Paid Maternal Leave is Associated with Infant Brain Function at 3-Months of Age

Natalie H. Brito¹, Denise Werchan², Annie Brandes-Aitken¹, Hirokazu Yoshikawa¹, Ashley Greaves¹, & Margaret Zhang¹

¹Department of Applied Psychology, New York University, New York, NY, 10003

²Department of Population Health, NYU Langone Health, New York, NY, 10016

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Corresponding Author:
Natalie Hiromi Brito
New York University
Kimball Hall 405W
246 Greene Street
New York, NY 10003
natalie.brito@nyu.edu

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ABSTRACT

The first few months of postnatal life are critical for establishing key neural connections that support the development of subsequent social, cognitive, and linguistic skills. Yet, the United States lacks a national policy of paid family leave during this important period of early brain development, despite previous research demonstrating links between paid leave and improved maternal mental health, lower rates of infant mortality, and increases in cognitive skills during toddlerhood. The current study examined associations between paid maternal leave and infant brain function at 3-months of age using electroencephalography (EEG). Even after controlling for influential infant and family characteristics, results indicate that compared to unpaid leave, experiences of paid leave were related to distinct EEG profiles, possibly reflecting more mature patterns of brain activity. Findings from this study support past work demonstrating the benefits of paid leave on infant cognitive development and extend this work into early neural functioning. Together with past research, this work suggests that policy interventions mandating paid family leave may lead to reductions in sociodemographic health disparities and set the stage for healthy neurocognitive development.

INTRODUCTION

The period after birth is often a vulnerable time for mothers. Typical experiences for new mothers include post-birth complications, lactation difficulties, sleep deprivation, and chronic stress (Abou-Dakn et al., 2009; Saxbe et al., 2018). As expected, there is variation in how long these experiences may last, but a large-scale study reported that new mothers did not physically and emotionally recover until at least 5.5 months after birth (Brody, 2017). Despite the many challenges occurring during this transition, 23% of working mothers in the United States return to work within 10 days of giving birth (American College of Obstetricians and Gynecologists, 2018), most often due to lack of income. This is in stark contrast to guidelines that mothers need at least 6 weeks to recover after a vaginal delivery and 12 weeks after a C-section (Daisley, 2014).

Virtually every country in the world provides new parents with paid family leave, with most countries providing at least 6-9 months of paid leave to new mothers on average (Blum et al., 2018; Khan, 2020; Nandi et al., 2018). The U.S. is the only high-income country to not have a federal policy mandating paid leave to working caregivers who give birth. As such, only 17% of all employed workers in the U.S. have access to paid parental leave through their employers (Bureau of Labor Statistics, U.S. Department of Labor, 2018.). Although the Federal Medical Leave Act (FMLA) enables new caregivers to receive 12-weeks of job-protected *unpaid* leave, eligibility criteria severely restrict access to this policy for most working parents. Thus, even this unpaid benefit is typically only accessible for women who are college-educated or live in two-parent households (Han et al., 2009).

Presently, nine states and the District of Columbia offer some form of paid leave that allows caregivers to have partially paid time off work to care for a new child (Kaiser Family Foundation, 2020). Introduction of a paid leave program at the state level doubled the length of leave taken, particularly among mothers from lower-income households (Brainerd, 2017). This leave affords caregivers the time to attend postnatal healthcare visits for themselves and for their infants, which has been shown to translate into gains in a number of indicators of health. Studies have demonstrated that paid leave is associated with a 47% decrease in the odds of re-hospitalization for infants and a 51% decrease in odds of re-hospitalization for mothers ((Jou et al., 2018), as well as reduced incidences of postpartum depression (Mandal, 2018). Additionally, a previous study found that children whose mothers returned to work within 12 weeks post-birth were 3.4 percentage points less likely to receive their required immunizations and 7.4 percentage points less likely to be breastfed (Berger & Waldfogel, 2004). Often, the overall benefits of paid leave are driven by families from lower-SES households (Lichtman-Sadot & Bell, 2017), indicating that paid leave may have a bigger effect for caregivers who currently cannot afford to take unpaid leave after giving birth.

Impact of paid leave on infant development

The absence of a U.S. federal paid leave policy makes it difficult to study the intricate effects of paid leave on subsequent child outcomes beyond indicators of physical health. The potential benefits on developmental outcomes are more abundantly illustrated in international studies. For example, a study conducted in Chile examined changes after expanding the duration of paid

leave (from 12 weeks to 24 weeks) and found increases in the probability of breastfeeding, decreases in maternal stress, and positive effects on children's cognitive abilities, particularly for families from lower-SES households (Albagli & Rau, 2018). Similarly, researchers in Korea reported positive associations between paid leave and a composite measure of infant development assessing motor, communication, problem-solving, and social skills (Hwang & Jung, 2016). On the other hand, Baker and Milligan (2010) found little impact of increasing the length of paid leave in Canada on assessments of parenting behaviors, child social skills or motor development during toddlerhood. But this analysis excluded families from single-parent households and examined the length, rather than the initial implementation, of paid leave policies. Results from international studies indicate promising benefits of paid leave, but it is difficult to compare results across countries with varying levels of government support and social safety nets (i.e. childcare, medical insurance coverage) (Burtle & Bezruchka, 2016).

