The RAVLT is used to assess

verbal learning and memory, including subdomains of learning such as proactive

inhibition, retroactive inhibition, and retention. We included it in the present study as a

measure of auditory and verbal learning in a task involving inhibition and retention.

Table 1: RAVLT word lists.

List 1:	List 2:
Drum	Desk
Curtain	Ranger
Bell	Bird
Coffee	Shoe
School	Stove
Parent	Mountain
Moon	Glasses
Garden	Towel
Hat	Cloud
Farmer	Boat
Nose	Lamb
Turkey	Gun
Color	Pencil
House	Church
River	Fish

Verbal Paired Associates Task

The Verbal Paired Associates task (VPA) was modeled on the work of Uttl,

Graf, and Richter (2002). It consists of two trials. In the study section of each, 15 pairs

of words (such as frog-neck or bank-milk) were presented on the screen for 500

milliseconds per pair, with a blank screen between pairs. After the study portion,

participants were given a recall test. The first word of each pair was listed, in scrambled

order, and participants were asked to type in the second word of the pair. The second

trial followed the same method and used the same word pairs as the first, but in a

different order of presentation. Word lists and order of presentation for both the study and recall segments appear below in Table 2. Participants were scored based on the number of words they correctly recalled in each trial. Versions of the VPA are widely used as measures of explicit episodic memory. We included the VPA to assess plasticity in the domain of verbal and associative learning.

Table 2: Word pairs and their study and test order presentation by trial

Study order	Recall order	Study order	Recall order
Trial 1		Trial 2	
Frog-neck	Rose (flower)	Bank-milk	Obey (inch)
Metal-iron	Fruit (apple)	Frog-neck	Bank (milk)
Foot-tree	Room (face)	Room-face	Hill (ring)
School-grocery	Coal (year)	School-grocery	Crush (dark)
Fruit-apple	Metal (iron)	Coal-year	Coal (year)
Hill-ring	School (grocery)	Girl-sign	Room (face)
Baby-cries	Hill (ring)	Rose-flower	Foot (tree)
Obey-inch	Frog (neck)	Obey-inch	Girl (sign)
Crush-dark	Cabbage (pen)	Baby-cries	Baby (cries)
Girl-sign	Bank (milk)	Fruit-apple	Metal (iron)
Coal-year	Girl (sign)	Metal-iron	Frog (neck)
Room-face	Obey (inch)	Cabbage-pen	Fruit (apple)
Rose-flower	Foot (tree)	Foot-tree	Rose (flower)
Cabbage-pen	Baby (cries)	Crush-dark	School (grocery)
Bank-milk	Crush (dark)	Hill-ring	Cabbage (pen)

Stroop Task

The Stroop task was taken from Stroop's 1935 work, as well as a model for mounting a Stroop task on Qualtrics developed by Barnhoorn and colleagues (2014). Participants were shown names of colors written in different colored fonts - the words were *red*, *blue*, *green*, and *yellow*, and they were written in red, blue, green, or yellow font. Words were presented on the screen one at a time. Participants were instructed to

28

indicate (using keyboard keys) the font color of the words, ignoring the written name of the color, and to provide their response as quickly and accurately as possible. For example, if the word *yellow* written in red font was shown, participants should hit the key corresponding to red (for the font color), rather than the key corresponding to yellow. After participants hit a keyboard key, a white cross would be shown briefly and then the next word would appear. Participants were given 20 practice trials with feedback - if they hit the wrong key, they were told what they should have pressed instead, and were reminded which key corresponded to which font color. After practicing, the full trial began. First, 20 words in which the written word color and font color matched - e.g., it said *red* and was written in red font - were presented, to be analyzed as a baseline measure of the participants reaction time. Then, 96 more words were shown. In half of the words, the written word color and the font color matched. In the other half, the written word color and the font color did not match - e.g., it said *green* and was written in blue font. Participants were scored based on reaction time on trials in which they hit the correct key. The Stroop task is a measure of executive function rather than learning; it specifically targets selective attention, processing speed, cognitive flexibility, and response inhibition. We included it out of interest in seeing if such executive function skills were different in new mothers. It also may be of interest as a covariate in our data analysis – perhaps higher executive functioning affects learning ability or breastfeeding success, for example.

Attention Network Task

The Attention Network Task was based on work by Fan and colleagues (2002). Participants were told they would view a central fixation cross, followed by a single

arrow or array of arrows presented on the screen. The arrow(s) would appear either above or below the central fixation cross (which was always visible). Participants were asked to indicate quickly and accurately using their left and right keyboard keys which direction - left (<) or right (>) - the central arrow of the array (or, if only one arrow appeared, the only arrow) was pointing. In some trials, the central arrow would be surrounded by congruent arrows (e.g., <<<<<); in some trials, it would be surrounded by incongruent arrows (e.g., <<><<); and in some trials, the central arrow would be presented alone. Additionally, the arrow presentation was preceded by different cue conditions. In some conditions, *X*s would appear as a cue indicating when or where the arrow would appear. If the cue was at the center or both above and below the fixation cross, it indicated that the arrow would appear shortly. If the cue was only above or below the fixation cross it indicated both that the trial would occur shortly and where it would occur (above or below the fixation cross). Participants were informed of the arrow arrays and the spatiotemporal cues, and told they should attend when and where indicated by the cues. Participants were given an 8-trial practice round, followed by a 96-trial test. Participants were scored based on reaction time on trials in which they hit the correct key. The ANT task, like the Stroop task, is a measure of executive function rather than a learning task. It assesses aspects of attentional control: alerting (changes in reaction time based on cuing), orienting (changes in reaction time based on cues indicating where a target will occur), and executive control (changes in reaction time and accuracy in determining the direction of the target, with congruent or incongruent flankers). We included it for reasons similar to the Stroop task inclusion; to see how executive function might interact with or predict other variables.

Demographics Questionnaire

The demographics questionnaire we included, which asked questions to establish basic information about participants, was a standard measure used by all studies in the Acquiring Minds lab. The questionnaire investigated variables like socioeconomic status, age, native language, and other general information. Several questions were added for the purpose of this study; participants were asked if they have a child, when they had their child, and if they were currently breastfeeding; if they were currently working and how many hours per week; and how many times per week they engaged in moderate to vigorous physical exercise (the latter two could impact their ability to successfully breastfeed). The demographics questionnaire was included for two reasons: first, it is important to get basic information about the diversity of our sample, for funding purposes as well as understanding our sample. Second, some factors measured could have an effect on either learning ability or the transition to motherhood. For example, we know that socioeconomic status is associated with breastfeeding success (Flacking, Nyqvist, and Ewald, 2007), and we know that age affects learning performance (Pascaul-Leone, Amedi, Fregni, and Merabet, 2005), so we will have to incorporate both factors into our data analysis as control variables.

Depression Anxiety Stress Scale

The DASS-21 is a shortened version of the original DASS, developed by Henry and Crawford (2005) (see Appendix A for full measure). It consists of 21 items - 7 items each related to depression, anxiety, and stress. Items take the form of statements (such as, 'I found it difficult to relax' and 'I couldn't seem to experience any positive feeling at all'), and participants were told to think about how much the items applied to

them over the past week. Participants indicated answers on a 4-point scale, ranging from 'Did not apply to me at all' to 'Applied to me very much, or most of the time'. Each category could be analyzed separately, or a composite score could be used as a general measure of distress. We collected this information because it could affect our results - stress and depression may impact performance on learning tasks, and are known to affect breastfeeding success (Field, 2010) - and we may need to account for these possible effects during data analysis.

Multidimensional Scale of Perceived Social Support

The MSPSS is a scale developed by Zimet, Dahlem, Zimet, and Farley (1988) to assess a person's subjective feelings of social support (see Appendix B for full measure). It consists of 12 items, 4 each related to family, friends, and any significant other. Items are in statement format (examples include, 'There is a special person who is around when I am in need' and 'My family is willing to help me make decisions'), and participants were asked to indicate how they feel about each statement on a 7-point scale, ranging from 'Very strongly disagree' to 'Very strongly agree'. We administered this measure to participants because social support is known to affect breastfeeding success (Raj and Plichta, 1998), and could possibly affect learning task performance, so we may want to account for its influence during data analysis.

