

# Development of temperamental regulation of infants at 6 and 24 months: Associations with maternal soothing and distress

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## Abstract

**Background and Aims:** In the neurobiological theory of attention, the orienting network mainly supports the temperamental regulatory function in infancy, with soothing methods such as visual attention distraction influencing its development. The attention distraction method chosen for soothing is thought to be influenced by maternal sensitivity, which has been found to decrease with poor maternal mental health. We hypothesize that the degree of maternal distress may affect the choice of attention distraction soothing method. Further, individual differences in being soothed by attention distraction will be associated with the temperamental regulation function in infancy/toddlerhood.

**Method:** Structural equation modeling (SEM) was conducted on longitudinal data at 6 and 24 months on a sample ( $N = 1892$ ) drawn from the sub-cohort of the Japan Environment and Children's Study (JECS). Temperament was examined through the short Infant Behavior Questionnaire-Revised (Japanese version) and the Early Childhood Behavior Questionnaire (Japanese version). Distress in caregivers was measured through the Kessler Psychological Distress Scale (Japanese version) at prenatal and 1-year-postnatal stages. Individual differences in using visual distraction soothing methods were also measured using tailor-made items.

**Results:** Postnatal maternal distress at 12 months was negatively related to the tendency to use visual attention distraction as a soothing method ( $\beta = -0.06$ ,  $p = 0.006$ ) at 24 months. When we applied the subscale of the temperamental regulatory factor in SEM, the more the mothers chose the distraction method for soothing, i.e., the more the toddlers experienced it, the higher their attention shifting scores ( $\beta = 0.07$ ,  $p = 0.002$ ).

**Conclusion:** The findings support the view that caregivers' choice of method for distracting offspring's attention from distress may be associated with the development of self-regulation during infancy and toddlerhood.

## KEYWORDS

distraction, longitudinal study, maternal distress, soothing, temperament

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## 1 | BACKGROUND

Recent neuroscience studies have clarified the framework for temperament research, showing that the development of attention, including the control of orienting and the development of executive attention, is involved in the major basis for the development of self-regulation.<sup>1</sup> These studies define temperament as constitutional individual differences in reactivity and self-regulation in emotion, activity, and attention.<sup>2</sup> Even in infancy, there is evidence for a broad dimension of positive reactivity, negative affectivity, and a regulatory factor that may include contributions from both caregiver and individual self-regulation. The infant's orientation to distractors presented by the caregiver during crying provides an early example of such emotional regulation.<sup>3</sup>

The orientation of attention appears to suppress the expression of the brain's computations of emotion.<sup>4</sup> In early infancy, this control primarily involves the orienting attention network, including the parietal lobe and frontal eye fields, with dramatic development taking place during the first 12 months of life. By age 3 to 4 and soon after, another attentional regulation dimension, the frontal executive attention network, which involves the anterior cingulate and basal ganglia, takes over this control role.<sup>5</sup> From infancy to toddlerhood, the connectivity of brain structures also changes, and self-regulation is now called "effortful control," defined as the ability to voluntarily regulate both behavior and attention.

The manner in which infants are soothed may play a role in the growth of connections between the orienting and executive attention networks.<sup>6</sup> Referring to the psychobiological theory of attention,<sup>5</sup> soothing methods such as visual attention distraction may facilitate the development of temperamental self-regulation. The effect of maternal soothing behaviors in reducing infant reactivity has been investigated in infant inoculation contexts.<sup>7-9</sup> Lewis and Ramsay conducted two longitudinal studies of infants aged 2 and 6 months using adrenocortical functioning as a measure of infant stress response and also examined daily distress unrelated to inoculation.<sup>7</sup> Though consistency was found in the pattern of maternal soothing method, no relationship was found between maternal soothing and infants' stress response. However, even if soothing methods do not affect the stress response itself, adrenocortical functioning, a fine-grained analysis of specific maternal soothing behaviors, might have resulted in different findings.

