

# Understanding the maternal brain in the context of the mental load of motherhood

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Bridget L. Callaghan<sup>1</sup>, Clare McCormack<sup>2</sup>, Pilyoung Kim<sup>3,4</sup> & Jodi L. Pawluski<sup>1</sup>  

The transition to motherhood is a time when nearly all aspects of a female's existence are modified—from her biological processes to her social role. In recent years we have substantially increased our interest in this developmental period of a woman's life (matrescence), with a focus on the neurobiology of motherhood and maternal mental health. However, one potential set of factors that is likely driving maternal vulnerability to mental illness is the growing burden of the mental load of motherhood. This mental load is part and parcel of bearing and parenting a young child, but its impact on mothers is undeniable. Here, we review how this mental load may impact the maternal brain and outline how it may be especially pronounced in the modern day, as mothers are dealing with additional pressures such as poverty, single parenthood, lack of institutional policies for parents, and the rise of intensive mothering ideologies. We contextualize the mental load of motherhood within the framework of maternal brain plasticity, and we urge future researchers to consider this framework when studying maternal mental health more broadly. There is an urgent need to approach research with an understanding of what the majority of mothers experience to make advances in supporting a healthy transition to motherhood.

In recent years we have begun to acknowledge the importance of the transition to motherhood on the mother herself, often using the term 'matrescence'<sup>1</sup> for this additional developmental phase of life that 80% of women will go through. Matrescence is perhaps the only time in adult life when nearly all aspects of a female's existence are modified—from her biological processes to her social role. These changes that accompany motherhood often transcend sociodemographic boundaries, and are more impactful when there are limited resources for the support of childrearing and domestic labor<sup>2</sup>, in addition to the already enduring and persistent effects of existing issues such as isolation, poverty, racism and sexism.

Over the past decade, there has been increasing interest in the neurobiology of motherhood and how neurobiological changes may be related to maternal mental health. Although much research has focused

on either the biological changes (for example, neuroplasticity<sup>3</sup>) or social changes (for example, lack of social support<sup>4</sup>) that contribute to mental illness in mothers, far fewer studies have focused on how social factors interact with the biological changes inherent to motherhood to amplify the risk of poor maternal outcomes. Such questions sit at the frontier of research targeted at understanding the complex interacting web of features that influence a woman's mental health as she becomes a mother. These factors are made ever more complex in that they change across time, culture, race and socioeconomic strata.

One of the most scientifically understudied, yet much discussed, of the features impacting maternal health over the past few years is the mental load of motherhood. The general concept of mental load originated in the field of psychology during the 1950s<sup>5</sup>, and in 1984 it was first defined in the context of motherhood as *la charge*

<sup>1</sup>Department of Psychology, The University of California, Los Angeles, CA, USA. <sup>2</sup>Department of Child and Adolescent Psychiatry, NYU Grossman School of Medicine, New York, NY, USA. <sup>3</sup>Department of Psychology, University of Denver, Denver, CO, USA. <sup>4</sup>Department of Psychology, Ewha Woman's University Seoul, Seoul, South Korea. <sup>5</sup>Univ Rennes, Inserm, EHESP, Irset (Institut de Recherche en Santé, Environnement et Travail), UMR\_S 1085, Rennes, France. ✉e-mail: [j.pawluski@gmail.com](mailto:j.pawluski@gmail.com)

*mentale*, ‘the mental burden of the double day fraught with constant tension, adjusting different, but not autonomous, times and spaces, which interfere in a multiplicative way’<sup>6</sup>. Over the years, terms such as ‘maternal thinking’<sup>7</sup>, ‘emotion work’<sup>8</sup>, and ‘affective labor’<sup>9</sup> have been used to express and conceptualize aspects of the invisible labor of mothering. Today, the ‘mental load of motherhood’ is defined as a combination of the cognitive labor of family life—the thinking, planning, scheduling and organizing of family members—and the emotional labor associated with this work, including the feelings of caring and being responsible for family members<sup>10</sup> (note that affective labor—labor practices that involve ‘the production and manipulation of affects and requires human contact and proximity’<sup>9</sup>—may be more appropriate here). Simply put, ‘the mental load involves keeping track of the work that needs to be done while simultaneously managing the past, present, and future emotions of each family member individually and the family as a whole’<sup>10</sup>.

Decades of feminist critique have highlighted the importance of the mental load of motherhood, particularly in the context of persistent gender inequities in patriarchal society<sup>11</sup>, yet how this mental load interacts with maternal brain plasticity and mental health remains a substantial knowledge gap. The aim of this Review is, therefore, to introduce the concept of the mental load of motherhood as a framework to understand the neurobiology of matrescence, particularly with regards to future research on maternal mental health.