Five Facet Mindfulness Questionnaire

The Five Facet Mindfulness Questionnaire was taken from work by Baer and colleagues (2006). It is intended to assess several aspects of mindfulness - observing, describing, acting with awareness, nonjudging of inner experience, and nonreactivity to

inner experience. The FFMQ consists of 39 items related to these facets of mindfulness (with seven or eight questions representing each of the five facets) - example items are

Figure 2: Example FFMQ items for each facet of mindfulness. Taken from Baer et al., 2006

Facet	Example Item
Observing	I notice the smells and aromas of things.
Describing	I am good at finding words to describe my feelings.
Acting with awareness	I find myself doing things without paying attention. (R)
Nonjudging of inner experience	I think some of my emotions are bad or inappropriate and I should not feel them. (R)
Nonreactivity to inner experience	I perceive my feelings and emotions without having to react to them.

NOTE: R = reverse-scored item (higher scores represent higher levels of mindfulness).

shown in Figure 2 (for the full measure, see Appendix C). Each item was in statement form, and presented with a 5-point scale ranging from 'Never or very rarely true' to 'Very often or always true'. Participants were asked to select the scale point that most closely corresponded to their opinion of the item or what is generally true of them. We included the FFMQ because we were interested in how mindfulness might affect performance on learning assessments.

Interpersonal Mindfulness in Parenting Scale

The Interpersonal Mindfulness in Parenting Scale was taken from the work of Duncan (2007). It assesses mindfulness in parent-child interactions - the version used here is specific to infant interactions. The IM-P consists of 27 items in statement format related to parent-infant interactions (for example, "I am aware of how my moods affect the way I treat my baby" and "When times are really difficult with my baby, I tend to

33

blame myself"). For the full measure, see Appendix D. Participants were given a 5-point scale ranging from 'Never true' to 'Always true' and asked to select which point corresponds most to their usual experience for each item. The IM-P was included in the present study to assess the impact that mindfulness in infant-child interactions might have on the transition to motherhood.

Edinburgh Postnatal Depression Scale

The Edinburgh Postnatal Depression Scale was developed by Cox, Holden, and Sagovsky (1987). It is a measure used to assess mother's postnatal feelings of depression, in which participants were asked to indicate on a 4-point scale to what extent each of 12 statements reflected their experiences. Examples of statements are "I have felt scared or panicky for no very good reason" and "I have looked forward with enjoyment to things" (for full measure, see Appendix E). Given evidence suggesting that depression can affect a mother's transition to parenthood – including ability to breastfeed successfully (Field, 2010) – we included this measure as a way to evaluate feelings of depression in mothers, as it may interact with or simply skew other variables we are measuring.

Breastfeeding Experiences Questionnaire

The Breastfeeding Experiences Questionnaire was developed for this study. It contains a mix of questions with numeric responses (for example, 'On average, how many times a day do you breastfeed your child?'), free response questions (for example, 'Please write what supplements to breast milk your child receives'), yes / no questions (for example, 'Does your child use a pacifier regularly?'), and questions about subjective

success and challenges that mothers are asked to answer on a 5-point scale (for full measure, see Appendix F). It also included several items from the Infant Behavior Questionnaire, developed by Rothbart (1981), which were added to evaluate infants' temperament across domains such as activity level and soothability. The goal of the BEQ was to assess breastfeeding success and mothers' challenges related to breastfeeding, quantify how often a child is breastfeeding, and identify possible risk factors or confounding variables for successful breastfeeding.

Results

While we do not yet have enough data for a full presentation of findings, it is important to provide a preliminary assessment of the measures we are using, particularly the learning tasks, which are so crucial to the success of our investigative undertaking. It is imperative that the learning assessments we use show a reasonable degree of individual variability, so that we can both pick up on any differences between groups (e.g., new mothers versus non-mothers), and between individuals. We also should see relatively normal distributions in the results, without significantly skewed scores, which would help validate our measures. Thus, we conducted a preliminary analysis on the results from our three learning tasks (the Statistical Learning task, RAVLT, and VPA) to assess the validity of the measures.

Statistical Learning Task

Scores on the statistical learning task ranged from 10 to 32 (the maximum possible score), with a mean of 19 and standard deviation of 5.9. Frequency and distribution of scores are shown in Figure 3, below. At first glance, the results look fairly normal, and the test appears sensitive to individual differences, given the wide range of answers. However, for an objective way to validate the test, we used two tests of normalcy: the Kolmogorov-Smirnova (K-S) and Shapiro-Wilk (S-W). The K-S and S-W tests both compare data to a hypothetical normal distribution with the same mean and standard deviation, and determine whether the data is significantly different from normal (p value of less then .05) or not (p value greater than .05). Each test differs in exactly how it assesses normalcy – the S-W is highly specific and requires a full data set

with exact values for mean and standard deviation, while the K-S is more general and correspondingly less powerful. We decided to report both. In each case, the null hypothesis is normalcy, so a p value of less than .05 indicates the data are not normally distributed. For the Statistical Learning scores (N=33), the K-S statistic was .087, p=.200; the S-W statistic was .966, p=.371. Both tests indicated that our data were normal. While the pattern of data may change as more results are collected, it is an encouraging start to see that scores on the Statistical Learning task currently follow a normal distribution, which also appears to show individual differences.

Figure 3: Frequency of scores on the Statistical Learning Task.
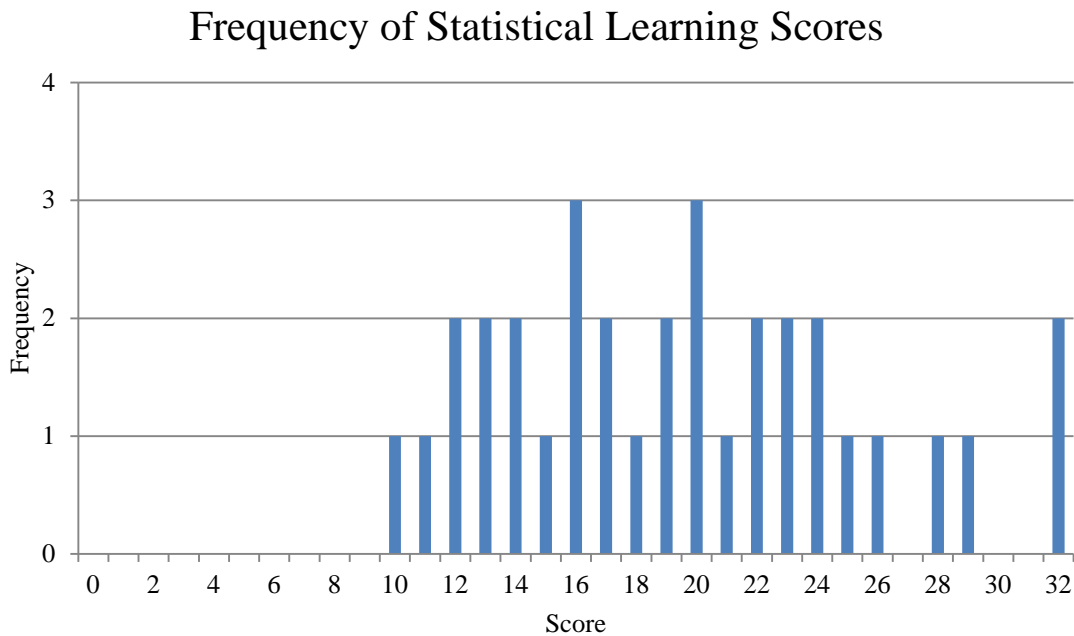

Rey Auditory Verbal Learning Task

For the RAVLT, grand average scores – the average of scores on all five trials – ranged from 5 to 13, with a mean of 10 and standard deviation of 1.9 – frequency of grand average values are shown in Figure 4, below. Subjectively, the scores appear

normally distributed, but possibly with less of a range than we would like – ideally, scores would follow a wider distribution, so that we could pick up on individual differences between participants. The relatively narrow range of our results is possibly due to ceiling effects on some of the trials. On trials 3 and 5, for example, some participants achieved the maximum possible score, which may indicate that individual variability is hidden due to multiple individuals achieving the highest score. For this

Figure 4: Frequency of grand average scores – average of all five trial scores - on the RAVLT.