In response, Jahromi et al. examined changes in mothers' behaviors to reflect infants' developmental maturation in an inoculation context at 2 and 6 months using eight categories of maternal soothing behaviors.<sup>8,9</sup> One of these, namely distraction, was defined as the mother making overt attempts to direct the infant's attention away from the continued discomfort caused by the shot. The results indicated that distraction was not effective at the highest level of distress, including injections administered to infants, which may be consistent with previous studies.<sup>10,11</sup>

In Nakagawa & Sukigara,<sup>11</sup> 189 infants were investigated longitudinally through questionnaires to examine the effects of soothing strategies on the early development of temperament. To assess

### Keynotes

- In the neurobiological temperament model, the orienting attention network mainly supports the regulatory function in infancy, with soothing methods, including visual attention distraction, influencing its development.
- In the sub-cohort of the Japan Environment and Children's Study, the relationship between maternal distress and mothers' choice of distraction as a soothing method and between the degree of being soothed by distraction and infants/toddlers' regulatory function were examined at 6 and 24 months ( $N = 1892$ ).
- Higher maternal distress at 12 M postpartum was associated with fewer distraction methods, and more distraction at 24 M was associated with higher attention shifting at 24 M.

temperament, the researchers implemented the Infant Behavior Questionnaire-Revised (IBQ-R)<sup>12</sup> with infants as well as the Early Childhood Behavior Questionnaire (ECBQ)<sup>13</sup> with toddlers. In addition, caregivers were given 20 scenarios<sup>14</sup> in which infants and toddlers showed negative emotionality and asked to choose one of five options representing possible actions in each scenario: Cuddling/Giving love, Visually distracting, Offering drinks or snacks, Waiting for the infant/toddler to fall quiet, and Not applicable. The results of correspondence analysis revealed that the soothing method chosen depended on the situation.<sup>11</sup> For example, physiological pain such as that resulting from an injection or startling stimuli such as a wailing siren were strongly linked to methods of cuddling and giving love but not to visual attention distraction. In other words, the study revealed that the method used to distract visual attention such as drawing the infant's attention to novel objects or activities was generally associated with situations of frustration in which things did not go as the child expected. Regarding the relationship with temperament, maternal use of distracting as a soothing technique during infancy was found to be positively associated with higher Negative Affect in toddlers at 24 months.<sup>11</sup> Although this finding did not support the researchers' hypothesis, it may be consistent with evidence that more maternal soothing was associated with less rapid infant quieting, suggesting that infant temperament influences maternal soothing rather than maternal soothing influencing infant temperament.<sup>7</sup>

Soothing methods are known to be affected by maternal sensitivity.<sup>15</sup> However, the choice of distraction method has been found not to be stable over time compared to other soothing methods such as holding, touching, or feeding. This choice is most likely linked to the mothers' perception of whether her child is sufficiently developed to respond to it.<sup>9</sup> In other words, it may be related to maternal sensitivity, that is, whether mothers adjust their use of individual behaviors to match their infants' development. In turn, this form of maternal sensitivity is closely related to the caregiver's mental health.<sup>16-18</sup>

In relation to the above, the effect of postpartum depression (PPD) treatment on infant emotion regulation was investigated utilizing robust multimethod assessments at both physiological and behavioral levels.<sup>19</sup> Participants were 40 infants (Mean age: 5.6 months; SD 2.7) mothers with major depressive disorder in the first postpartum year and 40 healthy control infants (Mean age: 5.9 months; SD 2.6) of nondepressed mothers. The infants were matched one-to-one in terms of age, gender, and family's socio-economic status. Only mothers with PPD received 9-week cognitive behavioral therapy (CBT). In the first visit following the first CBT session, poor emotion regulation was found in infants of mothers with PPD relative to the healthy control group (the baseline visit for infants). However, in the second visit after the maternal PPD treatment was completed, these mothers' infants displayed adaptive changes in physiological and behavioral measures of improved regulation of emotion. That is, previously observed signs of poor infant emotion regulation such as greater right frontal electroencephalographic alpha asymmetry (FAA) in resting state, lower heart rate variability (HRV), and low scores on the temperament Orienting/Regulation scale in IBQ-R as measured through multimethod assessment generally improved.

To elucidate the putative mechanisms through which PDD interventions may change infant emotion regulation, the authors also investigated associations between changes in maternal depression (as assessed by the Edinburgh Postnatal Depression Scale), bonding (the general factor scale of the Postpartum Bonding Questionnaire), maternal emotion regulation (the neuroticism subscale of the Revised NEO Personality Inventory), and the infant emotion regulatory function.<sup>19</sup> However, as neither form of maternal mental change accounted for changes in infants, the authors suggested that improvements in the maternal ability to predict and anticipate their infants' needs may play a role in changing infant emotion regulation.<sup>20</sup>

