Supplemental Material

Time-Frequency Decomposition of Event-Related Potentials

Event-related potentials (ERPs) are often scored by calculating an average of activity in a particular time-window following an event of interest (Luck, 2014). However, neural activity in a given time-window contains the summed activity of many thousands, or even millions, of neurons firing simultaneously (Luck, 2014); that is, psychological processes (e.g., sensory, cognitive, affective, motor) often occur concurrently, and depending on how relevant electrical signals are conducted to the level of the scalp, an observed ERP waveform may reflect activation of multiple populations of neurons underlying multiple psychological phenomena (Weinberg, Ethridge, Ait Oimeziane, & Foti, in press). One approach to addressing this problem is time-frequency decomposition, which involves differentiating overlapping neural signals based on their relative power at different frequencies of electrical activity (Bernat, Williams, & Gehring, 2005; Herrmann, Rach, Vosskuhl, & Strüber, 2014). Critically, power in different spectral frequency bands may be differentially associated with important individual differences, such as risk for depression (Nelson et al., 2018).

It has been suggested that the RewP is composed of oscillations in multiple frequency bands including delta (~1-4 Hz) and theta (~4-8 Hz; Bernat et al., 2015). In the time-window of the RewP, activity in the delta frequency has been shown to be particularly sensitive to the receipt of reward feedback, while activity in the theta frequency has been shown to be particularly sensitive to loss, or nonreward, feedback (Bernat et al., 2015). Additionally, initial evidence suggests that reward-related delta activity may have a neural generator in the striatum, while loss-related theta activity may have a neural generator in the anterior cingulate cortex (Foti et al., 2015). Together these findings indicate that different neuroelectric frequencies of activity

associated with the RewP may demonstrate distinct associations with depression-related risk factors, and abnormalities in these different frequencies may have unique implications for the development of psychopathology. Thus, the present work examined the traditional time-domain scored RewP as well as delta and theta power within the time-window of the RewP for two primary reasons: 1) to assess whether time-frequency decomposition provided unique information as compared to the time-domain domain scored RewP in examining intergenerational associations and depression risk across adolescence; and 2) to assess whether these data supported previous evidence suggesting that power in the delta frequency, specifically, is linked to depression risk.

Daughter Age and Neural Response to Reward

The intergenerational concordance and depression risk analyses reported in Tables 3 and 4 in the main body of the manuscript, respectively, were repeated with daughter age in years as an independent variable instead of Pubertal Development Scale (PDS) scores. As reported in Tables A and B, results were largely consistent with those described in the manuscript. We were primarily interested in the mother gain response by daughter development and mother depression status by daughter development interactions predicting daughter gain response in the delta frequency, and we found that these effects were comparable across PDS and age analyses (mother delta gain interaction: PDS β = .34, age β = .33; mother depression status interaction: PDS β = -.32, age β = -.26). However, there were some minor differences between the PDS and age analyses. For instance, for the intergenerational concordance analyses in the time-domain (Table A), the mother loss by age interaction was not statistically significantly associated with daughter gain response *(b* = -2.11, standard error = 1.17, p = .08), although the β values were comparable (PDS β = -.24, age β = -.20). Similarly, in the delta frequency, mother gain response was not significantly associated with daughter gain response (b = -0.43, standard error = 0.22, p = .06) but again the β values were comparable (PDS β = -.24, age β = -.23). Overall, the same effects of interest were evident when both PDS and age were used as measures of development; however, it is important to note that daughter age was reported in years, making it a coarser measure of development than PDS scores.

Table A. *Simultaneous regressions examining the moderating effect of daughters' age on associations between mothers' and daughters' neural responses.*