Previous studies examining outcomes related to paid family leave in the U.S. have largely focused on maternal or infant physical health. There have been a few studies examining the impact of the length of leave on child developmental outcomes in the U.S. (i.e., Clark et al., 1997; Ruth Feldman et al., 2004; Pisciella, 2008; Plotka & Busch-Rossnagel, 2018), but these studies did not specifically examine differences in paid vs. unpaid leave status. There is only one study, to our knowledge, that has examined these associations for families living in the United States. Kozak and colleagues (2021) examined parental self-report assessments of language, cognitive, and socioemotional outcomes for toddlers (24-36 months, N = 328) in relation to paid vs unpaid leave status for mothers. Results indicated that mothers who had access to paid leave after birth had toddlers with significantly higher language scores than children of mothers who took unpaid leave, even after accounting for differences in family income and length of leave. Furthermore, paid leave was also related to better socioemotional skills, but this effect was only present for mothers from lower-SES households. These findings suggest that expanding access to paid leave could be beneficial to all families, and may have an even larger benefit for under-resourced households (Kozak et al., 2021).

Potential mechanisms explaining links between paid leave and child outcomes

The first several months after birth are a sensitive period for an infant's socio-emotional and cognitive development (Knudsen, 2004; Sheridan & Nelson, 2009) as key neural connections within the brain are emerging in the context of consistent, warm, and contingent social interactions between the infant and caregiver (Shonkoff & Phillips, 2000b). There are multiple potential mechanisms that could explain how access to paid leave could be beneficial for promoting healthy infant outcomes, including affording families the time to establish sensitive and responsive parent-child interactions and decreasing experiences of chronic maternal stress.

The quality of parent-child interactions has been found to scaffold children's subsequent cognitive and social-emotional development (Bigelow et al., 2010; Ruth Feldman & Eidelman, 2009; Gregory & Rimm-Kaufman, 2008). Quality is often measured within the child development literature using the constructs of maternal sensitivity and mother-infant reciprocity. Maternal sensitivity is typically defined as the ability to notice, interpret, and appropriately respond to infant cues (Beebe & Steele, 2013). Mother-infant reciprocity, sometimes referred to as dyadic reciprocity or synchrony, refers to the coordinated, back-and-forth exchanges of

affective and behavioral cues (Ruth Feldman, 2007). Past research has also indicated that an absence of these behaviors may contribute to long-term negative outcomes for physiological and emotional development (Clark et al., 1997; Shonkoff & Phillips, 2000a). Both maternal sensitivity and mother-infant reciprocity have been linked to better emotion regulation and attachment security in children (Ruth Feldman et al., 2014.; Kogan & Carter, 1996; Raikes et al., 2007; Rifkin-Graboi et al., 2015) and the quality of parent-child interactions has also been shown to be predictive of infant brain function, assessed via electroencephalography (EEG), during the first two years of life (Bernier et al., 2016).

Previous research has reported a developmental pattern of brain activation whereby children demonstrate decreases in lower-frequency resting EEG power, alongside increases in higher-frequency resting EEG power as children develop (Bell, 1998; Cuevas & Bell, 2011; John et al., 1980; Marshall et al., 2004). This pattern of brain activity has been suggested to reflect organization and maturation of cortical brain regions (Corning et al., 1982; Thatcher et al., 2008). Higher levels of maternal stress have also been associated with distinct patterns of infant brain function (St. John et al., 2017; Pierce et al., 2019; Troller-Renfree et al., 2020). Although stress is a common experience for caregivers in the first several months after birth, high levels of chronic stress can impede a caregiver's ability to respond to their infant's cues in a sensitive and synchronous manner (Crnic et al., 1983; Lutz et al., 2012). Higher levels of maternal perceived stress (Pierce et al., 2019) and increased concentrations of cortisol in maternal saliva ((St. John et al., 2017) and hair (Troller-Renfree et al., 2020) samples have been associated with heightened levels of lower-frequency (i.e., theta) EEG power and/or reductions in higher-frequency (i.e., alpha, beta, gamma) EEG power during the first year of life. In addition to links to maternal stress, this pattern of brain activation has been also been associated with disparities in language, cognitive, and socioemotional skills (Brito et al., 2016, 2019; Corning et al., 1986; Maguire & Schneider, 2019; McLaughlin et al., 2010).