According to the above-mentioned temperamental theory,<sup>5</sup> the increase in the Orienting/Regulation score observed in subsequent CBT for PPD mothers showed improvements in the functioning of the orienting attention network in infancy. While it is not easy to specify the reasons for this finding, one possibility is that following PPD relief through CBT, mothers with improved maternal sensitivity may be able to use visual distraction soothing techniques adapted to their child, which may facilitate attentional control in these infants.<sup>21</sup>

In response, our longitudinal study of infants and toddlers aged 6 to 24 months analyzed the influence of visual attention distraction on early temperamental regulation in terms of soothing techniques by mothers. We hypothesize that adequate maternal use of distracting as a soothing technique during infancy is related to maternal sensitivity, which may be influenced by psychological distress. Our hypotheses are: (1) As regards mothers, the stronger the degree of psychological distress, the lower the tendency to use visual attention distraction methods for soothing, and (2) As regards infants and toddlers, the more attention distraction is experienced, the higher the temperamental regulatory function.

## 2 | METHOD

### 2.1 | Recruitment and procedure

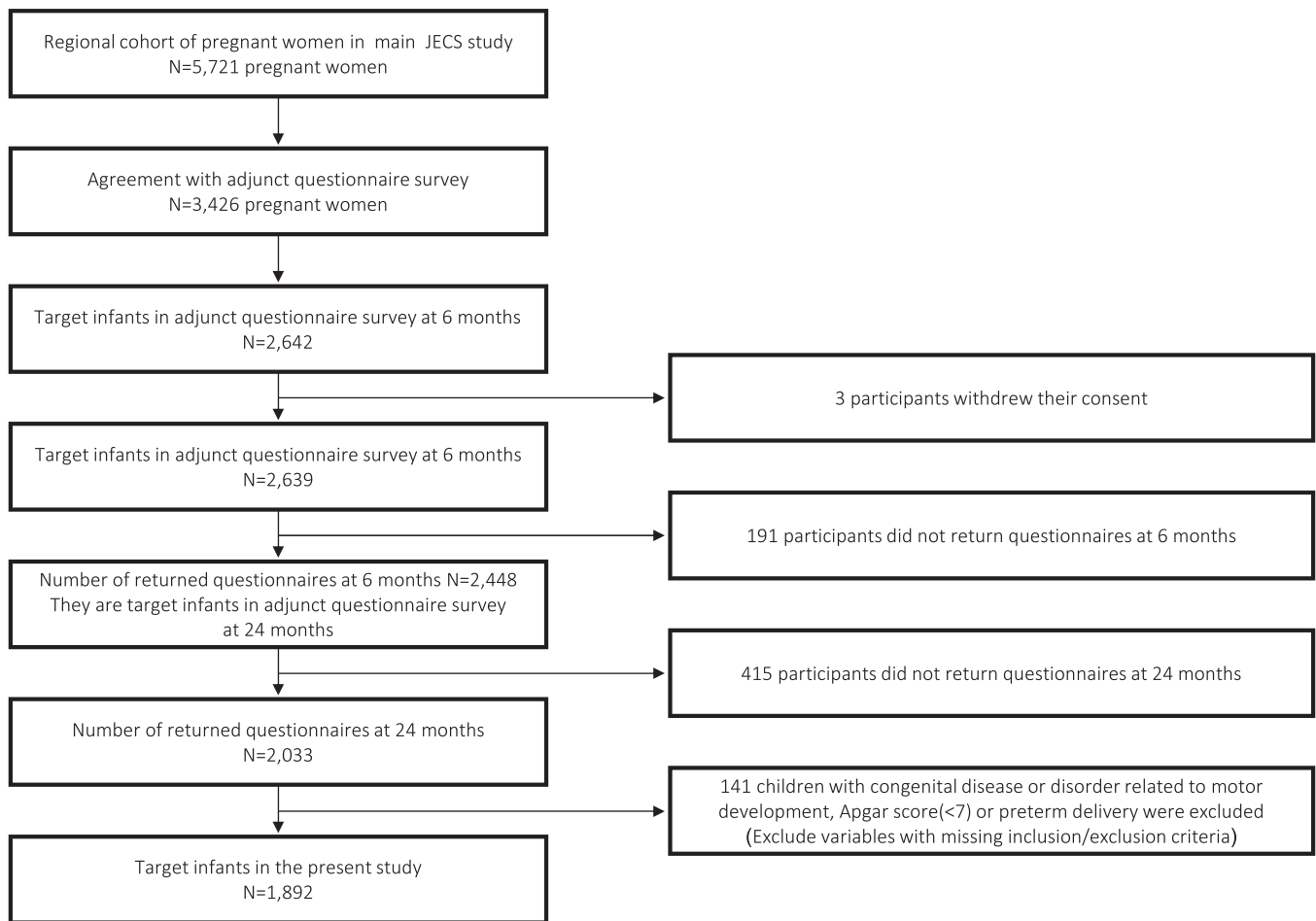
This research involved the Aichi Regional Sub-cohort of the Japan Environment and Children's Study (JECS) funded by Japan's Ministry of the Environment as an Adjunct Study. All procedures involving human subjects in the JECS protocol were reviewed and approved by the Institutional Review Board on Epidemiological Studies of the Ministry of the Environment (Ethical No.100910001) and the Ethics Committees of the Nagoya City University Graduate School of Medical Sciences (Approval No. 60-00-0574). Participants were part of the Aichi Regional Sub-cohort of the JECS project (JECS-A) of infants born from mothers recruited between 2011 and 2014. This included 5721 pregnant women residing in Ichinomiya City and Nagoya City along with their 5554 infants.<sup>22</sup> This sample was predominantly Asian by race, similar to the demographics of Japan's vital statistics. Written informed consent was obtained from all participants. Starting in August 2013, self-administered questionnaires were sent out and filled out by the mothers. Responses were mailed and collected until October 2017.