Predictor	*b* (SE)	95% CI	*β*
	Time-Domain (predicting gain)		
Daughter loss	0.90 (0.08)	[0.74, 1.06]	.77***
Daughter age	0.30 (0.61)	[-0.91, 1.52]	.03
Mother gain	-0.28 (1.10)	[-2.47, 1.91]	-.03
Mother loss	0.77 (1.11)	[-1.42, 2.97]	.09
Mother gain*Daughter age	0.99 (1.12)	[-1.24, 3.22]	.10
Mother loss*Daughter age	-2.11 (1.17)	[-4.44, 0.22]	-.20
		Total R^2 = .61, F(6, 88) = 23.36, p < .001	
	Delta Frequency (predicting gain)		
Daughter delta loss	0.78 (0.13)	[0.52, 1.03]	.53***
Daughter age	-0.10 (0.16)	[-0.42, 0.23]	-.05
Mother delta gain	-0.43 (0.22)	[-0.87, 0.01]	-.23
Mother delta loss	0.69 (0.21)	[0.27, 1.10]	.37**
Mother delta gain*Daughter age	0.64 (0.28)	[0.09, 1.19]	.33*
Mother delta loss*Daughter age	-0.37 (0.23)	[-0.82, 0.09]	-.22
		Total R^2 = .34, F(6, 87) = 7.44, p < .001	
	Theta Frequency (predicting loss)		
Daughter theta gain	0.60 (0.11)	[0.38, 0.82]	.56***
Daughter age	0.15 (0.16)	[-0.17, 0.47]	.09
Mother theta gain	0.26 (0.16)	[-0.06, 0.57]	.16
Mother theta loss	-0.15 (0.16)	[-0.48, 0.17]	-.10
Mother theta gain*Daughter age	0.04 (0.16)	[-0.28, 0.36]	.03
Mother theta loss*Daughter age	0.08 (0.14)	[-0.19, 0.35]	.07
		Total R^2 = .30, F(6, 85) = 6.01, p < .001	

Note. *p < .05, **p < .01, *** p < .001.

Table B. *Simultaneous regressions examining the moderating effect of maternal depression status on associations between daughters' age and neural responses.*

Predictor	*b* (SE)	95% CI	*β*
	Time-Domain (predicting gain)		
Daughter loss	0.85 (0.11)	[0.63, 1.07]	.69***
Daughter age	0.64 (0.77)	[-0.90, 2.17]	.07
Mother depression	-0.69 (0.77)	[-2.23, 0.85]	-.08
Daughter age*Mother depression	0.40 (0.76)	[-1.12, 1.93]	.05
		Total R^2 = .52, $F(4, 62) = 16.95$, $p < .001$	
	Delta Frequency (predicting gain)		
Daughter delta loss	0.65 (0.17)	[0.30, 1.00]	.42***
Daughter age	-0.11 (0.21)	[-0.52, 0.31]	-.06
Mother depression	-0.04 (0.21)	[-0.46, 0.38]	-.02
Daughter age *Mother depression	-0.49 (0.21)	[-0.92, -0.07]	-.26*
		Total R^2 = .29, $F(4, 61) = 6.36$, $p < .001$	
	Theta Frequency (predicting loss)		
Daughter theta gain	0.65 (0.14)	[0.37, 0.93]	.58***
Daughter age	0.33 (0.22)	[-0.11, 0.76]	.19
Mother depression	-0.34 (0.19)	[-0.72, 0.05]	-.19
Daughter age *Mother depression	0.06 (0.19)	[-0.32, 0.44]	.03
		Total R^2 = .28, $F(4, 61) = 5.90$, $p < .001$	

Note. *$p < .05$, *** $p < .001$. "Mother depression" = mother depression history based on SCID-5.

Adult-Child Concordance and Pubertal Development

The intergenerational concordance analyses reported in Table 3 in the main body of the manuscript were repeated with randomly paired adults and adolescents. The aim of these analyses was to examine whether the moderating effects of PDS on mother-daughter neural associations were due to the familial nature of these responses, or whether developmental shifts in neural associations would be evident when comparing any adult-adolescent pair. As reported in Table C, no significant moderating effects were found with randomly paired dyads, supporting the notion that development of the positive valence system may be, at least in part, familial.