Current Study

The literature clearly illustrates that paid leave contributes to the physical and mental well-being of both mothers and infants (Berger & Waldfogel, 2004; Jou et al., 2018; Mandal, 2018) and paid leave may support early child cognitive and socioemotional development (Kozak et al., 2021). The present study aims to extend these findings by examining whether experiences of paid vs. unpaid maternity leave are associated with differences in infant brain activation patterns early in life. We hypothesize that infants of mothers with paid leave will demonstrate decreases in lower-frequency EEG power and increases in higher-frequency EEG power compared to infants whose mothers took unpaid leave. Paid leave may afford mothers the time needed to establish and engage in sensitive and synchronous interactions in the first few months of life. Additionally, unpaid leave may heighten levels of stress within the home during this already stressful perinatal period. For these reasons, we also examine if paid leave is associated with the quality of parent-child interactions and maternal stress.

METHODS

Participants

The initial sample included 100 infants (63 males; age $M = 3.46$ months, $SD = 0.38$) who were recruited from community events, family services, health care providers, and flyers posted at local businesses around New York City. Participants were excluded from participating in the study on the basis of birth before 36 weeks' gestation, multiple births, or presence of developmental disorders. Families were invited to participate in the study when infants were 3-months of age and data collection took place at New York University between May 2018 and December 2019. Families were compensated for their time and transportation was provided to all families to reduce participant burden. Only mothers who reported that they took time off after childbirth and either returned to work or intended to return to work within the child's first year of life were included in the final sample ($n = 80$). The racial breakdown of infants in the final sample was as follows: 44% two or more races, 31% White, 18% Black, 6% Asian, and 1% unreported. The sample also comprised 48% of mothers identifying as Hispanic or Latino. Annual household income ranged from \$3,000 to \$500,000 (*Median* = \$100,000), see Table 1 for additional sociodemographic information. All research procedures were approved by the New York University IRB.

Table 1.
Demographics

Type of Leave		Median	SD
Mothers with Unpaid Leave (n = 33)	Gestational Age at Birth (weeks)	39	1.37
	Infant Age (months)	3.32	0.37
	Maternal Education (years)	14	3.42
	Annual Family Income	\$52,000	97,502
	Leave Duration (weeks)	12.55	4.10
Mothers with Paid Leave (n = 47)	Gestational Age at Birth (weeks)	39	1.17
	Infant Age (months)	3.48	0.39
	Maternal Education (years)	18	3.30
	Annual Family Income	\$120,000	129,900
	Leave Duration (weeks)	12.75	3.37

Measures

Demographic Questionnaire

Families were given questionnaires to complete during the 3-month visit to obtain demographic information including maternal and infant age, race, and ethnicity. Caregivers also reported their highest level of education attained and annual household income. Family income-to-needs ratio (ITN), which is the total household income divided by the federal poverty line for the corresponding number of adults and children in the home, was included as the SES variable of interest. To correct for skew, family ITN was log-transformed and extreme values greater than 2 SDs above the median ($n = 6$; 7%) were Winsorized by replacing these values with the value representing 2 SDs above the median.

Family Leave Questionnaire

Caregivers were asked about their pre- and post-birth employment. Mothers were asked: (1) if they took time off work after giving birth, (2) if this time off was compensated monetarily, and (3) how long they took off before returning to work. For mothers who were still on leave at the 3-month visit, they were asked for an estimate of when they would return to work. Mothers that reported that they had access to paid leave were also asked what percentage of their income was compensated during their time off (0-100%). If mothers reported any monetary compensation during their leave, they were categorized as having paid leave. Caregivers who reported no employment history or indicated no plans to return to work after birth were excluded from the sample.

Perceived Stress Scale

The Perceived Stress Scale (PSS; Cohen et al., 1983) was used to assess self-reported maternal stress. The PSS includes 14-questions that assess the degree to which the respondent has perceived situations as stressful within the last month. Items are rated on a five-point Likert scale ranging from 0 (never) to 4 (very often). A total score is the sum of scores from all items (after 4 items are reverse scored), with scores ranging from 0 to 40.

Physiological Stress (Hair Cortisol)

A small hair sample was collected from caregivers, with each sample weighing at least 15 mg. Each hair sample was trimmed to be approximately 3 cm long (measured from the end closest to the root). As human hair grows approximately 1 cm per month, each sample contains cortisol deposited during roughly the past three months. The samples were stored at -40°C until sent for analysis. Each sample was weighed, washed twice in isopropanol to remove external contaminants, ground to a fine powder, and extracted with methanol. The methanol extract was evaporated, re-dissolved in an assay buffer, and analyzed along with standards and quality controls by a sensitive and specific enzyme-linked immunosorbent assay (Salimetrics, Carlsbad, CA). Assay readout was converted to pg cortisol per mg dry hair weight. Intra- and inter-assay coefficients of variation for this assay are <10%. Hair cortisol values were log-transformed to correct for skew (Chen et al., 2015).