## The mental load of motherhood

Parenting involves a demanding array of physical and mental tasks. Although the physical tasks are often visible, such as picking children up from baseball practice or doing the dishes, the mental tasks are less so (for example, anticipating the need for baseball pickup, planning the pickup, reminding, and monitoring the outcome). In heterosexual couples, both forms of labor are still shouldered primarily by women, particularly after the transition to parenthood. With regard to physical labor, mothers take on 2 hours of additional work per day, whereas fathers only increase their daily workload by 40 minutes<sup>12</sup>. On days when fathers are not engaged in paid work outside the home, they participate in leisure activities 47% of the time that mothers are engaged in childcare and 35% of the time that mothers are engaged in housework<sup>13</sup>. By contrast, on days where mothers are not engaged in paid work outside the home, the percent of time they participate in leisure activities while fathers are caregiving or doing housework is just 16% and 19%, respectively<sup>13</sup>.

Although these data on physical load are striking, what is more glaring are the gender disparities in the mental load of parenthood. If we look at the research on cognitive labor alone, we see that, although women perform more of the cognitive labor overall, they also specifically engage in more of the anticipating and monitoring stages of that cognitive labor than men<sup>14</sup>. In addition, the majority of cognitive labor associated with family life also includes emotional labor, as cognitive tasks involve caring for a loved one, which is emotional, regardless of the task<sup>10</sup>. Thus, the mental load of parenthood encompasses the constant remembering, thinking about, and doing of the cognitive and emotional work of the family, which is predominantly done by mothers.

## The maternal brain

Mothers will often feel that their brain is not functioning as it should, citing ‘mommy brain’ as the reason for these feelings. ‘Mommy brain’ often refers to a feeling of forgetfulness and has been associated with the isolation and mental health issues that many mothers face<sup>15,16</sup>. However, this term, in itself, needs a rebrand, as the maternal brain has the capacity to function well during this time and it is probably the mental overload that mothers carry that impacts how their brain is functioning<sup>15,17</sup>. Generally, we may consider the mental load as a kind of ‘stress’, and the effect of stress has been a focus of research on the parental brain. Before outlining this research, it is important to review

the normative and healthy changes in the female brain during the transition to motherhood. This knowledge has resulted from years of research in animal models and, more recently, in humans<sup>18,19</sup> (for a review of brain changes in fathers and non-birthing parents, see ref. 20). In the following section, we will briefly summarize the key structural and functional brain changes in human mothers (Fig. 1).

## Maternal brain structural changes

Perhaps the most robust findings on the maternal brain relate to how the gray matter volumes of several brain areas change with pregnancy<sup>21</sup>. Research shows that from preconception to after birth, first-time mothers undergo extensive and highly consistent reductions of ~1% in regional gray matter volumes in brain areas that are important for aspects of motherhood (note that second-time mothers have not been studied). The more recent research shows that these reductions in volume may be more extensive in late pregnancy<sup>22</sup>. The brain areas most affected by pregnancy are those important for the ability to mentalize or cognitively infer the needs of others (theory of mind) and, thus, are critical for aspects of sensitive caregiving<sup>21,23</sup>. These brain changes are highly consistent, with 92% of mothers showing similar structural adaptations that persist for years after birth<sup>24</sup>.

We have proposed that this structural reorganization represents a ‘fine-tuning’ of the maternal brain to facilitate the transition to parenting<sup>25</sup>. In line with this idea, structural decreases in gray matter volume in the maternal brain are associated with increases in the quality of mother-to-infant bonding and the absence of hostility toward their newborn in the postpartum period<sup>21,24</sup>. Thus, structural brain changes across pregnancy are adaptive and important for mothering.

This fine-tuning interpretation of structural brain changes in mothers is consistent with the interpretations posed regarding structural brain reorganization during adolescence, another important developmental stage that has been the subject of far more extensive study. Specifically, structural brain changes seen in adolescence are numerous and are generally thought to represent a maturational process where brain networks are fine-tuned to support changing behavioral and cognitive skills<sup>26</sup>. Not only are the interpretations of structural brain changes in matrescence and adolescence similar, but new mothers and adolescent girls have nearly identical neuroanatomical modifications (for example, reductions in cortical thickness) compared to adult women who are not mothers<sup>27</sup>.