Table C. *Simultaneous regressions examining the moderating effect of pubertal development on associations between adult and adolescent neural responses.*

Predictor	*b* (SE)	95% CI	*β*
	Time-Domain (predicting gain)		
Adolescent loss	0.92 (0.09)	[0.75, 1.09]	.76***
PDS	-0.35 (0.66)	[-1.67, 1.00]	-.04
Adult gain	0.11 (1.20)	[-2.28, 2.49]	.01
Adult loss	-0.11 (1.19)	[-2.47, 2.26]	-.01
Adult gain*PDS	-0.67 (1.60)	[-3.85, 2.52]	-.09
Adult loss*PDS	1.65 (1.43)	[-1.19, 4.49]	.25
		Total R^2 = .59; $F(6, 86) = 20.72$, $p < .001$	
	Delta Frequency (predicting gain)		
Adolescent delta loss	0.65 (0.14)	[0.37, 0.92]	.45***
PDS	-0.09 (0.18)	[-0.45, 0.28]	-.05
Adult delta gain	0.15 (0.23)	[-0.31, 0.60]	.08
Adult delta loss	-0.29 (0.23)	[-0.74, 0.17]	-.16
Adult delta gain*PDS	0.05 (0.20)	[-0.35, 0.45]	.03
Adult delta loss*PDS	-0.03 (0.26)	[-0.55, 0.48]	-.02
		Total R^2 = .23; $F(6, 85) = 4.15$, $p = .001$	
	Theta Frequency (predicting loss)		
Adolescent theta gain	0.48 (0.12)	[0.24, 0.72]	.46***
PDS	-0.03 (0.18)	[-0.39, 0.34]	-.02
Adult theta gain	0.13 (0.18)	[-0.23, 0.48]	.08
Adult theta loss	0.21 (0.18)	[-0.14, 0.56]	.13
Adult theta gain*PDS	-0.14 (0.18)	[-0.50, 0.22]	-.08
Adult theta loss*PDS	-0.07 (0.18)	[-0.42, 0.29]	-.04
		Total R^2 = .23; $F(6, 83) = 4.24$, $p = .001$	

Note. *** $p < .001$.

Maternal Depression History Including Subthreshold Diagnoses

The depression risk analyses reported in Table 4 in the main manuscript were repeated including the three mother-daughter dyads previously excluded due to the mother participant meeting criteria for only a subthreshold major depressive episode in her life. As is shown in Table D, the previously reported effects did not change as a result of including these participants.

Table D. *Simultaneous regressions examining the moderating effect of maternal threshold and subthreshold depression status (combined threshold and subthreshold diagnoses) on associations between pubertal development and daughters' neural responses.*

Predictor	*b* (SE)	95% CI	*β*
	Time-Domain (predicting gain)		
Daughter loss	0.83 (0.11)	[0.62, 1.05]	.69***
PDS	0.08 (0.76)	[-1.45, 1.61]	.01
Mother depression	-0.73 (0.76)	[-2.24, 0.78]	-.09
PDS*Mother depression	0.16 (0.75)	[-1.33, 1.65]	.02
		Total R^2 = .51 F(4,65) = 16.92, p < .001	
	Delta Frequency (predicting gain)		
Daughter delta loss	0.67 (0.16)	[0.34, 1.00]	.44***
PDS	0.05 (0.20)	[-0.35, 0.46]	.03
Mother depression	-0.001 (0.20)	[-0.41, 0.41]	.00
PDS*Mother depression	-0.52 (0.20)	[-0.92, -0.12]	-.28*
		Total R^2 = .29; F(4,64) = 6.53, p < .001	
	Theta Frequency (predicting loss)		
Daughter theta gain	0.55 (0.13)	[0.28, 0.81]	.49***
PDS	0.03 (0.21)	[-0.40, 0.45]	.02
Mother depression	-0.29 (0.19)	[-0.67, 0.09]	-.17
PDS*Mother depression	0.13 (0.19)	[-0.25, 0.51]	.08
		Total R^2 = .26; F(4,64) = 5.49, p =.001	

Note. *p < .05, *** p < .001.