Parent-Child Interaction

Infants were placed in an infant rocking seat, and mothers were seated across from them, enabling face to face interaction. Each dyad was given a standardized set of toys including a book, stacking cups, and a rattling ball, and were instructed to play like they normally would at home for five minutes. The interactions were video recorded and experimenters left the room during the task. Quality of mother-infant interactions were assessed using the Coding Interactive Behavior (CIB; Feldman, 1998) measure. The CIB is a global rating scale of 22 parent behaviors, 16 child behaviors, and 5 dyadic behaviors. Each behavioral code was coded on a 5-point scale, where 1 denotes a minimal level of the specific behavior and 5 denotes a maximal level across the 5-minute interaction. The interactions were also coded for the extent that they were parent-

led (i.e., the extent the parent was preoccupied with “teaching” the infant, re-directed the infant’s attention, or directed the infant to parent-led activities). Inter-rater reliability was established between four independent coders on 30% of the data and Fleiss’ Kappa ranged from 0.71 to 1.0.

Confirmatory factor analysis (CFA) was used to derive a composite measure of maternal sensitivity using the following CIB behavioral codes: maternal positive affect, gaze towards the child, acknowledgement of the child’s cues, imitation, appropriate range of affect, resourcefulness, and supportive presence. All variables loaded significantly ($ps < .001$) and model fit was excellent, RMSEA = 0.05, 90% C.I. (0, 0.14), CFI = .98, $\chi^2 = 16.25$, $p = 0.30$. Similarly, CFA was also used to derive a global composite measure of dyadic reciprocity, indexed by CIB codes for dyadic reciprocity, adaptation-regulation, and fluency, which showed model convergence with all variables loading significantly ($ps < .01$). The resulting factor score estimates for composite measures of maternal sensitivity and dyadic reciprocity were used in subsequent analyses.

EEG Data Acquisition & Processing

Resting EEG data were acquired while infants watched a video of engaging, non-social stimuli (e.g., bubbles, spinning wheel) while seated on their caregivers’ laps. The recording room was dimly lit and an experimenter was nearby to soothe the infant with bubbles or a toy if the infant became too fussy. Infants provided between 40 and 550 seconds of resting data. EEG was recorded using a 64-channel HydroCel Geodesic Sensor Net (Electrical Geodesic, Inc., Eugene, OR) and amplifier (Electrical Geodesic, Inc., Eugene, OR; EB NEURO S.p.A., Firenze, Italy). Electrode impedances were kept below 100 K Ω and the sampling rate was recorded at 1000Hz.

All EEG files were processed in batch electroencephalography automated processing platform (BEAPP) software to ensure standardization in data processing and cleaning across all files (Levin et al., 2018). Continuous resting EEG files were converted from NetStation format to Matlab (2018b) format. Data preprocessing was carried out using the Harvard Automated Processing Pipeline for EEG (HAPPE), an automated preprocessing pipeline designed for infant EEG data (Gabard-Durnam et al., 2018). First, a 1 Hz high-pass and 100 Hz low-pass filter was applied to each EEG dataset. Second, the data, which was originally sampled at 1000 Hz was resampled with interpolation to 250 Hz, following guidelines for further HAPPE processing. The third step involved artifact removal and included CleanLine’s multitaper approach to removing 60 Hz electrical noise, bad channel rejection, and wavelet-enhanced ICA for artifact rejection with automated component rejection through the Multiple Artifact Rejection Algorithm (Winkler et al., 2011) in EEGLAB. A subset of spatially distributed electrodes was selected for analysis with MARA: 2 3 5 6 8 9 10 11 12 13 14 18 20 24 25 28 30 31 34 35 39 40 42 44 48 50 52 57 58 59 60 (NetStation Geodesic 64- Channel Net). Bad channels that were initially rejected were repopulated using spherical interpolation to reduce bias in re-referencing and the signal was mean detrended. Finally, each EEG file was segmented into 2-second windows and each segment was assessed for remaining artifacts. Segment rejection thresholds were determined according to HAPPE’s automated rejection criteria ((Gabard-Durnam et al., 2018); see supplemental), which uses amplitude thresholding and assessment of segment likelihood using joint probability calculations.