Figure 1 consists of a flowchart showing the inclusion process followed in this study. Of the 5721 mothers initially contacted, 3426 agreed to participate in the study, of whom 2642 were sent a questionnaire 6 months about their child's life. After three participants later withdrew their consent, 191 participants who did not return the questionnaire were removed from the remaining 2639 participants. Further, 2033 questionnaires were returned at 24 months. Additionally, 141 children with congenital diseases or disorders related to motor development with an Apgar score of <7 either 1 min or 5 min after birth or preterm delivery (< 37 weeks) were excluded. Finally, responses from 1892 mothers, including three mothers of twins, were analyzed. Mothers completed the questionnaires from the onset of pregnancy to their child's second birthday. Following MacCallum et al.,<sup>23</sup> the minimum sample size was 782 based on a preliminary calculation (Alpha = 0.05; degrees of freedom in the SEM model = 10; desired power = 0.80; null root mean square error of approximation [RMSEA] = 0.05; alternative RMSEA = 0.08). Thus we judged that our sample size was satisfactory.

Maternal distress was assessed during mid- to late pregnancy (the prenatal stage) and at the time the infants were 1 year old (the postnatal stage). Temperament and soothing methods were measured at 6 and 24 months.

### 2.2 | Maternal distress

The Japanese version of the Kessler Psychological Distress Scale<sup>24</sup> is a 6-item inventory designed to screen for depressive and anxiety disorders, which asks respondents how frequently they experienced the following six symptoms over the previous 30 days: (1) nervousness; (2) hopelessness; (3) restlessness or fidgeting; (4) depression



**FIGURE 1** Participant flow diagram.

such that nothing can cheer them up; (5) feeling that everything is an effort; and (6) worthlessness. Items were self-rated on a five-point scale ranging from 0 = “none of the time” to 4 = “all of the time,” with higher scores indicating a greater tendency toward mental illness. Total scores were categorized as negligible (1–4), mild (5–8), moderate (9–12), and serious (13–24).<sup>25,26</sup>

### 2.3 | Soothing methods

Referring to Nakagawa and Sukigara,<sup>11</sup> two scenarios were noted in which caregivers are more likely to choose visual attention distraction methods. Generally speaking, in situations where things are not going as the child would like, thus causing compassion in mothers, infants are likely to experience a visual distraction soothing method. At 6 and 24 months, mothers were presented these two scenarios and asked to select one of six options that best described their offspring's behavior in each situation:

**Situation 1:** Your child starts crying when he or she tries to reach some item that should not be touched in a store and is told “NO.”

**Situation 2:** Your child becomes distressed when he or she is confined to a restricted space (infant or car seat, playpen, etc.).

The six response options were: (1) Cuddling or giving love; (2) Distracting or attracting the child's attention to a novel object or event; (3) Offering drinks or snacks; (4) Waiting for the child to fall quiet; (5) Not attempting to soothe the child because he or she neither cries nor fusses; (6) Does not apply. At 6 and 24 months, we counted the total frequency of Option (2) being selected (total score range: 0–2), respectively. Lower scores indicated less experience with being soothed through visual attention distraction.