If we look in more detail at how the brain changes in structure after pregnancy, it is clear that the early postpartum months are a time of dynamic brain plasticity in mothers (as well as non-birthing parents<sup>20</sup>). Longitudinal studies in the early postpartum period have observed transient increases in gray matter volume in cortical and subcortical areas in the maternal and paternal brain that are related to greater feelings of parental efficacy during this time<sup>28</sup>.

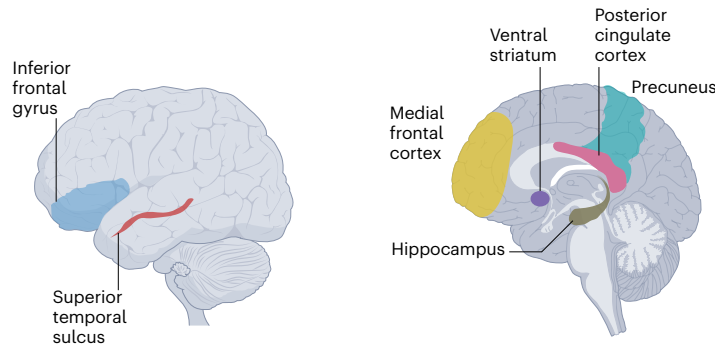
## Maternal brain functional changes

The effect of pregnancy and parenthood on the brain also involves functional changes that are driven by a host of neurophysiological mechanisms<sup>19</sup>. Several neural networks are strongly engaged and activated during a mother’s response to cues from an infant, even in pregnancy<sup>18,25</sup>. These networks include the brain’s reward system (which plays a crucial role in maternal motivation, involving brain areas such as the nucleus accumbens<sup>29</sup>), the brain’s empathy and theory of mind networks (which are essential in understanding the needs of an infant, involving brain areas such as the insula and prefrontal cortical areas<sup>30,31</sup>) and the brain’s networks for processing salience and emotion regulation in mothers in response to their infants (involving areas such as the amygdala and anterior cingulate gyrus<sup>32–34</sup>). Several longitudinal studies have also observed alterations in brain activity in key emotion-processing regions across the postpartum period<sup>31,35</sup>. These dynamic changes are associated with the duration of the maternal experience

**a****Pregnancy****Structural changes**

Minimal structural imaging has been performed during pregnancy, but research shows that pregnancy is associated with reductions in gray matter in a number of brain areas.

Critically, this decrease in brain volume is associated with increased mother–infant bonding and increased neural reactivity to the infant.

**Functional changes**

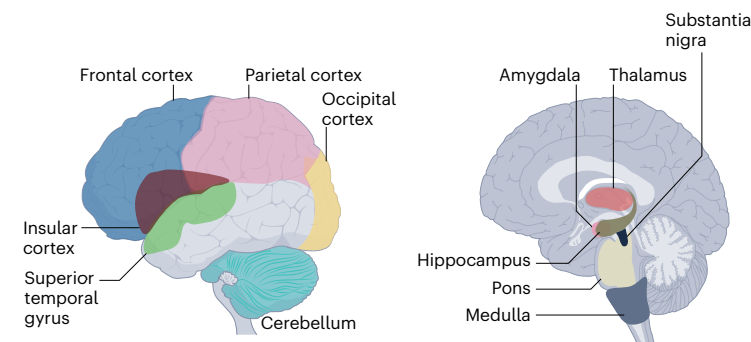
Minimal functional imaging or recordings have been performed during pregnancy, but tasks using electroencephalography (EEG) show differential EEG responses across a number of cortical regions in pregnancy.

Prenatal to postnatal increases in brain responses to infant faces predict stronger mother–infant bonding.

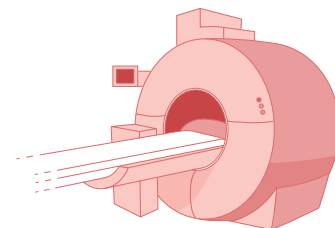
**b****Postpartum****Structural changes**

In the early postpartum period there are widespread transient increases in gray matter in the maternal brain.

Critically, some of these increases in gray matter are associated with positive maternal perceptions of the baby.

**Functional changes**

In the early postpartum period there are greater brain responses to cues of the infant in mothers within reward, empathy, salience and emotion-processing networks, with some of these changes being associated with secure bonding and sensitivity towards the infant.