EEG power decomposition was accomplished using Fast Fourier transformation using a multitaper windowing (3 windows) to decompose power into 2-second segments for each channel. Spectral power was computed for the frequency bands Theta (4-6 Hz), Low Alpha (6-9 Hz), High Alpha (9-13 Hz), Beta (13-19 Hz), Low Gamma (21-30Hz), High Gamma (31-45 Hz). At each channel, mean power within each frequency band was calculated across all segments and normalized by a log base 10 transformation. Power was then averaged across electrodes in each region of interest (ROIs): frontal cortex (2, 3, 5, 9, 10, 11, 12, 13, 14, 18, 57, 58, 59, 60), temporal cortex (20, 24, 25, 48, 50, 52), parietal cortex (28, 30, 31, 40, 44, 42), and occipital cortex (35, 39). Relative power (i.e., absolute power in one frequency band divided by total absolute power from all frequency bands) was computed and analyzed below.

Analysis Plan

Both continuous (percentage of income that was paid during leave) and categorical (paid vs. unpaid leave status) variables were used in subsequent analyses. There were no differences between the paid and unpaid leave groups in terms of gestational age at birth ($p = 0.23$), infant age ($p = .89$), or leave duration ($p = .72$), but there were significant differences in family income-to-needs ratio ($p < 0.01$). Nonetheless, in all analyses, gestational age at birth, infant sex, infant age, and family income-to-needs (ITN) ratio, were included as covariates as these variables have been previously found to impact early brain and cognitive development (Bradley & Corwyn, 2002; McCarton et al., 1996; Noble et al., 2012; Prior et al., 1993).

Among the 80 infants in the final sample, 25% ($n = 20$) were missing EEG data ($n = 12$ or 26% of the paid leave group and $n = 8$ or 24% of the unpaid leave group). Infants who were missing EEG data did not differ from those who had EEG data on any of the study variables or covariates ($ps > .18$). Full information maximum likelihood (FIML) was used to account for missing data in all analyses, as FIML produces unbiased parameter estimates.

Prior to analyses, we first checked for multivariate outliers across the EEG and sociodemographic variables using Mahalanobis distance, which indicated no multivariate outliers within or across groups. Prior to testing our primary hypotheses, we first ensured that there were no region- or hemisphere-specific differences in EEG power between paid leave groups using a series of repeated measures ANOVAs. We examined the frequency bands separately. Region (frontal, temporal, parietal, occipital) and hemisphere (left, right) were used as within-subject factors, paid leave group (paid, unpaid) was a between-subject-factor, and log-10 transformed absolute EEG power was the dependent variable. Age at test, infant sex, gestational age, and family ITN were used as covariates. Across all frequency bands, there were no significant interactions between paid leave group and brain region or hemisphere (all $ps > .07$, all $Fs < 3.37$), indicating no region- or hemisphere-specific differences between groups. Thus, we collapsed across brain regions and hemispheres for subsequent analyses.

Multiple linear regressions were used to test primary hypotheses regarding the association between maternal paid leave and relative EEG power. Exploratory analyses examined how experiences of paid leave, maternal stress, and parent-child interactions contributed to patterns of infant brain activation.

RESULTS

Paid Leave is Associated with Infant EEG Power

First, examining paid leave as a continuous variable, greater percent paid leave was associated with increased high alpha EEG power ($\beta = .34, p = .01$) and increased beta power ($\beta = .28, p = .04$), as well as reduced theta power ($\beta = -.31, p = .02$). There were no other significant effects of percent paid leave on infant EEG power ($ps > .07$).

Using categorical groups of paid vs. unpaid leave, infants of mothers who had some level of paid leave after birth demonstrated a distinct pattern of relative EEG activation from infants of mothers who took unpaid leave, controlling for covariates of interest. Notably, paid leave was associated with increased EEG power across higher frequency bands (high alpha, beta, and low gamma) and reduced EEG power across lower frequency bands (theta). Full regression results are reported in Table 1.

Table 2.
Multiple linear regression results.

	<i>Theta</i>	<i>Low Alpha</i>	<i>High Alpha</i>	<i>Beta</i>	<i>Low Gamma</i>	<i>High Gamma</i>
<i>Overall R²</i>	.19	.10	.26	.12	.17	.15
<i>Beta Coefficients</i>						
Infant Age (Days)	.27	-.28	-.40**	-.15	.13	.00
Infant Sex	-.00	.05	-.03	.01	.01	-.06
Gestational Age	-.04	-.18	-.09	-.02	.26	.36*
Income-to-Needs (ITN)	.22	.06	-.28	-.20	-.19	.01
Maternal Paid Leave	-.37*	-.12	.39**	.35*	.31*	.13

* *FDR-adjusted* $p < .05$; ** *FDR-adjusted* $p < .01$

We conducted sensitivity analyses to examine the robustness of the observed effects of paid leave on relative infant EEG power to potential bias from unobserved confounding variables. We used the coefficient of proportionality method (Dearing & Zachrisson, 2019; Oster, 2019), which indexes how large the impact of omitted variables would need to be, relative to observed confounders, to invalidate a result. Assuming conservative maximum R^2 values ranging from .8 to 1, we found that omitted variables would need to be 90%-350% as powerful as the observed socioeconomic and demographic covariates to nullify the results (Table 2). Notably, these values are well above recommended conservative thresholds for robustness (coefficients greater than or equal of 1.00 [100%]).