RAVLT Grand Average Frequencies
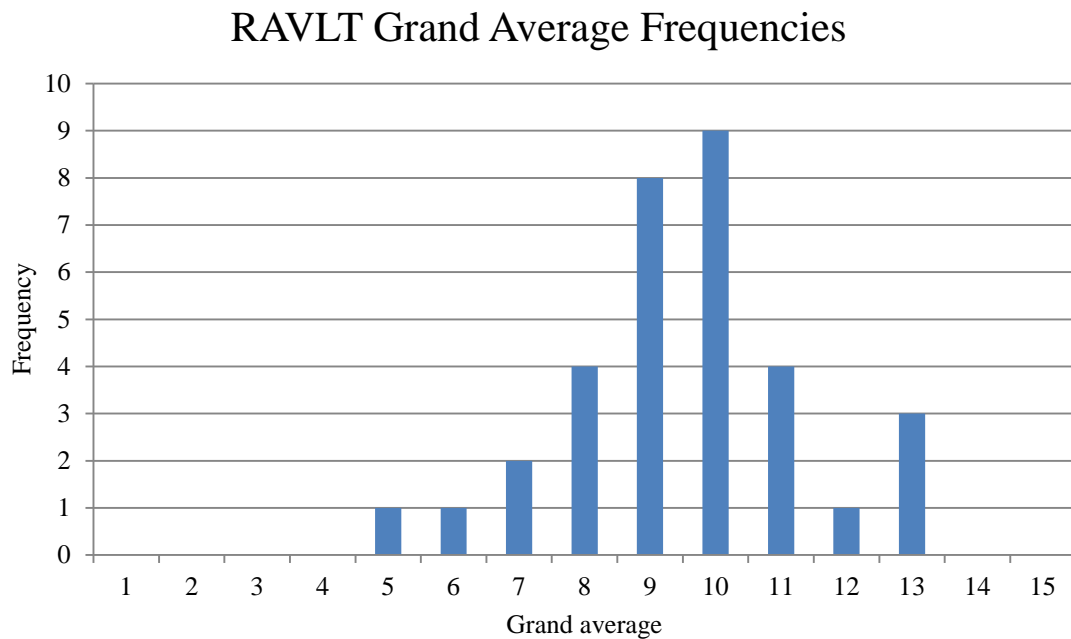
reason, once we have finished data collection and are ready to analyze the full set of results, we may choose to omit one or more of the trials from analysis, and create a RAVLT grand average score using three or four trials rather than all five. Regardless of whether adequate sensitivity to individual variation is present in the RAVLT, it is important to validate the measure by assessing the normalcy of the grand average score distribution. Again, we conducted K-S and S-W tests of normalcy. For RAVLT grand

average scores (*N*=33), the K-S statistic was .106, *p*=.200; the S-W statistic was .973, *p*=.563. Since both p values were greater than .05, our results point to our data on this task being normally distributed. While we will have to give more consideration with how to deal with the RAVLT data in terms of performance ceilings and range of scores, our preliminary data do not significantly depart from normalcy.

Verbal Paired Associates Task

Grand average scores – the average of both trial scores – on the VPA ranged from 2 to 15, with an average of 10 and standard deviation of 3.3. From Figure 5, which shows grand average score frequency, we can see that participants covered almost the

Figure 5: Frequency of grand average scores – average of both trial scores – on the VPA.

VPA Grand Average Frequencies
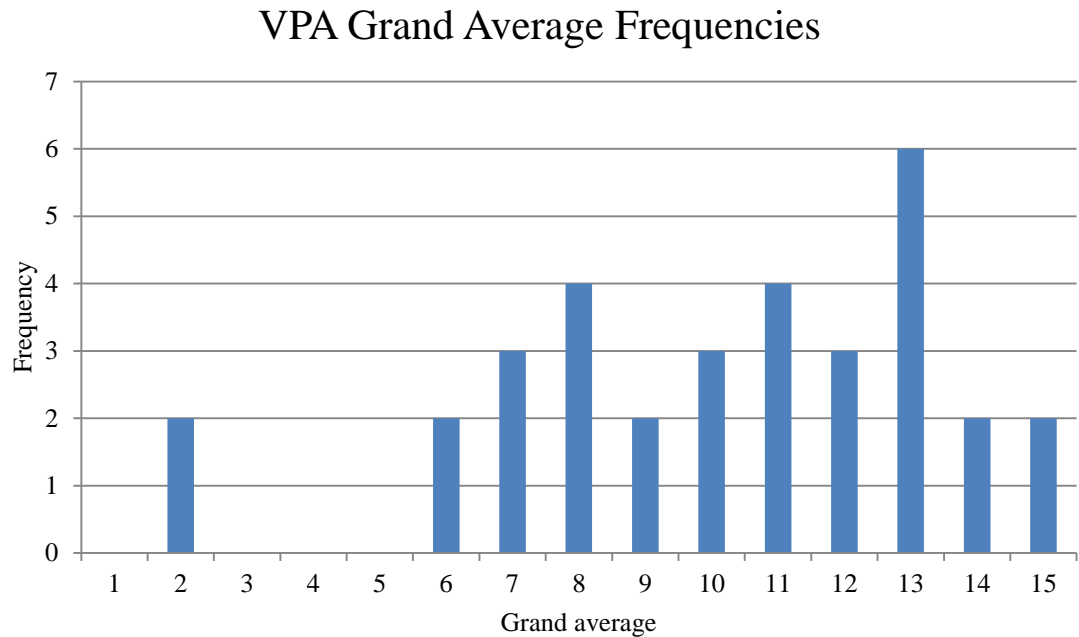
full range of possible scores, indicating a high level of sensitivity to individual differences. To gain a more objective sense of the VPA's validity as a measure, we again conducted the K-S and S-W tests to assess the distribution's normalcy. For VPA

39

grand average scores (*N*=33), the K-S statistic was .125, *p*=.200; the S-W statistic was .944, *p*=.089. Since both p values were greater than .05, our results display a normal distribution. Though we will need to assess VPA grand average scores again once we have our full set of data, our present results appear to be normally distributed and possess a high degree of sensitivity to individual differences.

Future Data Analysis

Of course, testing normalcy of the data is only the beginning of our analysis. We plan a range of other analyses to test our hypothesis, to examine whether our predictions are confirmed. First, we speculated that becoming a mother initiates changes that may open a period of plasticity potential. Our analysis, then, might proceed as follows. We could compare scores on learning tasks between women who had recently given birth (within a set time frame, such as 6 months) versus those who had not. According to our prediction, women who were closer to childbirth should show better performance on some or all of the learning tasks. We could conduct a regression analysis to predict learning potential based on number of weeks since childbirth, or simply look at the correlation between number of weeks since birth and scores on learning tasks. Perhaps the possible relationship between the two variables is not linear, in which case we would need to pull in more analytical techniques (as both regression and correlational analyses estimate linear relationships).

Next, we could investigate the question of whether breastfeeding, via the hormonal changes that lactation maintains, sustains a heightened level of learning ability. We would predict that new mothers who do not breastfeed would show a sharper decline in learning task performance post-childbirth (as the window of

enhanced plasticity passes), while breastfeeding mothers would show a much slower decline, as breastfeeding might sustain heightened plasticity. To address this issue, we might look at new mothers and compare scores on learning tasks between those who were currently breastfeeding and those who were not – we would predict that women who were breastfeeding would show higher performance on learning measures than mothers who were not. We would also predict that this difference would be greater as time since giving birth increases, as we predict non-breastfeeding mothers' learning ability will decline faster after childbirth than breastfeeding mothers'. Again, we could investigate this projected relationship via either correlational or regression analysis, or if necessary, use more complex analytical models.

Another of the most obvious data analyses to conduct would assess the relationship between learning ability and breastfeeding success. To do this, we would have to come up with a numerical score for breastfeeding success based on the BEQ. In the BEQ, we asked mothers to rate their subjective feelings of success and difficulty in breastfeeding on a numerical scale, so we could simply use one of these self-reported assessments, or come up with a score that includes information like length of time breastfeeding, supplements to breastmilk used, number of problems encountered in establishing and maintaining breastfeeding, or any number of other factors measured by the BEQ. Once we've determined what our experimental definition of breastfeeding success is and have derived a numerical value from the BEQ to represent it, we can then conduct regression or correlational analyses (or more complex analyses, if it is warranted) to see if scores on learning measures predicts breastfeeding success.