Table E. *Descriptive statistics for demographics, lifetime diagnostic information for mothers and never-depressed daughters included in the depression risk analyses.*

		Mother Depression Group *n* = 30	Mother Healthy Control Group *n* = 37
Mothers			
Demographics	Age (*M*(*SD*))	43.80 (6.74)	46.19 (4.86)
	Ethnicity (% Caucasian)	77%	84%
	Median family income	$60,000 to $79,000	$100,000 to $149,000
Lifetime diagnoses	Anxiety or Related Disorder[1] (% positive)	50%	.05%[2]
	Lifetime Substance Use Disorder	17%	0 %
Daughters			
Demographics	Age (*M*(*SD*))	13.47 (2.60)	13.70 (2.32)
	PDS (*M*(*SD*))	3.05 (0.91)	3.05 (0.78)
	Ethnicity (% Caucasian)	63%	65%
Lifetime diagnosis	Anxiety or Related Disorder (% positive)	27%	19%

Note. [1]e.g., Generalized anxiety disorder, social anxiety disorder, specific phobia, agoraphobia, separation anxiety disorder, obsessive-compulsive disorder, posttraumatic stress disorder. [2]Two healthy control mothers had a lifetime diagnosis of a specific phobia.

Current Symptoms of Depression and Neural Response to Reward

The depression risk analyses reported in Table 4 in the main manuscript were repeated using the full sample (i.e., not excluding participants based on diagnostic criteria described in the manuscript). In these analyses, instead of using categorical diagnostic information as was done in the main manuscript, depression was measured continuously based on self-reported symptoms over the two-week period prior to the laboratory visit. Mother symptoms were measured using the General Depression (GD) subscale of the Inventory of Depression and Anxiety Symptoms (IDAS-II; Watson et al., 2012) and daughter symptoms were measured using the Mood and Feelings Questionnaire (MFQ; Angold et al., 1995). Results from these analyses did not demonstrate significant associations between the independent variables and daughter neural responses, with the exception of daughter neural responses to loss (time-domain, delta) or gain (theta), which significantly predicted neural responses to the alternate type of feedback (see Table F).

While these findings might appear contradictory to those reported in the manuscript, evidence suggests that neural responses in the time-window of the RewP may be trait-like rather than state-like, and therefore, may be most appropriately considered potential markers of depression *proneness* rather than depression symptomatology (Bowyer et al., 2019; Kujawa, Hajcak, & Klein, 2019; Kujawa, Proudfit, & Klein, 2014; Weinberg & Shankman, 2017). We did not expect, therefore, that mothers' current symptoms of depression would be significantly associated with daughters' neural responses. Future work grounded in the RDoC framework may benefit from using continuous measures of lifetime psychopathology to examine the research questions addressed here, however, reliably obtaining dimensional measures of lifetime psychopathology remains an ongoing challenge for the field (e.g., Shankman et al., 2018).

Considering the evidence that mothers' current symptoms of depression may not be an ideal indicator of familial depression risk as it relates to reward dysfunction (Bowyer et al., 2019; Weinberg & Shankman, 2017), we also conducted depression risk analyses similar to those presented in Table 4 with mothers' depression history defined by SCID-5 diagnosis, but included all daughters with available data (i.e., not excluding daughters based on diagnostic criteria described in the manuscript) and adjusted for daughters' current depressive symptoms using MFQ scores as an independent variable. In these analyses we also included the interaction between daughter MFQ and PDS in addition to the interaction between mother depression history and PDS as independent variables. Results, presented in Table G below, replicated the findings from the initial analysis (Table 4), which found that the only significant interaction was between pubertal development (PDS) and mother depression history in predicting daughters' neural response to reward in the delta frequency. These supplemental analyses provide additional support for the findings discussed in the manuscript and further highlight the importance of examining developmental processes as they relate to risk for psychopathology within an RDoC context.

Table F. *Simultaneous regressions examining the moderating effect of mothers' current symptoms of depression on associations between pubertal development and daughters' neural responses to gain and loss.*