Table 3.

Sensitivity to Omitted Variable Bias

Assumed Max R²	Theta	High Alpha	Beta	Low Gamma
1	2.79	1.54	1.04	0.89
.9	3.13	1.74	1.16	1.01
.8	3.57	2.00	1.31	1.15

Note: The reported values indicate the absolute value of the coefficient of proportionality.

Examining potential mechanisms explaining links between paid leave and infant EEG

Maternal stress

We next explored associations between paid leave and maternal indicators of stress. Controlling for ITN, paid leave status was associated with maternal cortisol concentration levels ($\beta = -.30$, $p = .04$), with experiences of paid leave being linked to lower cortisol levels. Importantly, ITN did not predict maternal cortisol levels ($p = .53$), indicating that elevated maternal cortisol is specific to differences in paid leave status and do not merely reflect SES differences. The continuous variable of percent paid leave was similarly associated with maternal cortisol levels ($\beta = -.29$, $p = .04$). Maternal perceived stress was not associated with experiences of paid leave (categorical: $p = .68$; continuous: $p = .43$). Multivariate linear regressions were used to estimate associations between maternal physiological stress and EEG power across each frequency band, adjusting for covariates of interest. Results indicated that maternal cortisol in and of itself was not associated with infant EEG power ($ps > .13$), nor any interactions between paid leave and maternal cortisol on relative EEG power ($ps > .14$).

Parent-Child Interactions

We then examined associations between paid leave and parent-child interactions. Controlling for ITN, infant age, infant sex, and maternal cortisol, the categorical variable of paid leave did not predict maternal sensitivity ($p = .29$) nor mother-infant reciprocity ($p = .14$). Maternal paid leave status was also not associated with the extent that interactions were parent-led ($p = .07$).

When examining the continuous variable of percent paid leave, both higher levels of sensitivity ($\beta = .28$, $p = .02$) and reciprocity ($\beta = .25$, $p = .05$) were associated with greater percent paid leave (Figure 1). The extent that interactions were parent-led was also associated with lower percent paid leave ($\beta = -.44$, $p = .001$). There were no associations between PCI behaviors and infant EEG power ($ps > .07$), nor any interactions between paid leave and PCI behaviors on EEG power values ($ps > .13$).

Figure 1. Associations between percentage of income provided during leave and mother-infant interaction quality.

Exploratory analyses examining profiles of brain function in relation to mother-infant interactions and paid leave

Finally, we used latent class analysis to isolate unique profiles of whole brain infant EEG patterns to further explore maternal characteristics that are associated with global differences in brain function. Mplus version 8.1 was used to fit latent class models to infant EEG power across all frequency bands. Each LCA was initialized 2000 times, with 100 iterations for the final stage of optimization. A 2-class model was selected as the best fit, based on the Bayesian information criterion ($BIC = 986.62$), a high entropy value (.89, indicating low classification error), high posterior probabilities (indicating high confidence that an individual assigned to a given profile actually belongs to that profile; class 1 = .98, class 2 = .96).

The first latent class accounted for 68% of the sample and the second accounted for 32% (Figure 2). Class 1 was characterized by relatively higher EEG power across lower frequencies (theta; 4-9 Hz) and relatively reduced EEG power across higher frequencies (9-45 Hz). In contrast, Class 2 was characterized by relatively reduced power across low frequency bands (4-9 Hz) and relatively increased power across high frequency bands (9-45 Hz). Based on most likely class membership, 86% of infants in class 2 had mothers with paid leave and 14% had unpaid leave, whereas 45% of infants in class 1 had paid leave while 55% had unpaid leave.

Figure 2. Two profile model of EEG relative activation patterns. **A)** Class 1 had higher relative EEG power across low frequency bands (theta). **B)** Class 2 was characterized by increased relative EEG power across higher frequency bands, a profile typically reflecting greater maturational development. **C)** Classification of infants based on most-likely profile membership. **D)** Mothers with paid leave were over 6 times as likely to have infants classified in the higher Hz EEG profile. No other variables predicted profile membership.

We then examined predictors of EEG class membership using the 3-step procedure to account for measurement error associated with most-likely class membership (Asparouhov & Muthén, 2014). Full results are shown in Figure 2D. Notably, paid leave was the only significant predictor of class membership ($p = .01$), with infants in Higher Hz EEG class being over 7 times more likely to have mothers with paid leave relative to infants in the Lower Hz EEG. Infant age, infant sex, gestational age at birth, ITN, maternal sensitivity, and mother-infant reciprocity were not significant predictors of latent class membership ($ps > .14$).