Finally, we should note that we have thus far only discussed planned analyses involving learning tasks and the BEQ. Of course, we have collected information using a great number of measures that should not be ignored or left unevaluated. However, looking at relationships such as those between social support (from the MSPSS questionnaire) and breastfeeding success (from the BEQ), or how anxiety (from the DASS-21) might interact with breastfeeding success and learning score, or how mindfulness (from the FFMQ or IM-P) affects breastfeeding, are secondary concerns to the analyses already discussed. We will certainly look at all the data collected, but a thorough look at everything – and a plan for how we should delve into the full wealth of data – will take time, and have to wait until after the primary data analysis detailed above.

Discussion

It is important to note that the present study should be considered as a proof of concept; that is, it is intended to provide evidence to guide further research on the potential relationship between cognitive plasticity and motherhood. If our study garners support for the hypothesis that childbirth potentiates a period of enhanced learning in mothers, we would be justified in future study of a possible link between motherhood and learning. With that in mind, we should consider how various results of the present study should be interpreted, and what future studies would give greater insight into potential connections between plasticity and the transition to motherhood.

Thus far, we know that learning can be enhanced through hormones, and that transitioning to motherhood induces – and breastfeeding maintains – hormonal changes in women. We have also seen that critical periods indicate timeframes of heightened plasticity, and that there is evidence for a critical period to initiate breastfeeding. Given this evidence, we developed our study to explore whether becoming a mother potentiates learning. At this point, we can make very few conclusions about our results. Our learning tasks appear to be sensitive to individual differences, and our results have thus far followed a normal distribution. As women continue to participate in our study and our sample size increases, we will be able to conduct a full data analysis and interpret our results.

This research has the potential to reveal a range of valuable findings, regardless of whether our hypothesis receives support. It is possible none of our predictions will be supported by our results. This does not mean, however, that our hypothesis is incorrect (though of course, it might be). In considering the present study, there are many reasons

why we might not garner support for the theory that motherhood potentiates a period of enhanced plasticity.

One significant consideration in interpreting our forthcoming results is that the learning tasks we selected may not pick up on enhanced learning potential in new mothers (if it is, in fact, elevated). As discussed in the introduction, plasticity may be increased in women post-childbirth in a wide variety of domains, or a select few areas. If the latter is true, then we may have utilized tasks in domains of learning that do not exhibit increased potential in new mothers. A thorough investigation of our hypothesis would eventually involve exploring performance on as wide a range of learning tasks as is feasible. It is also possible that we did successfully identify learning tasks in domains that are impacted by motherhood, but the differences in learning ability between new mothers and non-mothers may be too subtle for the specific tasks we used to detect. For this reason, it is especially important that we eventually have a large sample size, as more participants would allow for smaller effects to become detectable. In terms of learning tasks, another potential reason results may not support our predictions is that we have not included any longitudinal measures. In transitioning to motherhood, women generally learn how to perform tasks over time – however, all the plasticity assessments used in our study take less than an hour. So, if learning potential is heightened primarily for skills gained over a longer temporal period, we would perhaps be unable to pick up on plasticity changes without long-term learning tasks.

On a similar note, there may be other problems associated with conducting a study within a short period of time. Because learning ability varies a great deal between individuals, there may not be striking group differences that we can detect between new

mothers and similar-aged women, but there could be differences in individual women's

plasticity levels before and after they have a child. To fully assess how becoming a

mother affects learning potential, we would have to recruit participants before they have

a child – ideally, even before they become pregnant – and measure their plasticity level

both long before and shortly after giving birth. A final issue that could result in data that

does not support our hypothesis is timing of participation. If women complete the study

six months after giving birth, is that within the window of enhanced plasticity? Would

three months be safe, or six weeks, or three weeks? At present, there is little information

to guide us regarding exactly when mothers might exhibit greater learning ability, so it's

hard to know if we have recruited enough participants to complete the study soon

enough after having a child.

  While it is vital to consider what it would mean if our data do not conform to

our predictions, we should also discuss what we would learn if our results do follow our

expectations. If one or more of our predictions proves correct, our study will lend

support to our hypothesis. We would have evidence to suggest that, as hypothesized,

physiological changes initiated by giving birth potentiate learning, and would be

justified in further research to explore this new realm of study. If our predictions prove

accurate, it would indicate that plasticity changes can be detected by short-term learning

tasks, and there are apparent differences between groups (e.g., new mothers compared

to non-mothers of a similar age) rather than exclusively individual differences over

time. Additionally, it would indicate which domains of learning might be affected,

depending on which learning tasks showed effects. While there may be many more

areas that show enhanced plasticity as well – and it is of course possible that some

domains might show far stronger effects than the domains we chose to investigate – we would have a starting point to continue research. As a proof of concept study, our current research would be very far from the last word on plasticity in new mothers – rather, it should serve as a springboard to further research.

More than simply supporting our hypothesis, significant results in the present study would have considerable, far-reaching implications. Conventionally, people have believed that learning potentially irreversibly declines after childhood, but recent research has shown that is not entirely true – while the general trend of learning decline holds, there are certain circumstances under which adults can exhibit a resurgence of plasticity (Vecsey et al, 2007; Miller, Campbell, & Sweatt, 2008; Guan et al, 2009; Hensch et al., 2013; Werker & Hensch, 2015). As well, some domains of functioning seem to retain plasticity throughout healthy adulthood (Neville & Bavelier, 2002). The present work, if it follows our predictions, would lend support to this new understanding of learning as far more variable and susceptible influence from a variety of factors than previously thought. In fact, new mothers could provide a perfect model for investigating factors affecting later-life learning. Moreover, critical periods are generally associated with childhood, but our work could indicate that some critical periods – e.g., windows to learn how to breastfeed – open late in life. Perhaps this study could lead to better understanding of how critical periods operate, and how to re-open them in adulthood. Additionally, our research has the potential to implicate the post-childbirth hormonal cascade in facilitating enhanced learning. This would set the stage for further investigation into the roles hormones – particularly, prolactin and oxytocin – play in potentiating plasticity. In general, we believe our study taps into factors

46

affecting learning that are not well understood and in need of future study; in that regard, this work has potentially significant implications for further work in plasticity across the human lifespan.

Similarly, our work investigates the transition to motherhood in a novel way. Factors previously ignored – notably, learning plasticity – might have significant effects on how well mothers adapt to their novel circumstances. If our hypothesis receives support, it might lead to a better understanding of why some women are capable of breastfeeding with ease, while others struggle to learn how to lactate. While the study does not directly point to a solution, it does imply that interventions to support learning ability could greatly help some women to more effectively care for their child. While further research would be necessary to learn why individual differences in plasticity might exist, our study would certainly contribute to our understanding of transitioning to motherhood, and hopefully how to empathize with and assist mothers who are experiencing considerable challenges in learning how to be a competent parent.

In the end, perhaps the most important result of our study would be providing a potential frame within which to study factors that enhance learning in adults. Conceivably, a thorough analysis of how plasticity might be facilitated in new mothers would lead to a better understanding of how learning ability might be heightened in the broader population, which in turn could set the stage for future investigation into techniques to enhance cognitive plasticity in adulthood. With that in mind, we can consider areas of further research that would develop our knowledge base. Many future avenues have been presented already in our discussion, but a few seem like the most logical next steps and deserve further examination.

First, the hormonal component of learning, particularly in new mothers, deserves investigation. Since we posit that hormones, like prolactin and oxytocin, are the driving forces of a plasticity window, then it is important to understand exactly how the post-childbirth hormonal cascade - and hormone levels in general – affect learning. A step beyond the present research, then, would be measuring levels of prolactin and oxytocin in new mothers and seeing if those levels predict performance on learning tasks. Further research could manipulate hormone levels and study the effects that differing levels of various hormones might have on plasticity. This branch of research could specifically have applications for enhancing learning, or developing interventions for mothers having difficulty with lactation.