**Fig. 1 | Maternal brain changes associated with pregnancy and parenting.** **a,b**, Summary of key structural and functional changes reported in pregnant women (**a**) and new mothers in the early postpartum period (**b**). Pregnancy is largely characterized by structural changes that involve gray matter and total brain volume reductions in the cortical and subcortical areas. Functional changes in pregnancy are limited, but a growing body of research shows that pregnancy alters brain activity in a number of cortical regions and that this brain activity can

be related to postpartum mother–infant bonding. In contrast, brain changes in the postpartum period are widespread in the cortex, midbrain and brainstem, and involve volume and gray matter expansion. Functional changes postpartum occur in a number of brain areas in response to infant cues (photographs, cry sounds and so on) as well as at rest. During pregnancy and postpartum, brain changes are associated with a mother's caregiving behavior and mother–infant bonding, suggesting, in both cases, that these brain changes are adaptive.

and possibly reflect adaptations to the continuous development of the infant.

It should be noted that pregnancy-related neuroplasticity alone is not sufficient to induce parenting behavior. Ongoing exposure to offspring and experience of caregiving is necessary for the maintenance of these behaviors. In rodent models, which are vital to understanding the maternal brain, mother rats who are separated from their offspring at birth show a diminished display of caregiving behaviors<sup>36</sup>. Moreover, virgin adult female rats exhibit caregiving behavior following sufficient offspring exposure, which demonstrates clear nonhormonal contributors to the development of parental behavior<sup>37</sup>. This counters the dated notion of a purely biological 'maternal instinct'<sup>38</sup>. We also know that

primary caregivers (fathers or mothers) show very similar activity in the amygdala (a hub of the parental brain network) in response to a child, again pointing to the importance of experience parenting and not pregnancy alone<sup>39</sup>.

A considerable amount of converging evidence points to the existence of dynamic neuroplasticity associated with matrescence and parenthood, which serves an adaptive purpose to support the mother in the execution of her new parental role, ensuring offspring survival. This plasticity also supports the parents themselves as they adjust to their new role. However, with such a remarkable degree of neuroplasticity, it is important to consider potential wide-reaching impacts on the wellbeing of mothers.

## Matrescence as a sensitive period

Although neuroplasticity during matrescence is considered to be primarily adaptive, this period of development is also a time of sensitivity to stressors, including heightened mental load. Turning to developmental neuroscience provides insights into how periods of high neuroplasticity pose both potential costs and benefits to mental health. Beginning at the earliest stages of development, neuroplasticity facilitates the formation of brain networks through experience-dependent synaptic strengthening or weakening<sup>40</sup>—a foundational process underlying all learning. Neuroplasticity generally declines with age. However, certain periods are considered sensitive periods in which experiences and exposures have a particularly pronounced effect on shaping the brain and behavior<sup>41,42</sup>. This sensitivity is especially clear in early childhood as core neural networks are developing, but it also occurs in middle childhood and throughout adolescence. During adolescence (a stage of development characterized by changing social roles as well as cognitive and emotional adaptations), much like matrescence, there is substantial neuroplasticity in a number of brain regions<sup>43</sup>. This heightened neuroplasticity, although normative and healthy, is associated with increased vulnerability to mental illness<sup>44</sup>. Thus, much like adolescence, neuroplasticity is a necessary feature of matrescence, yet simultaneously, it is linked to risk—a model that may guide our understanding of the maternal brain in the presence of the mental load of modern-day motherhood.

## Parenting stress and the maternal brain

It is well known that stress alters brain structure and function across the lifespan<sup>45</sup>, including during parenting<sup>46</sup>. The concept of stress is multifaceted, consisting of both objective and subjective components, yet often in parental brain research the specific role of parenting stress is emphasized. Parenting stress refers to physiological and psychological reactions to the demands, stress, and challenges arising from caring for a child<sup>47</sup>. Although a certain level of parenting stress is normal, high levels of perceived parenting stress may suggest difficulties in adjusting to parenthood, reflected in associations with maternal depression and harsh parenting styles<sup>48</sup>.

When we look specifically at the impact of stress on the maternal brain during pregnancy and the postpartum period, we see that it is associated with altered neural responses to infant cues. As early as late pregnancy, higher levels of perceived stress are associated with a greater brain response to low-distress, but not high-distress, infant cries<sup>49</sup>. This suggests that stress can alter how a parent may process and respond to ambiguous infant cues even before their infant arrives. During early motherhood, higher levels of parenting stress are associated with reduced activity in maternal brain areas important for decision making and emotion regulation. This research shows reduced activation in the orbitofrontal gyrus in mothers while watching videos of their toddler<sup>50</sup> and reduced amygdala activation to positive facial expressions from a mother's infant<sup>51</sup>. Mothers who feel more stressed in their role as a parent also have reduced neural synchrony with their children (3–4 years of age) in brain regions important for social cognitive functions (attention, working memory and emotion regulation), such as the inferior frontal gyrus and dorsolateral prefrontal cortex<sup>52</sup>. This same relationship between parenting stress and interbrain synchrony is not evident in father–child dyads<sup>53</sup>.