These results are consistent with the prior analyses and indicate that widespread differences in infant relative EEG profiles are predicted by experiences of paid leave, over and above the effects of sociodemographic or maternal/infant characteristics. However, paid and unpaid leave may likely contribute to infant EEG patterns through a variety of potential mechanisms. In

addition, paid leave is likely associated with a number of confounding characteristics, over and beyond the sociodemographic factors that we controlled for in all analyses. To further probe potential mechanisms and control for confounding variables, we conducted exploratory post-hoc multiple linear regressions directly comparing infants of mothers with paid leave who were classified into the lower Hz EEG profile (paid/low Hz group), infants of mothers without paid leave who were classified into the lower Hz EEG profile (unpaid/low Hz group), and infants in the higher Hz EEG profile (high Hz group). These direct comparisons afford a more precise examination of the proximal variables that may contribute to brain development in infants of mothers with paid or unpaid leave.

Results indicated significant differences between groups in levels of maternal cortisol and the extent of parent-led interactions (Figure 3). Notably, the unpaid/low Hz group showed higher maternal cortisol levels than both the paid/low Hz group ($\beta = -.38, p = .02$) and the higher Hz group ($\beta = -.31, p = .05$), controlling for ITN. There were no differences in maternal cortisol levels between the high Hz and paid/low Hz groups ($p = .60$). Dyads in the paid/low Hz group also exhibited lower levels of parent-led interactions than dyads in both the higher Hz group ($\beta = -.39, p = .04$) and unpaid/low Hz group ($\beta = -.50, p < .01$), controlling for ITN, maternal cortisol, infant age, and infant sex. Dyads in the unpaid/low Hz group did not differ from dyads in the higher Hz group ($p = .78$). There were no differences in maternal sensitivity or dyadic reciprocity between groups ($ps > .07$). Taken together, these results suggest that elevated maternal physiological stress specifically associated with unpaid leave, and not simply SES, may have impacts on infant neural functioning that are observable as early as 3 months of age.

Figure 3. Within the low Hz EEG profile, mothers with unpaid leave had significantly greater cortisol levels than mothers of infants in the low Hz paid leave profile and the higher Hz profile. In addition, dyads in the paid leave/low Hz EEG profile showed significantly lower levels of parent-led interactions. Cross bars represent group means with 95% bootstrapped confidence intervals.

DISCUSSION

A recent systematic review concluded that paid leave results in improved maternal and child health, and that experiences of unpaid leave do not have the same effect on economic or health indicators (Nandi et al., 2018). Results from the current study extend previous findings into the domain of infant brain function and suggest associations between experiences of paid leave and profiles of EEG activation that may potentially reflect a more mature profile of brain function. This financially stable, job-protected time may increase the period of bonding needed for new dyads to foster sensitive, reciprocal interactions (Rossin-Slater et al., 2013), and could reduce the stress and worry over finances that may potentially hinder these experiences (McKelvey et al., 2002).

One experience, multiple mechanisms

There are many possible pathways through which access to paid time off after childbirth could be beneficial for early brain development and child outcomes. First, past research has shown that having dedicated paid leave would provide mothers the time and resources to attend postpartum medical and mental health care for themselves. This could have the effect of decreasing incidences of maternal re-hospitalization and postpartum depression or anxiety (Berger & Waldfogel, 2004; Jou et al., 2018; Mandal, 2018), with subsequent impacts on child brain structure (Lebel et al., 2016). Paid leave would also ensure that mothers are able to take their infant to important pediatric visits so that clinicians can provide essential immunizations to infants and evaluate any post-birth complications or developmental delays that may impact trajectories of neurocognitive development.

Although both paid and unpaid leave may afford caregivers the opportunity to prioritize these early health behaviors, financially supported time off may substantially decrease maternal tension resulting from reduced income or the pressure to return to work. Mothers often cope with the many stressors of returning to work before feeling physically or mentally ready, hassles of needing to find childcare, or juggling the countless challenges of both working and caring for a newborn, including but not limited to demands associated with breastfeeding and exhaustion from sleep deprivation. When given the opportunity, mothers with access to paid leave are more likely to spend time at home with their newborns (Rossin-Slater et al., 2013), allowing for a consistent and predictable home environment where the mother-infant dyad can develop routines and practice learning cues from each other through repeated interactions (Zigler & Hall, 2000). Within the first few months of life, these sensitive and contingent behavioral responses form the basis of vital developmental capacities related to regulation and attachment. Past research has reported that not taking any maternity leave or taking a shorter leave after childbirth was negatively associated with parent-child interaction quality and attachment security in infants (Clark et al., 1997; Plotka & Busch-Rossnagel, 2018). Although these studies did not specifically examine instances of paid vs. unpaid leave, they nonetheless illustrate the importance of early social interactions for caregiving behaviors and the mother-child relationship.