A second area of future research would involve a range of learning tasks. As previously mentioned, we don't know what specific brain areas or learning domains might be affected by motherhood. Thus, it is not clear whether the learning tasks we chose will pick up on differences between mothers and non-mothers; that is, we do not know the extent to which distinct domains are potentiated – or not – for learning. It will be important in future studies to carefully select learning tasks across a wide range of spheres capable of plasticity. Whether that would entail longitudinal tasks, verbal tasks, auditory tasks, motor skills development, or other domains remains up to the discretion of future researchers.

A final notable direction for future study would involve longitudinal investigation. Whether or not group differences on learning task performance between mothers and non-mothers exist is the focus of the present work, but for greater understanding of the relationship between plasticity and motherhood, investigating

individuals across time will be important as well. Exactly how hormone levels rise and fall, when plasticity enhancement peaks, and how great a change in learning ability motherhood potentiates are questions that would require longitudinal research to answer. Initially, this could perhaps involve simple pre-childbirth and post-childbirth tests on learning tasks to investigate differences, but research could expand to include hormone assays, recruiting women before they become pregnant, and administering tests of plasticity level at a variety of time-points.

Taken together, these three routes for future research could lead to a wide range of results, with implications across many areas of study. However, to justify such research, we rely on the results of the present study. In this sense, our research becomes a cornerstone – it serves as a first step in a field of unknown potential.

In conclusion, while it is too early to know what precisely can be taken away from our current work, we know our findings will be far from the last word on the topic of motherhood and plasticity. Research in learning and motherhood seem to indicate that having a child potentiates a period of enhanced plasticity, and this work is, as far as we are aware, the first to assess this relationship in human mothers. Whether or not our work garners support for our hypothesis, this is an area of research ripe for investigation, and full of important implications for better understanding how adults learn, and specifically, how women learn to become mothers. In the end, the ultimate hope for this project is that it is useful; that it meaningfully impacts further research, and that it sheds light on the importance of investigating new mothers.

Appendices

Appendix A: Depression Anxiety Stress Scale

Please read each statement and select the answer that indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

Scale points: Did not apply to me at all; Applied to me to some degree, or some of the time; Applied to me to a considerable degree, or a good part of time; Applied to me very much, or most of the time.

1. I found it hard to wind down
2. I was aware of dryness of my mouth
3. I couldn't seem to experience any positive feeling at all
4. I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)
5. I found it difficult to work up the initiative to do things
6. I tended to over-react to situations
7. I experienced trembling (eg, in the hands)
8. I felt that I was using a lot of nervous energy
9. I was worried about situations in which I might panic and make a fool of myself
10. I felt that I had nothing to look forward to
11. I found myself getting agitated
12. I found it difficult to relax
13. I felt down-hearted and blue
14. I was intolerant of anything that kept me from getting on with what I was doing
15. I felt I was close to panic
16. I was unable to become enthusiastic about anything
17. I felt I wasn't worth much as a person
18. I felt that I was rather touchy
19. I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)
20. I felt scared without any good reason
21. I felt that life was meaningless

Appendix B: Multidimensional Scale of Perceived Social Support

We are interested in how you feel about the following statements. Read each statement carefully. Indicate how you feel about each statement.

Scale points: Very Strongly Disagree, Strongly Disagree, Mildly Disagree, Neutral, Mildly Agree, Strongly Agree, Very Strongly Agree.

1. There is a special person who is around when I am in need.
2. There is a special person with whom I can share my joys and sorrows.
3. My family really tries to help me.
4. I get the emotional help and support I need from my family.
5. I have a special person who is a real source of comfort to me.
6. My friends really try to help me.
7. I can count on my friends when things go wrong.
8. I can talk about my problems with my family.
9. I have friends with whom I can share my joys and sorrows.
10. There is a special person in my life who cares about my feelings.
11. My family is willing to help me make decisions.
12. I can talk about my problems with my friends.

Appendix C: Five Facet Mindfulness Questionnaire

 Please rate each of the following statements using the scale provided. Choose the option that best describes your own opinion or what is generally true for you.
 Scale Points: Never or very rarely true, Somewhat true, Moderately true, More often than not true, Very often or always true.

1. When I'm walking, I deliberately notice the sensations of my body moving.
2. I'm good at finding the words to describe my feelings.
3. I criticize myself for having irrational or inappropriate emotions.
4. I perceive my feelings and emotions without having to react to them.
5. When I do things, my mind wanders off and I'm easily distracted.
6. When I take a shower or a bath, I stay alert to the sensations of water on my body.
7. I can easily put my beliefs, opinions, and expectations into words.
8. I don't pay attention to what I'm doing because I'm daydreaming, worrying, or otherwise distracted.
9. I watch my feelings without getting lost in them.
10. I tell myself that I shouldn't be feeling the way I'm feeling.
11. I notice how foods and drinks affect my thoughts, bodily sensations, and emotions.
12. It's hard for me to find the words to describe what I'm thinking.
13. I am easily distracted.
14. I believe some of my thoughts are abnormal or bad and I shouldn't think that way.
15. I pay attention to sensations, such as the wind in my hair or sun on my face.
16. I have trouble thinking of the right words to express how I feel about things.
17. I make judgments about whether my thoughts are good or bad.
18. I find it difficult to stay focused on what's happening in the present.
19. When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it.
20. I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.
21. In difficult situations, I can pause without immediately reacting.
22. When I have a sensation in my body, it's hard for me to describe it because I can't find the right words.
23. It seems I am "running on automatic" without much awareness of what I'm doing.
24. When I have distressing thoughts or images, I feel calm soon after.
25. I tell myself I shouldn't be thinking the way I'm thinking.
26. I notice the smells and aromas of things.
27. Even when I'm feeling terribly upset, I can find a way to put it into words.
28. I rush through activities without being really attentive to them.
29. When I have distressing thoughts or images, I am able just to notice them without reacting.
30. I think some of my emotions are bad or inappropriate and I shouldn't feel them.
31. I notice visual elements in art or nature, such as colors, shapes, textures, or patterns of light and shadow.
32. My natural tendency is to put my experiences into words.
33. When I have distressing thoughts or images, I just notice them and let them go.
34. I do jobs or tasks automatically, without being aware of what I'm doing.

35. When I have distressing thoughts or images, I judge myself as good or bad, depending what the thought/image is about.
36. I pay attention to how my emotions affect my thoughts and behavior.
37. I can usually describe how I feel at the moment in considerable detail.
38. I find myself doing things without paying attention.
39. I disapprove of myself when I have irrational ideas.

Appendix D: Interpersonal Mindfulness in Parenting Scale

The following questions ask about you and your child. Please read the instructions carefully before you begin.

Please answer the following questions as they relate to your experience with your most recent child, regardless of whether or not you have other children. If your child is 2 months old or younger, please answer questions as they relate to your current experience. If your child is older than 2 months, please recall as best you can your experiences in the first 1-2 months of your child's life, and answer questions with that time range in mind.

The following statements describe different ways that parents interact with their children on a daily basis. Please tell me whether you think the statement is "Never True," "Rarely True," "Sometimes True," "Often True," or "Always True" for you. Remember, there are no right or wrong answers and please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each statement separately from every other statement.

Scale points: Never True, Rarely True, Sometimes True, Often True, Always True.

1. I find myself distracted when I am with my baby because I am busy doing or thinking about something else at the same time.
2. When I'm upset with my baby, I notice how I am feeling before I take action.
3. I notice how changes in my baby's mood affect my mood.
4. I often react negatively when my child fusses or cries.
5. I am aware of how my moods affect the way I treat my baby.
6. I rush through activities with my baby without being really attentive to him/her.
7. I have difficulty accepting my baby's growing independence.
8. How I am feeling tends to affect my parenting decisions, but I do not realize it until later.
9. It is hard for me tell what my baby is feeling.
10. When I am spending time with my baby, my mind wanders off and I am easily distracted.
11. When my baby cries or fusses, it makes me so upset I say or do things I later regret.
12. I tend to be hard on myself when I make mistakes as a parent.
13. When my baby does something that upsets me, I try to keep my emotions in balance.
14. When times are really difficult with my baby, I tend to blame myself.
15. When things I try to do as a parent do not work out, I can accept them and move on.
16. I am often so busy thinking about other things that I realize I am not really paying attention to my baby.
17. When I do something as a parent that I regret, I try to give myself a break.
18. In difficult situations with my baby, I pause without immediately reacting.
19. It is easy for me to tell when my baby is uncomfortable or needs something.
20. I tend to criticize myself for not being the kind of parent I want to be.
21. I pay close attention to my baby when we are spending time together.
22. I am kind to my baby when he/she is upset.