Of the limited number of neuroimaging studies looking at parenting stress and its effect on the maternal brain, most are based on maternal reports of stress and not on physiological stress indicators, such as cortisol. However, one study directly measured a mother's cortisol response to a stressful situation and found that a mother's cortisol response trajectory to a stressor is associated with reduced maternal brain activity in response to the cry of her infant<sup>54</sup>. This reduction in brain activity occurs in brain regions involved in maternal motivation, empathy and emotion regulation, including the thalamus, striatum, orbitofrontal gyrus, medial prefrontal cortex, anterior cingulate cortex and insula<sup>54</sup>.

In addition to parenting stress, there are a number of other stressors that are associated with changes in the maternal brain and probably contribute to the mental load of motherhood<sup>46</sup> (Fig. 2). One such stressor that has been studied is poverty<sup>55</sup>. Low income is associated with reduced maternal brain responses to infant cries in brain regions involved in emotion and affective regulation, such as the medial and lateral prefrontal cortex<sup>56</sup>. Similar brain patterns of activation are observed when mothers experience elevated exposure to socioeconomic, physical, environmental, and psychosocial stressors, for example, low income, financial stress, substandard housing, crowding at home, marital dissatisfaction, and violence. A greater number of stressors are associated with reduced maternal brain activation to infant cries in brain areas important for emotional and cognitive empathy, such as the insula, inferior frontal gyrus and superior temporal gyrus<sup>57</sup>. On the other hand, low-income mothers is associated with increased amygdala response to infant distress, which is further associated with more intrusive parenting behaviors<sup>58</sup>. The heightened amygdala response to infant distress may reflect a mother's hypervigilance to protect her infant, whereas the reduced activation in other brain regions may contribute to adaptive or maladaptive parenting behaviors, depending on the current environment.

In summary, studies that examine the role of stress (such as parenting stress or poverty) on maternal brain activity show that high levels of stress are often associated with dampened brain responses to both positive and negative cues from infants, as well as less inter-brain synchrony between a mother and her child. These changes in maternal brain activity are associated with altered maternal caregiving behaviors. This research highlights the importance of understanding how parenting stress and, ultimately, the mental load of motherhood, affect neuroplasticity in the maternal brain.

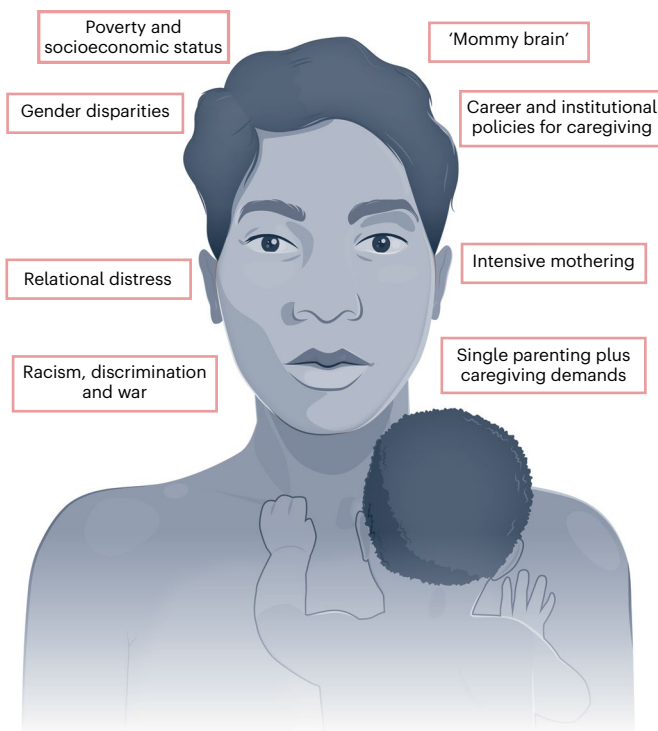
## Perinatal mental illness and its neurobiology

We know that matrescence is a time when suicide is a leading cause of maternal death<sup>59</sup>, as well as when a postpartum psychiatric admission is a greater mortality risk for women than almost all other single causes<sup>60,61</sup>. During pregnancy, up to 18% of women will be diagnosed with depression<sup>62</sup>, with up to 19.2% being diagnosed in the first postpartum year<sup>63</sup>. Notably, the risk for affective episodes and postpartum psychosis is highest among first-time mothers<sup>64</sup>, suggesting a sensitivity to biological changes and stressors associated with the initial transition to motherhood, consistent with the notion of matrescence as an important neurodevelopmental process.