### 2.4 | Temperament

Temperament was assessed through the modified Japanese short version of the IBQ-R<sup>27</sup> and the short version of the ECBQ.<sup>28</sup> The questionnaire elicits data on the frequency of occurrence of temperament-related behaviors over the past 1–2 weeks on a seven-point scale from Never (1) to Always (7). Factor analyses of scores on these questionnaires generated the typical three-factor framework.<sup>29</sup> In addition to the two broad factors of Positive Emotionality/Surgency and Negative Affect, a third factor, namely Effortful Control, was extracted at 24 months, emerging as Orienting/Regulation in infants aged 3 to 12 months. All of these factors have been replicated by several cross-cultural and psychometric

**TABLE 1** Characteristics of variables in this study (categorical).

Characteristics	n	%
Child sex		
- Female	948	(50.1)
- Male	944	(49.9)
- Missing	0	
Mother's highest level of education		
- High school or lower	574	(30.3)
- Junior or vocational college	699	(36.9)
- University or higher	604	(31.9)
- Missing	15	
Partner's highest level of education		
- High school or lower	599	(31.7)
- Junior or vocational college	308	(16.3)
- University or higher	957	(50.6)
- Missing	28	
Maternal age		
- <20	13	(0.7)
- 20-29	647	(34.2)
- 30-39	1137	(60.1)
- ≥40	95	(5.0)
- Missing	0	
Annual household income (10,000JPY)		
- <200	40	(2.1)
- 200-400	490	(25.9)
- 400-600	651	(34.4)
- 600-800	350	(18.5)
- 800-1000	156	(8.2)
- ≥1000	82	(4.3)
- Missing	123	
Maternal smoking habit		
- Nonsmoker	1258	(66.5)
- Ex-smoker	578	(30.5)
- Current smoker	32	(1.7)
- Missing	24	
Existence of child siblings at around one month postpartum		
- No	832	(44.0)
- Yes	1057	(55.9)
- Missing	3	
Parental maternal distress: Mid-late pregnancy, K6		
- Negligible: 0-4-	1347	(71.2)
- Mild: 5-8	352	(18.6)

**TABLE 1** (Continued)

Characteristics	n	%
- Moderate: 9-12	118	(6.2)
- Severe: ≥13	67	(3.5)
- Missing	8	
Postnatal maternal distress: 1 month after delivery, K6		
- Negligible: 0-4-	1407	(74.4)
- Mild: 5-8	285	(15.1)
- Moderate: 9-12	108	(5.7)
- Severe: ≥13	64	(3.4)
- Missing	28	

Abbreviation: K6, Kessler Psychological Distress Scale.

Note. Three sets of twins were included.

investigations.<sup>30-32</sup> The recommended scale calculations based on these factors have been used in hundreds of empirical studies, and we retained this scoring method to maintain consistency with prior studies. Moreover, we applied the soothability scale (e.g., When singing or talking to your baby, how often did s/he soothe immediately?) at 6 months and the attentional-shifting scale at 24 months (e.g., When playing outdoors, how often did your child look immediately when you pointed at something?), both of which are subscales of the temperamental regulatory factor.

## 2.5 | Potential covariates

Based on previous reports that lower household income is associated with higher risk of PPD<sup>33</sup> or mothers' distress,<sup>34</sup> this could be accounted for as a covariate factor. Annual household income (below JPY 200, 200 to 400, 400 to 600, 600 to 800, 800 to 1000, and 1000 or higher × 10,000 [approximately USD 1 = JPY 152 as of August 2024]) was elicited in the questionnaire during the second or third trimesters. Relevant covariates included child gender (female or male), mother's highest level of education (high school or below, junior or vocational institution, university or above), partner's highest level of education (high school or below, junior or vocational institution, university or above), mother's age (during the second or third trimester), maternal smoking habit (Nonsmoker, ex-smoker, or current smoker; second or third trimester), existence of child sibling(s) (1 month after delivery), pregnancy (delivery) weeks (total, days), and child's birth weight (g). Finally, our adjunct JECS study extracted these variables from the questionnaire used in the main JECS study.