23. When I am having a hard time with parenting, I feel like other parents must have an easier time of it.
24. When my baby is going through a difficult time, I try to give him/her the nurturing and caring he/she needs.
25. When something my baby does upsets me, I get carried away with my feelings.
26. I can tell what my baby is feeling even if he/she is quiet.
27. I try to be understanding and patient with my baby when he/she is having a hard time.

Appendix E: Edinburgh Postnatal Depression Scale

      As a mother, we would like to know about your feelings. Please read the following instructions carefully before you begin

      Please answer the following questions as they relate to your experience with your most recent child, regardless of whether or not you have other children. If your child is 2 months old or younger, please answer questions as they relate to your current experience. If your child is older than 2 months, please recall as best you can your experiences in the first 1-2 months of your child's life, and answer questions with that time range in mind.

      Please check the answer that comes closest to how you have felt in the past 7 days (or if your child is older than 2 months, in a typical week during their first 2 months of life), not just how you feel today.

      For questions, see below:

In the past 7 days:

1. I have been able to laugh and see the funny side of things
   - ☐ As much as I always could
   - ☐ Not quite so much now
   - ☐ Definitely not so much now
   - ☐ Not at all

2. I have looked forward with enjoyment to things
   - ☐ As much as I ever did
   - ☐ Rather less than I used to
   - ☐ Definitely less than I used to
   - ☐ Hardly at all

*3. I have blamed myself unnecessarily when things went wrong
   - ☐ Yes, most of the time
   - ☐ Yes, some of the time
   - ☐ Not very often
   - ☐ No, never

4. I have been anxious or worried for no good reason
   - ☐ No, not at all
   - ☐ Hardly ever
   - ☐ Yes, sometimes
   - ☐ Yes, very often

*5 I have felt scared or panicky for no very good reason
   - ☐ Yes, quite a lot
   - ☐ Yes, sometimes
   - ☐ No, not much
   - ☐ No, not at all

*6. Things have been getting on top of me
   - ☐ Yes, most of the time I haven't been able to cope at all
   - ☐ Yes, sometimes I haven't been coping as well as usual
   - ☐ No, most of the time I have coped quite well
   - ☐ No, I have been coping as well as ever

*7 I have been so unhappy that I have had difficulty sleeping
   - ☐ Yes, most of the time
   - ☐ Yes, sometimes
   - ☐ Not very often
   - ☐ No, not at all

*8 I have felt sad or miserable
   - ☐ Yes, most of the time
   - ☐ Yes, quite often
   - ☐ Not very often
   - ☐ No, not at all

*9 I have been so unhappy that I have been crying
   - ☐ Yes, most of the time
   - ☐ Yes, quite often
   - ☐ Only occasionally
   - ☐ No, never

*10 The thought of harming myself has occurred to me
   - ☐ Yes, quite often
   - ☐ Sometimes
   - ☐ Hardly ever
   - ☐ Never

Appendix F: Breastfeeding Experiences Questionnaire

Breastfeeding Experiences Questionnaire

Present tense questions are for people who are currently breastfeeding, past tense questions are for people who indicated that they previously breastfed but are not currently.

This questionnaire asks about your experiences related to breastfeeding.

Please answer as many of the following questions as possible, as honestly as possible. The more information we receive from you, the greater our ability to conduct valuable and high-quality research.

Some questions ask for numerical answers, in which case, please write your best estimate of the exact number. Some questions ask that you select one of several options; it may be difficult to select one, but please try to select the most accurate and honest option you can. Some questions ask that you provide written information, or include space to provide further comments; please write any information you feel is relevant. Some questions may not apply to you, in which case please select N/A.

You may feel uncomfortable answering some questions, in which case you may choose not to answer the question. Please bear in mind, however, that all of your responses are confidential and will be treated with great care.

The following questions are to establish basic information about your child(ren).

Do you have a child or children?

                                                                    Yes   No

      If answer is no, skip this questionnaire.

If yes, how many children do you have?

How old are your children?

Are you currently breastfeeding a child?

                                                                    Yes   No

      If yes, please answer the following questions as they relate to your current breastfeeding experience, regardless of whether or not you have breastfed other children previously. If you have been breastfeeding for 2 months or less, please answer questions as they relate to your current experience. If you have been breastfeeding for 2 months or more, please recall as best you can your experiences in the first 1-2 months breastfeeding your child, and answer questions with that time range in mind.

      What is your child's age in weeks or months?

Have you breastfed, or tried to breastfeed, a child before?

Yes   No

If yes, please answer the following questions as they relate to your most recent breastfeeding experience, regardless of whether or not you have breastfed other children previously. Please recall as best you can your experiences in the first 1-2 months breastfeeding your child, and answer questions with that time range in mind.

If answer is no, skip this questionnaire.

How long did you breastfeed? Please list the lengths of all previous breastfeeding experiences.

How long ago did you stop breastfeeding your most recent child?

The following questions are about your experiences regarding breastfeeding difficulty and success. The questions focus on two time ranges: initiating breastfeeding, and the time since then as you've maintained breastfeeding.

How long after birth did you initiate breastfeeding? Please estimate the number of minutes or hours:

How difficult was it for you to initiate breastfeeding?

1	2	3	4	5
Very difficult	Somewhat difficult	Neutral	Somewhat easy	Very easy

How successful do you feel your breastfeeding initiation was?

1	2	3	4	5
Very unsuccessful	Somewhat unsuccessful	Neutral	Somewhat successful	Very successful

Please comment on your experiences initiating breastfeeding:

How difficult has maintaining breastfeeding been for you? / How difficult was maintaining breastfeeding for you?

1	2	3	4	5
Very difficult	Somewhat difficult	Neutral	Somewhat easy	Very easy

How successful do you feel you've been at maintaining breastfeeding? / How successful do you feel you were at maintaining breastfeeding?

1	2	3	4	5
Very unsuccessful	Somewhat unsuccessful	Neutral	Somewhat successful	Very successful

Please comment on your experiences maintaining breastfeeding:

The following questions are about you and your child's daily breastfeeding habits.

When did your breast milk (rather than colostrum) first come in?

On average, how many times a day do / did you breastfeed your child?

On average, how long is / was each breastfeeding session? Please estimate the number of minutes:

On average, how many times a day does / did your child drink breast milk from a bottle?

On average, how many times a day do / did you pump milk?

On average, what volume of milk do / did you pump per day?

How would you rate your child's behavior while nursing?

1	2	3	4	5
Very relaxed	Somewhat relaxed	Neutral	Somewhat active	Active

Further comments:

The following questions are about supplements to your breast milk your child may receive, including the type and quantity of supplements, as well as pacifier use.

Does / did your child receive any supplements to breast milk (for example, formula or any other liquids)? Please select one:

Yes　　No

If yes:

> On average, how many times per day does / did your child receive supplements to breast milk?

> How old was your child when you began supplementing breast milk?

> Please write what kind of supplementation your child receives / received:

> Please write your reasons, if any, for supplementing:

Does / did your child use a pacifier regularly? Please select one:

Yes　　No

Further comments:

The following questions are about your night feeding habits, your sleep habits, and the quality of you and your child's sleep.

On average, how many times do / did you breastfeed your child during the night?

On average, how many times do / did you wake up in the night?

On average, how many hours of sleep do / did you get each night?

On average, what is / was the quality of your sleep each night?

1	2	3	4	5
Very poor	Poor	Fair	Good	Very good

On average, what is / was the quality of your child's sleep each night?

1	2	3	4	5
Very poor	Somewhat poor	Neutral	Somewhat good	Very good

Does / did your child sleep with you?

1	2	3	4	5
Never	Rarely	Sometimes	Usually	Always

Further comments:

The following questions are about your goals for breastfeeding, both in general and in terms of establishing a routine, as well as your success in attaining your goals.

How long do / did you plan on breastfeeding your child?