The perinatal period is also a time when the risk of mental illness (or relapse) is greater in mothers than in fathers, with a clear association between childbirth and the onset of postpartum mental illness in first-time mothers but not first-time fathers<sup>64,65</sup>. However, it should also be noted that the risk of severe perinatal mental illness is high both at the initial transition to motherhood and following subsequent pregnancies<sup>66</sup>.

There is no doubt that perinatal mental illness is an important public health concern in need of improved identification, intervention, and prevention. Despite the prevalence and costs for the mother and developing child, our understanding of the neurobiological mechanisms mediating perinatal mental illness is limited, particularly in relation to the social factors that are linked to these illnesses. Here we briefly summarize key findings from neurobiological research on postpartum depression, as the majority of brain-imaging research has focused on this perinatal mental illness<sup>3</sup> (for a review of the neurobiology of other perinatal mental illnesses, see ref. 67).

Postpartum depression is associated with altered structural and functional neuroplasticity in the maternal brain. When looking at structural neural modifications, postpartum depression is associated with several neuroanatomical modifications in cortical thickness and surface area in brain areas important for empathy (for example,



**Fig. 2 | The mental load of motherhood.** Representation of some main contributors to the mental load of modern-day motherhood. Mothers must juggle the responsibilities of parenting in the context of the mental load, which includes factors such as ongoing gender disparities in parenting and domestic labor, nuclear families' lack of institutional support for caregiving, financial burden, the distress of 'mommy brain', intensive mothering ideologies that are strongly instilled in modern Western cultures, and caregiving demands, including the stress of single parenting, which is a growing demographic across the world. For many women, living in conditions of psychological and physical danger due to discrimination and war increases the load.

the insula) and sensory function (for example, the parietal cortex), to name a few<sup>68</sup>. Functional brain changes are more widely studied in postpartum depression, showing associations between depression and alterations in activation of brain regions important for empathy, stress regulation, motivation, emotion regulation, learned reward, and executive function<sup>3,69</sup>. For example, elevated levels of depression in new mothers are associated with an enhanced response in the amygdala to positive infant cues and a decrease in functional connectivity between the amygdala and insular cortex, compared to mothers without depression<sup>70</sup>.

The question of whether these neural activation patterns with depression differ in mothers and nonmothers is important to consider to further understand the impact of motherhood on the neurobiology of mental illness. So far, only one study has compared brain activity in mothers with postpartum depression and nonmothers with major depression<sup>71</sup>. This research shows that postpartum depression in new mothers is associated with an increase in activation of the amygdala to an infant cue when compared to nonmothers with major depression, healthy mothers, and nonmothers. It should also be noted that major depression in nonmothers is associated with minimal levels of activation in the amygdala in response to an infant cue.

The reasons for these differences in the association between depression and activity in the maternal brain remain to be determined. Although postpartum depression and major depression share similar symptomatology, they are differentiated by timing of onset

(matrescence) as well as by the social context that comes with motherhood, for example, the excessive worry and/or guilt surrounding parenting abilities that occur in many women with postpartum depression. As with the association between low income and the maternal amygdala response mentioned above, this hyperactivation of the amygdala in postpartum depression may be related to alterations in a mother's response to her infant, something that is often evident in mothers with postpartum depression<sup>72</sup>.

The uniqueness of the relationship between perinatal mental illness on the adult female brain has encouraged researchers to consider the importance of matrescence when investigating the neurobiology of disease states and further highlights this as a sensitive developmental period. In addition, the substantial mental load of modern-day motherhood, experienced in the context of this sensitive neurodevelopmental period, may represent a 'perfect storm' of factors contributing to mental health risks for mothers.

## Mental load of modern motherhood

Although it is evident that the maternal brain is altered with pregnancy, parenting, and stress, to fully understand how the mental load of motherhood impacts the maternal brain and maternal mental health we need to acknowledge the impact of modern-day motherhood on mothers. To do this, we must go beyond investigating the concept of 'parenting stress' and instead investigate the key factors that contribute to mental load, including the degree of gender disparities in the physical and mental tasks of parenting, mentioned above, but also the major familial, institutional, and social factors surrounding motherhood in the modern era (Fig. 2). (Note that our focus is on countries with cultures that are typically more individualistic, as the majority of research has been done in these countries and these countries show the highest rates of parental burnout<sup>73</sup>.)