Predictor	*b* (SE)	95% CI	*β*
	Time-Domain (predicting gain)		
Daughter loss	0.90 (0.08)	[0.74, 1.07]	.77***
Daughter MFQ	-0.002 (0.04)	[-0.09, 0.09]	-.003
PDS	-0.33(0.66)	[-1.64, 0.98]	-.04
Mother GD	0.12 (0.65)	[-1.17, 1.41]	.01
PDS*Mother GD	0.24 (0.62)	[-0.99, 0.46]	.03
		Total R^2 = .59; $F(5, 88) = 24.96$, $p < .001$	
	Delta Frequency (predicting gain)		
Daughter delta loss	0.71 (0.14)	[0.44, 0.98]	.49***
Daughter MFQ	0.10 (0.40)	[-0.68, 0.89]	.03
PDS	-0.02 (0.19)	[-0.39, 0.35]	-.01
Mother GD	0.09 (0.18)	[-0.27, 0.45]	.05
PDS*Mother GD	-0.18 (0.17)	[-0.53, 0.16]	-.10
		Total R^2 = .25; $F(5, 87) = 5.86$, $p < .001$	
	Theta Frequency (predicting loss)		
Daughter theta gain	0.53 (0.11)	[0.31, 0.74]	.49***
Daughter MFQ	-0.21 (0.33)	[-0.87, 0.46]	-.06
PDS	0.07 (0.17)	[-0.27, 0.41]	.05
Mother GD	0.01 (0.15)	[-0.29, 0.31]	.01
PDS*Mother GD	-0.14 (0.15)	[-0.43, 0.15]	-.09
		Total R^2 = .25; $F(5, 87) = 5.84$, $p < .001$	

Note. *** $p < .001$. "GD" = General Depression subscale of the IDAS-II. "MFQ" = Mood and Feelings Questionnaire.

Table G. *Simultaneous regressions examining associations between lifetime maternal depression diagnosis and daughters' pubertal development, daughters' current depressive symptoms, and daughters' neural responses to gain and loss.*

Predictor	*b* (SE)	95% CI	*β*
	Time-Domain (predicting gain)		
Daughter loss	0.88 (0.09)	[0.70, 1.05]	.75***
Daughter MFQ	-0.15 (0.76)	[-1.66, 1.36]	-.02
PDS	-0.13 (0.85)	[-1.82, 1.57]	-.01
Mother depression	-0.39 (0.65)	[-1.68, 0.90]	-.04
Daughter MFQ*PDS	-0.87 (0.95)	[-2.75, 1.01]	-.09
Mother depression*PDS	0.11 (0.65)	[-1.17, 1.40]	.01
	Total R^2 = .57; $F(6, 82)$ = 18.20, p < .001		
	Delta Frequency (predicting gain)		
Daughter delta loss	0.71 (0.13)	[0.44, 0.97]	.48***
Daughter MFQ	0.16 (0.20)	[-0.24, 0.55]	.08
PDS	-0.02 (0.22)	[-0.45, 0.41]	-.01
Mother depression	-0.18 (0.17)	[-0.51, 0.15]	-.10
Daughter MFQ*PDS	-0.14 (0.24)	[-0.63, 0.34]	-.07
Mother depression*PDS	-0.58 (0.17)	[-0.91, -0.25]	-.32***
	Total R^2 = .36; $F(6, 81)$ = 7.42, p < .001		
	Theta Frequency (predicting loss)		
Daughter theta gain	0.57 (0.12)	[0.33, 0.81]	.51***
Daughter MFQ	-0.15 (0.18)	[-0.52, 0.21]	-.09
PDS	0.28 (0.22)	[-0.16, 0.72]	.18
Mother depression	-0.28 (0.15)	[-0.59, 0.02]	-.18
Daughter MFQ*PDS	0.21 (0.23)	[-0.25, 0.66]	.11
Mother depression*PDS	0.08 (0.16)	[-0.23, 0.39]	.05
	Total R^2 = .26; $F(6, 81)$ = 4.63, p < .001		

Note. *** $p \leq .001$. "MFQ" = Mood and Feelings Questionnaire.

Sensitivity Analyses

Sensitivity analyses using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) were conducted to establish the smallest effect size we had at least 80% power to detect with α error probability set to .05

Table H. *Sensitivity analyses depicting smallest detectable effects with 80% power and α* error probability set to 0.05.

	f^2	R^2
Intergenerational Concordance Analyses (predictors = 6)		
Time-Domain (n = 95)	.08	.08
Delta (n = 94)	.09	.08
Theta (n = 92)	.09	.08
Depression Risk Analyses (predictors = 4)		
Time-Domain (n = 67)	.12	.11
Delta and Theta (n = 66)	.12	.11

Supplemental References

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