1	2	3	4	5	6
Less than one month	One to three months	Three to six months	Six months to one year	One to two years	More than two years

How important is breastfeeding to you?

1	2	3	4	5
Very unimportant	Somewhat unimportant	Neutral	Somewhat important	Very important

What are (or were) your goals, if any, for successful breastfeeding (for example, breastfeeding exclusively, breastfeeding for a certain length of time, breastfeeding with ease, or establishing a breastfeeding routine)?

How successful do / did you feel you have been in attaining your breastfeeding goals?

1	2	3	4	5
Very unsuccessful	Somewhat unsuccessful	Neutral	Somewhat successful	Very successful

Further comments:

The following questions are about social, professional, and informal support for breastfeeding.

How supportive of breastfeeding is / was your partner?

1	2	3	4	5
Very unsupportive	Somewhat unsupportive	Neutral	Somewhat supportive	Very supportive

How supportive of breastfeeding is / was your extended family (for example, mother, sisters, aunts, or other close relatives)?

1	2	3	4	5
Very unsupportive	Somewhat unsupportive	Neutral	Somewhat supportive	Very supportive

How supportive of breastfeeding are / were your close friends?

1	2	3	4	5
Very unsupportive	Somewhat unsupportive	Neutral	Somewhat supportive	Very supportive

Do / did you feel that you have / had adequate social support to successfully breastfeed?

1	2	3	4	5
Not at all	Very little	Somewhat	Very much	Extremely

Do / did you feel that you have / had adequate resources to successfully breastfeed (for example, access to lactation consultants, breast pumps, or support groups)?

1	2	3	4	5
Not at all	Very little	Somewhat	Very much	Extremely

Do / did you feel that you have / had adequate information and knowledge to successfully breastfeed?

1	2	3	4	5
Not at all	Very little	Somewhat	Very much	Extremely

Have / did you received / receive professional or informal support to initiate or maintain breastfeeding (for example, lactation consultants or breastfeeding groups)? Please select one:

Yes   No

If the answer to the previous question is yes, when did you first receive professional or informal support?

Please describe the professional or informal support you have received:

The following checklist is intended to assess problems or difficulties you may have encountered that would affect breastfeeding. Please check any and all items that have applied to you during breastfeeding:

- premature child or other birth complications
- unable to start breastfeeding until more than 24 hours after birth
- child disinterest in breastfeeding
- child only wants to nurse on one breast
- problems with latch
- difficulty with milk supply
- child not gaining weight adequately
- child illness that interfered with breastfeeding
- illness that made breastfeeding difficult or painful
- illness related to breastfeeding (e.g., mastitis)
- cracked or bleeding nipples
- clogged ducts or milk doesn't flow properly
- inverted or flat nipples
- difficulty pumping
- lack of or inadequate support for breastfeeding
- work or life schedule interferes with breastfeeding
- other (please elaborate):

Further comments:

The following items are intended to assess your child's behavior. Again, if your child is older than 2 months old, please think back to your experiences in your child's first 1-2 months of life and complete this scale with that age in mind.

For each, a 1-7 scale is used:

1	2	3	4	5	6	7
Never	Very rarely	Less than half the time	About half the time	More than half the time	Almost always	Always

Feeding:
      During feeding, how often did the baby:
            lie or sit quietly?
            squirm or kick?
            wave arms?

Sleeping:
      During sleep, how often did the baby:
            toss about in the crib?
            move from the middle to the end of the crib?
            sleep in one position only?
      Before falling asleep at night during the last week, how often did the baby:
            show no fussing or crying?
      After sleeping, how often did the baby:
            fuss or cry immediately?
            play quietly in the crib?
            cry if someone doesn't come within a few minutes?
      How often did the baby:
            seem angry (crying and fussing) when you left her/him in the crib?
            seem contented when left in the crib?
            cry or fuss before going to sleep for naps?

Bathing and Dressing:
      When being dressed or undressed during the last week, how often did the baby:
            wave his/her arms and kick?
            squirm and/or try to roll away?
      When put into the bath water, how often did the baby:
            splash or kick?
            turn body and/or squirm?
      When face was washed, how often did the baby:
            fuss or cry?
      When hair was washed, how often did the baby:
            fuss or cry?

Play:

       When something the baby was playing with had to be removed, how often did s/he:

              cry or show distress for a time?

              seem not bothered?

Daily Activities:

       When placed on his/her back, how often did the baby:

              wave arms and kick?

              squirm and/or turn body?

              fuss or protest?

       When placed in an infant seat or car seat, how often did the baby:

              wave arms and kick?

              squirm and turn body?

              lie or sit quietly?

              show distress at first; then quiet down?

       How often during the last week did the baby:

              protest being placed in a confining place (infant seat, play pen, car seat, etc.)?

       When the baby wanted something, how often did s/he:

              become upset when s/he could not get what s/he wanted?

              have tantrums (crying, screaming, face red, etc.) when s/he did not get what s/he wanted?

References

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. Assessment, 13(1), 27-45.

Barclay, L., Everitt, L., Rogan, F., Schmied, V., & Wyllie, A. (1997). Becoming a mother—an analysis of women's experience of early motherhood. Journal of Advanced nursing, 25(4), 719-728.

Barnhoorn, J. S., Haasnoot, E., Bocanegra, B. R., & van Steenbergen, H. (2014). QRTEngine: An easy solution for running online reaction time experiments using Qualtrics. Behavior research methods, 1-12.

Bulmer, M. G. (1979). *Principles of Statistics*. Dover.

Casteron, R. (2014). The Return of the Critical Period: Old-aged Prodigies and Teaching Old Dogs New Tricks. Neuro. King's College London Neuroscience Society. Retrieved from http://kclneurosoc.org/neuroscience-society-online-journal/the-return-of-the-critical-period-old-aged-prodigies-and-teaching-old-dogs-new-tricks/

Centers for Disease Control and Prevention. (2014). Breastfeeding Report Card: United States: 2014. Retrieved from http://www.cdc.gov/breastfeeding/data/reportcard.htm

Chung, M., Raman, G., Chew, P., Magula, N., Trikalinos, T., & Lau, J. (2007). Breastfeeding and maternal and infant health outcomes in developed countries. Evid Technol Asses (Full Rep), 153, 1-186.

Colen, C. G., & Ramey, D. M. (2014). Is breast truly best? Estimating the effects of breastfeeding on long-term child health and wellbeing in the United States using sibling comparisons. Social Science & Medicine, 109, 55-65.

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. The British journal of psychiatry, 150(6), 782-786.

Dall, S. R., & Boyd, I. L. (2004). Evolution of mammals: lactation helps mothers to cope with unreliable food supplies. Proceedings of the Royal Society of London B: Biological Sciences, 271(1552), 2049-2057.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). CVLT, California Verbal Learning Test: Adult Version: Manual. Psychological Corporation.

Desai, N. S., Cudmore, R. H., Nelson, S. B., & Turrigiano, G. G. (2002). Critical periods for experience-dependent synaptic scaling in visual cortex. Nature neuroscience, 5(8), 783-789.

Duncan, L. G. (2007). Assessment of mindful parenting among parents of early adolescents: Development and validation of the Interpersonal Mindfulness in Parenting scale (Doctoral dissertation, The Pennsylvania State University).

Duncan, L. G., & Bardacke, N. (2010). Mindfulness-based childbirth and parenting education: Promoting family mindfulness during the perinatal period.Journal of Child and Family Studies, 19(2), 190-202.

Evenhouse, E., & Reilly, S. (2005). Improved estimates of the benefits of breastfeeding using sibling comparisons to reduce selection bias. Health services research, 40(6p1), 1781-1802.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. Journal of cognitive neuroscience, 14(3), 340-347.

Field, T. (2010). Postpartum depression effects on early interactions, parenting, and safety practices: A review. Infant Behavior and Development, 33(1), 1-6.

Fiser, J., & Aslin, R. N. (2002). Statistical learning of higher-order temporal structure from visual shape sequences. Journal of Experimental Psychology: Learning, Memory, and Cognition, 28(3), 458.

Flacking, R., Nyqvist, K. H., & Ewald, U. (2007). Effects of socioeconomic status on breastfeeding duration in mothers of preterm and term infants. The European Journal of Public Health, 17(6), 579-584.