### Intensive mothering ideology

In industrialized countries, mothers face immense pressure to engage in high-level parenting, which requires substantial amounts of time, effort, money, and emotional labor, and is referred to as 'intensive mothering'<sup>74</sup>. This ideology, originally described in 1996<sup>75</sup>, has several central beliefs: an essentialist belief that mothers are better parents, that caregiving should be child-centered, that mothers should derive satisfaction and reward from parenting, and, finally, that parents should provide constant intellectual stimulation for their children's optimal outcomes. In fact, today, parents spend 50% more time with their children than in the past<sup>76</sup>. Although the specific set of beliefs endorsed appears to differ from person to person, broad acceptance of the intensive mothering ideology is present across race and social class<sup>77,78</sup>. Despite this broad endorsement, or perhaps because of it, several studies show negative relationships between intensive mothering attitudes and maternal mental health<sup>79</sup>. Specifically, essentialist beliefs about maternal caregiving superiority are related to lower life satisfaction, and elevated beliefs about the challenges of parenting are related to higher depression in mothers.

The emotional stress of engaging in intensive parenting behaviors can lead mothers to neglect their own wellbeing and create feelings of inadequacy and guilt from not being able to live up to the ideals of intensive mothering<sup>80</sup>. Guilt, itself, is associated with alterations in the neural networks important for social cognition (theory of mind)<sup>81</sup>, and although not studied in the context of motherhood, one could speculate that the often prolonged guilt associated with 'failing' as a mother could substantially impact the maternal brain. Moreover, intensive mothering ideology, with its associated guilt, stress, and emergent anxiety, can remain with women across their lives<sup>82</sup>—mothering work is never done. Again, as gendered caregiving roles are often synonymous with this ideology, the impact of intensive parenting is borne, again, by mothers.

## The nuclear family

Throughout history, humans have practiced cooperative reproduction, in which extended social groups are responsible for raising children<sup>83</sup>. This idea, often called alloparenting, is very much divorced from modern-day conceptions of the traditional family. Established in the 1950s, with the rising social value placed on the nuclear family and influenced by the ‘gender crisis’ following postwar reindustrialization<sup>84</sup>, the continuing expectation today is that parenting is performed autonomously by a parent(s), most frequently the mother; labor performed in fulfillment of an assumed gender role, without recognition and with little outside assistance<sup>85</sup>. Additionally, in the context of a nuclear family, the quality of the relationship with the partner critically influences the wellbeing of mothers, as the partner is often the only available adult who can support the mother in parenting. Thus, a lack of support from the partner, or poor relationship quality, can negatively affect maternal mental health<sup>86</sup>. This style of family is no more functional than it is traditional, and the isolation and lack of social support are, arguably, important factors in the mental load of motherhood and maternal brain health.

If we look at social support alone, in addition to the inherent gender disparities the nuclear family perpetuates, it is well known that it acts as a buffer against mental illness such as depression, at all stages of the lifespan, but particularly in pregnancy and postpartum<sup>4</sup>. Social support during matrescence is also associated with improved neural connectivity in the maternal brain. Perceived social support is related to improved connectivity between the cerebellum, a hub in the social cognition network, and other brain networks in women with postpartum depression<sup>87</sup>. In addition, group parenting interventions such as Mom Power, which reduce parenting stress and improve parent–child interactions, are associated with changes in neural activity in parental brain areas related to ‘over mentalizing’ (for example, misattributing the child’s behavior) and ‘under coupling’ (for example, the parent is disengaged from observing how their physical or verbal actions make their child feel<sup>88</sup>). Indeed, although single mothers (a rapidly growing demographic in the USA and across the industrialized world<sup>89</sup>, particularly in minoritized populations) are at increased risk for perinatal depression, 40% of this relationship is accounted for by increased stress and a lack of social support<sup>90</sup>.

## Parental leave

Although the majority of today’s employed and childless millennial men espouse egalitarian views about work and caregiving responsibilities, less than half of the employed millennial fathers do<sup>91</sup>. Interestingly, such views seem to be related to the degree of family support within employment settings. This suggests that, despite intentions for an equal distribution of family labor, once millennials face the reality of working in an institution with nonsupportive family policies, fathers have little choice and tend to default to the traditional gender divisions of labor favored by previous generations. In addition to this, breadwinning mothers are three times more likely than breadwinning fathers to be responsible for organizing children’s activities and schedules, and to volunteer at children’s schools (Bright Horizons Modern Family Index). These mothers are also twice as likely to be in charge of all of the family responsibilities. This is an especially concerning statistic, as 40% of families now have the mother as the primary breadwinner<sup>92</sup>. Thus, although egalitarian attitudes about caregiving and household labor have improved over the last several decades, when faced with institutional demands, a lack of parental support in employment settings, and the challenges of parenting, it remains true that much of the physical and mental load of parenting falls on the laps of mothers.