Our main finding indicated that, compared to infants whose mothers had unpaid leave, infants whose mothers took paid leave after giving birth were more likely to have increased EEG power across higher frequency bands (high alpha, beta, low gamma, and high gamma), and reduced

EEG power across lower frequency bands (theta). This was true whether we examined paid leave continuously (i.e., percentage of income that was compensated during leave) or categorically (i.e., paid vs. unpaid leave status). This profile of early brain function has been demonstrated in previous studies as reflecting a more mature pattern of brain activation during childhood (Corning et al., 1982; Thatcher et al., 2008). Surprisingly, associations between paid leave and infant EEG remained significant even after accounting for factors like family income and parent-child interactions, which have previously been shown to predict early brain development (Brito & Noble, 2014; Hanson et al., 2013; Noble et al., 2015).

Within exploratory analyses we examined potential proximal mechanisms that might help to explain links between paid leave and infant EEG profiles. As a group, both maternal physiological stress and parent-child interactions were associated with experiences of paid leave. We also found that paid leave was a robust predictor of global EEG profiles, more so than infant/maternal characteristics, family income, or quality of parent-child interactions. Notably, EEG profiles characterized by increased power in higher frequency bands consisted almost entirely of infants of mothers with paid leave. When examining variation in paid leave status within profiles of lower frequency EEG, we observed differences in both maternal physiological stress and dyadic interactions, independent of socioeconomic status. Thus, it may be that this distal experience of paid leave, or lack thereof, may act upon infant brain development through multiple overlapping pathways that may take into account individualized family interactions and stressors.

Limitations and conclusions

While the present study is the first to examine if experiences of maternal paid leave are associated with differences in child brain function in a relatively socio-demographically diverse sample of families, causal inferences cannot be drawn from the study but rather results contribute to the non-experimental literature on child outcomes of paid leave. There are other limitations and considerations to also keep in mind. First, we focus on experiences of the mother and do not include information about support from secondary caregivers or extended family members. More information about the role of specific household (e.g., government assistance, paid/unpaid leave by partners) or family (e.g., childcare, emotional support) resources are needed in future studies to better understand the context in which paid vs. unpaid leave may be most beneficial. Second, although results indicate that paid leave is a robust predictor of early brain function, it is important to note that these brain activation profiles are not diagnostic in any way and do not necessarily reflect atypical or deficient neural development. Previous studies have reported correlations between the illustrated EEG profiles within this study and maternal stress (S. John et al., 2017; Pierce et al., 2019; Troller-Renfree et al., 2020) as well as discrepancies in neurocognitive outcomes during childhood (Brito et al., 2016, 2019; Corning et al., 1986; Maguire & Schneider, 2019; McLaughlin et al., 2010). The first few years of life are an important period of neural plasticity and the brain is shaped to reflect the child's ongoing experiences through a path-dependent process. Instead of characterizing these differential patterns of EEG activation as "good" or "poor" brain development, these differences likely illustrate adjustments to unique early environmental contexts, which may or may not be adaptive as the child's unique environmental context continually changes as they grow and develop

(Werchan & Amso, 2017). Future studies replicating these preliminary findings with larger sample sizes should consider the role adaptation to the early environment may have on brain development and subsequent outcomes by incorporating behavioral outcomes that could be associated with infant's adaptive processing.

Despite an abundance of evidence across an array of fields (e.g., economics, public health, and now neuroscience) suggesting that increasing access to paid leave is related to a wide range of benefits for both mother and child, there is still resistance to this globally supported public policy within legislatures across the United States. Without a national policy of paid leave, inequities created by existing family leave policies and societal norms will continue to escalate – contributing to even greater disparities in maternal and infant outcomes, particularly for families of color. Black mothers, single mothers, and mothers with lower levels of educational attainment have been reported to have significantly less access to both paid and unpaid leave than the national average (Houser & Vartanian, 2012). Paid leave may aid in mitigating maternal and infant mortality and hospitalization rates (Berger & Waldfogel, 2004; Jou et al., 2018), incidences of maternal mental health diagnoses (Mandal, 2018), and disparities in child developmental outcomes (Kozak et al., 2021). At the time of writing, 12 weeks of paid family leave has been proposed as part of the American Family Plan by the Biden Administration to be phased in over 10 years (White House Brief, 2021). Eligibility criteria for this leave needs to be lenient so that the majority of the population can qualify, particularly the most under-resourced families, with wage replacement benefits high enough that households can maintain economic stability. As a policy intervention, paid leave may permit mothers to physically and mentally recover from the many perinatal and postpartum challenges faced, as well as provide the opportunity to spend quality time with their new infant, potentially leading to reductions in sociodemographic health disparities and setting the stage healthy neurocognitive development.

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