Galván, A. (2010). Neural plasticity of development and learning. Human brain mapping, 31(6), 879-890.

Gross, S. M., Resnik, A. K., Nanda, J. P., Cross-Barnet, C., Augustyn, M., Kelly, L., & Paige, D. M. (2011). Early postpartum: A critical period in setting the path for breastfeeding success. Breastfeeding Medicine, 6(6), 407-412.

Guan, J. S., Haggarty, S. J., Giacometti, E., Dannenberg, J. H., Joseph, N., Gao, J., ... & Tsai, L. H. (2009). HDAC2 negatively regulates memory formation and synaptic plasticity. Nature, 459(7243), 55-60.

Henry, J. D., & Crawford, J. R. (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(2), 227-239.

Hensch T.K, Young A, Gervain J, Vines B.W, Chen L.M, Seo R.J, Werker J.F. (2013). Valproate reopens critical period learning of absolute pitch. Frontiers in Systems Neuroscience 7 (102)

Hensch, T. K. (2004). Critical period regulation. Annu. Rev. Neurosci., 27, 549-579.

Horwood, L. J., & Fergusson, D. M. (1998). Breastfeeding and later cognitive and academic outcomes. Pediatrics, 101(1), e9-e9.

Hughes, A., Williams, M., Bardacke, N., Duncan, L. G., Dimidjian, S., & Goodman, S. H. (2009). Mindfulness approaches to childbirth and parenting.British journal of midwifery, 17(10), 630.

Hurlemann, R., Patin, A., Onur, O. A., Cohen, M. X., Baumgartner, T., Metzler, S., ... & Kendrick, K. M. (2010). Oxytocin enhances amygdala-dependent, socially reinforced learning and emotional empathy in humans. The Journal of Neuroscience, 30(14), 4999-5007.

Kramer, M. S., Aboud, F., Mironova, E., Vanilovich, I., Platt, R. W., Matush, L., & Shapiro, S. (2008). Breastfeeding and child cognitive development: new evidence from a large randomized trial. Archives of general psychiatry, 65(5), 578-584.

Langer, E. J. (2000). Mindful learning. Current directions in psychological science, 9(6), 220-223.

Larsen, C. M., & Grattan, D. R. (2012). Prolactin, neurogenesis, and maternal behaviors. Brain, behavior, and immunity, 26(2), 201-209.

Léon-Carva, N., Lutter, C., Ross, J., & Martin, L. (2002). Quantifying the benefits of breastfeeding: a summary of the evidence. Washington DC: PAHO.

Levi, D. M. (2005). Perceptual learning in adults with amblyopia: a reevaluation of critical periods in human vision. Developmental psychobiology, 46(3), 222-232.

Miller, C. A., Campbell, S. L., & Sweatt, J. D. (2008). DNA methylation and histone acetylation work in concert to regulate memory formation and synaptic plasticity. Neurobiology of learning and memory, 89(4), 599-603.

Mitchell, D. E. (2004). The effects of early forms of visual deprivation on perception. The visual neurosciences, 1, 189-204.

Neville, H., & Bavelier, D. (2002). Human brain plasticity: evidence from sensory deprivation and altered language experience. *Progress in brain research*, *138*, 177-188.

Pascual-Leone, A., Amedi, A., Fregni, F., & Merabet, L. B. (2005). The plastic human brain cortex. Annu. Rev. Neurosci., 28, 377-401.

Pawluski, J. L., Walker, S. K., & Galea, L. A. (2006). Reproductive experience differentially affects spatial reference and working memory performance in the mother. Hormones and behavior, 49(2), 143-149.

Pletzer, B., Kronbichler, M., Aichhorn, M., Bergmann, J., Ladurner, G., & Kerschbaum, H. H. (2010). Menstrual cycle and hormonal contraceptive use modulate human brain structure. Brain research, 1348, 55-62.

Pletzer, B. A., & Kerschbaum, H. H. (2014). 50 years of hormonal contraception—time to find out, what it does to our brain. Frontiers in neuroscience, 8.

Pond, C. M. (1977). The significance of lactation in the evolution of mammals.Evolution, 177-199.

Raj, V. K., & Plichta, S. B. (1998). The role of social support in breastfeeding promotion: a literature review. Journal of Human Lactation, 14(1), 41-45.

Raz, N., Lindenberger, U., Rodrigue, K. M., Kennedy, K. M., Head, D., Williamson, A., ... & Acker, J. D. (2005). Regional brain changes in aging healthy adults: general trends, individual differences and modifiers. Cerebral cortex, 15(11), 1676-1689.

Rice, D., & Barone Jr, S. (2000). Critical periods of vulnerability for the developing nervous system: evidence from humans and animal models.Environmental health perspectives, 108(Suppl 3), 511.

Rivas, M., & Naranjo, J. R. (2007). Thyroid hormones, learning and memory.Genes, Brain and Behavior, 6(s1), 40-44.

Rothbart, M. K. (1981). Measurement of temperament in infancy.Child Development, 569-578.

Salomon, G., & Globerson, T. (1987). Skill may not be enough: The role of mindfulness in learning and transfer. International Journal of Educational Research, 11(6), 623-637.

Salthouse, T. A. (2009). When does age-related cognitive decline begin?.Neurobiology of aging, 30(4), 507-514.

Scheiner, S. M. (1993). Genetics and evolution of phenotypic plasticity. Annual review of ecology and systematics, 35-68.

Schmidt, M. (1996). Rey auditory verbal learning test: A handbook. Los Angeles: Western Psychological Services.

Shingo, T., Gregg, C., Enwere, E., Fujikawa, H., Hassam, R., Geary, C., & Weiss, S. (2003). Pregnancy-stimulated neurogenesis in the adult female forebrain mediated by prolactin. Science, 299(5603), 117-120.

Spreen, O., & Strauss, E. (1991). A compedium of neuropsychological tests. A compedium of neuropsychological tests.

Sowell, E. R., Peterson, B. S., Thompson, P. M., Welcome, S. E., Henkenius, A. L., & Toga, A. W. (2003). Mapping cortical change across the human life span. Nature neuroscience, 6(3), 309-315.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of experimental psychology, 18(6), 643.

Tomizawa, K., Iga, N., Lu, Y. F., Moriwaki, A., Matsushita, M., Li, S. T., ... & Matsui, H. (2003). Oxytocin improves long-lasting spatial memory during motherhood through MAP kinase cascade. Nature neuroscience, 6(4), 384-390.

Torner, L., Karg, S., Blume, A., Kandasamy, M., Kuhn, H. G., Winkler, J., ... & Neumann, I. D. (2009). Prolactin prevents chronic stress-induced decrease of adult hippocampal neurogenesis and promotes neuronal fate. The Journal of Neuroscience, 29(6), 1826-1833.

Tucker-Drob, E. M. (2011). Global and domain-specific changes in cognition throughout adulthood. Developmental psychology, 47(2), 331.

U.S. Department of Health and Human Services. (2011). The Surgeon General's Call to Action to Support Breastfeeding. Washington, DC: U.S. Department of Health and Human Services, Office of the Surgeon General.

UNICEF. (2014, August 4). Breastfeeding. Retrieved from http://www.unicef.org/nutrition/index_24824.html

Uttl, B., Graf, P., & Richter, L. K. (2002). Verbal Paired Associates tests limits on validity and reliability. Archives of Clinical Neuropsychology, 17(6), 567-581.

Vecsey, C. G., Hawk, J. D., Lattal, K. M., Stein, J. M., Fabian, S. A., Attner, M. A., ... & Wood, M. A. (2007). Histone deacetylase inhibitors enhance memory and synaptic plasticity via CREB: CBP-dependent transcriptional activation. The Journal of Neuroscience, 27(23), 6128-6140.

Volk, A. A. (2009). Human breastfeeding is not automatic: Why that's so and what it means for human evolution. Journal of Social, Evolutionary, and Cultural Psychology, 3(4), 305.

Werker, J. F., & Hensch, T. K. (2015). Critical periods in speech perception: New directions. Annual review of psychology, 66, 173-196.

Zimet, G. D., Dahlem, N. W., Zimet, S. G., & Farley, G. K. (1988). The multidimensional scale of perceived social support. Journal of personality assessment, 52(1), 30-41.