## Racism and war

The health impact of living in a racialized society is extensively compounded in parents in ethnic minorities, contributing substantially to the mental load of mothers in these communities. Disturbingly, the

impact of racism on the mental load can begin well before babies are born. For example, in the USA and UK, women of color are faced with sobering statistics on maternal mortality rates in their communities, with Black women almost four times more likely to die of pregnancy-related causes than white women<sup>93</sup>. The structural racism that mothers in ethnic minorities experience is often overlaid on extensive interpersonal experiences of racism, which contribute to higher maternal depression rates (up to 2.43 times greater odds of experiencing perinatal depression<sup>94</sup>), earlier preterm birth, and other adverse birth outcomes<sup>95</sup>.

The neurobiological impact of racial discrimination is clear, with associations between racism and alterations in the function of brain areas important for emotion regulation such as the anterior cingulate cortex and prefrontal cortex<sup>96</sup>, brain areas also important for parenting. This suggests that racial discrimination is a fundamental factor impacting the mental load of motherhood and the maternal brain in a large minority of women today. Extending this to the effect of war on the maternal brain, research shows that exposure to chronic war-related trauma is associated with ‘immature’ neural activity, when watching videos of individuals in pain, in maternal brain areas important for empathy. This neural pattern is further related to the degree of synchrony in mother–child interactions and, in turn, mediates relationships between war-trauma exposure and children’s empathic abilities<sup>97</sup>. As such, the effect of these traumas on the maternal brain can have important implications for the mother and subsequent generations.

## Unburdening the maternal mind and charting paths forward

Arguably, the greatest impact on women’s mental health is the transition to motherhood. It is also a time when society dismisses the wellbeing of the mother for the wellbeing of the child, ‘blaming’ her for how the child is developing, but without providing adequate support or resources for her as a parent or a person.

Essential to addressing maternal mental health and increasing our understanding of the maternal brain is an appreciation for the multitude of factors across the mother’s life, and in her current milieu, that impinge on her psychology and biology to influence how she navigates matrescence. The mental load of motherhood is, thus, critical to recognize, understand, and, ultimately, measure to fully comprehend this important life stage.

The mental load of motherhood is an interdisciplinary concept touching on psychological, sociological, political and biological factors—a term that reflects the various parts that make up what it is to be a mother in today’s society. We have outlined key factors that comprise the mental load of motherhood. These factors may impact some mothers more than others, but all should be considered when investigating the maternal brain and maternal mental health. We have to move beyond our segregated lines of inquiry to explore the interactions between mothers’ experiences at many levels (personal, familial, institutional, societal, and political) and maternal brain health.

To do this, we propose several future research directions for the study of maternal brain health. The first step would be to acknowledge and investigate experiences mothers frequently report struggling with, as outlined above (for example, guilt and mommy brain). The second step would be to encourage research that goes beyond clinical screening for mood symptoms and investigates additional aspects of the mental load related to external factors, taking into account domestic labor, caregiving support, and discrimination, to name a few. Ideally, a quantitative tool needs to be developed that would account for the current experiences of the mental load of motherhood in terms of the factors mentioned above. This tool could be used in combination with neurobiological and physiological measurements to aid in our understanding of the neurobiology of maternal mental health.

By exploring the multifaceted dimensions that impact motherhood, we can gain more precise knowledge about which factors, or

combinations of factors, substantially impact the maternal brain and mental health outcomes. Ultimately, this approach to future research will yield effective and meaningful clinical interventions, drive policy change, and provide mothers with options to move away from the modern-day essentialism of motherhood. It is time to capture the complexity of the mental load of motherhood and provide data for something that the majority of mothers are affected by.

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## Author contributions

J.L.P., B.L.C., C.M. and P.K. contributed to the writing and revision of the manuscript. J.L.P. proposed the topic of the manuscript and was responsible for the final revisions. B.L.C. created the figures.

## Competing interests

The authors declare no competing interests.

## Additional information

**Correspondence and requests for materials** should be addressed to Jodi L. Pawluski.

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