## 2.6 | Quantitative analysis

We employed IBM SPSS Statistics 25.0 (SPSS Inc.) to conduct descriptive statistics and correlation analysis and AMOS 25.0 (SPSS Inc.) to evaluate the possible relationship between maternal

**TABLE 2** Characteristics of variables in this study (continuous).

	<i>n</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	( <i>SD</i> )
Pregnancy (delivery) weeks (total, days)	1892	259.00	297.00	276.43	(7.92)
Child's birth weight (g)	1890	1784	4542	3089	(379)
Distraction at 6 M	1867	0.00	2.00	0.65	(0.70)
Orienting at 6 M	1892	2.61	6.92	4.97	(0.71)
Soothability at 6 M	1890	1.00	7.00	5.13	(1.05)
Distraction at 24 M	1822	0.00	2.00	0.99	(0.72)
Effortful control at 24 M	1889	2.16	6.63	4.53	(0.59)
Attention shifting at 24 M	1889	1.00	7.00	4.84	(0.83)

Note. Orientating Scale includes subscales of Duration of Orienting, Low Intensity Pleasure, Soothability and Cuddliness.

Effortful control Scale includes subscales of Duration of Orienting, inhibitory control, Attention Shifting, Low Intensity Pleasure and Cuddliness.

distress and infants' and toddlers' temperament by structural equation modeling (SEM). Twins were nested under their mother. Based on a previous study,<sup>11</sup> we drew assumed paths between maternal distress, soothing method, and temperamental variables. In our model, prenatal and postnatal maternal distress might subsequently influence how mothers soothe their offspring, in other words how mothers choose a distraction soothing method, which may represent individual differences in being soothed by a specific distraction method. As we hypothesize that the more experience caregivers have with attention distraction soothing methods, the more self-regulatory functions (i.e., Orienting at 6 months and Effortful Control at 24 months) will be promoted, we drew these paths at 6 and 24 months, respectively. In addition, given consistent evidence that maternal distress is associated with negative affect and difficult temperament,<sup>35</sup> we drew paths from maternal distress and temperament directly at 6 and 24 months, respectively. Household income was included for a control variable for maternal distress (see the first paragraph of Results). To assess model fit, model validity was assessed using the goodness of fit index (GFI) and adjusted goodness of fit index (AGFI) as well as the following indices: the chi-square statistic ( $\chi^2$ ), comparative fit index (CFI), and root mean square error of approximation (RMSEA). Missing data were handled by applying a Full Information Maximum Likelihood (FIML) estimation drawing on all available data to estimate model parameters without imputing missing values. The Akaike information criterion (AIC) was also used.

### 3 | RESULTS

The characteristics shown by mothers and infants are shown in Table 1. Table 2 reports descriptive information on trends in the use of soothing methods as well as temperamental variables at each time point, which are included as potential variables. In addition, correlation coefficients between Maternal Distress and the variables shown

in Tables 1 and 2 are presented in Table 3. Maternal Distress at both 6 and 12 months was significantly correlated with Household Income ( $r = -0.11$ ;  $r = -0.12$ ,  $ps < 0.001$ ) and Maternal Education ( $r = -0.08$ ,  $p < 0.001$ ;  $r = -0.07$ ,  $p = 0.005$ ). Since Household Income and Maternal Education were correlated ( $r = 0.28$ ,  $p < 0.001$ ), we chose the former because its coefficients were greater than 0.10 at both 6 and 12 m. In addition, Household Income was correlated with most Potential Covariates.

We tested the hypothesis that the stronger the degree of maternal distress, the lower the tendency to use visual attention distraction methods for soothing, and that infants and toddlers' temperamental regulation (i.e., Orienting/Regulation at 6 months, Effortful Control at 24 months) may be affected by caregivers' choice of visual distraction soothing method (Figure 2A). Household income as a control factor negatively influenced maternal distress during mid- to late pregnancy and 12 months after birth ( $\beta = -0.11$   $p < 0.001$ ;  $\beta = -0.06$   $p = 0.002$ ). Postnatal (1 year after birth) maternal distress was significantly negatively related to the tendency to use distraction soothing methods at 24 months ( $\beta = -0.06$ ,  $p = 0.006$ ) and negatively influenced Effortful Control ( $\beta = -0.11$ ,  $p < 0.001$ ). According to this model, the tendency to be soothed by attention distraction did not influence temperamental regulation in the infants or toddlers at either 6 or 24 months ( $\beta = -0.01$ ,  $p = 0.660$ ;  $\beta = 0.02$ ,  $p = 0.465$ ). While the model provided an acceptable fit to the data, it did not support our hypothesis;  $\chi^2(10) = 37.810$ ,  $p < 0.001$ ; GFI = 0.994; AGFI = 0.984; CFI = 0.965; RMSEA = 0.038; AIC = 73.810.

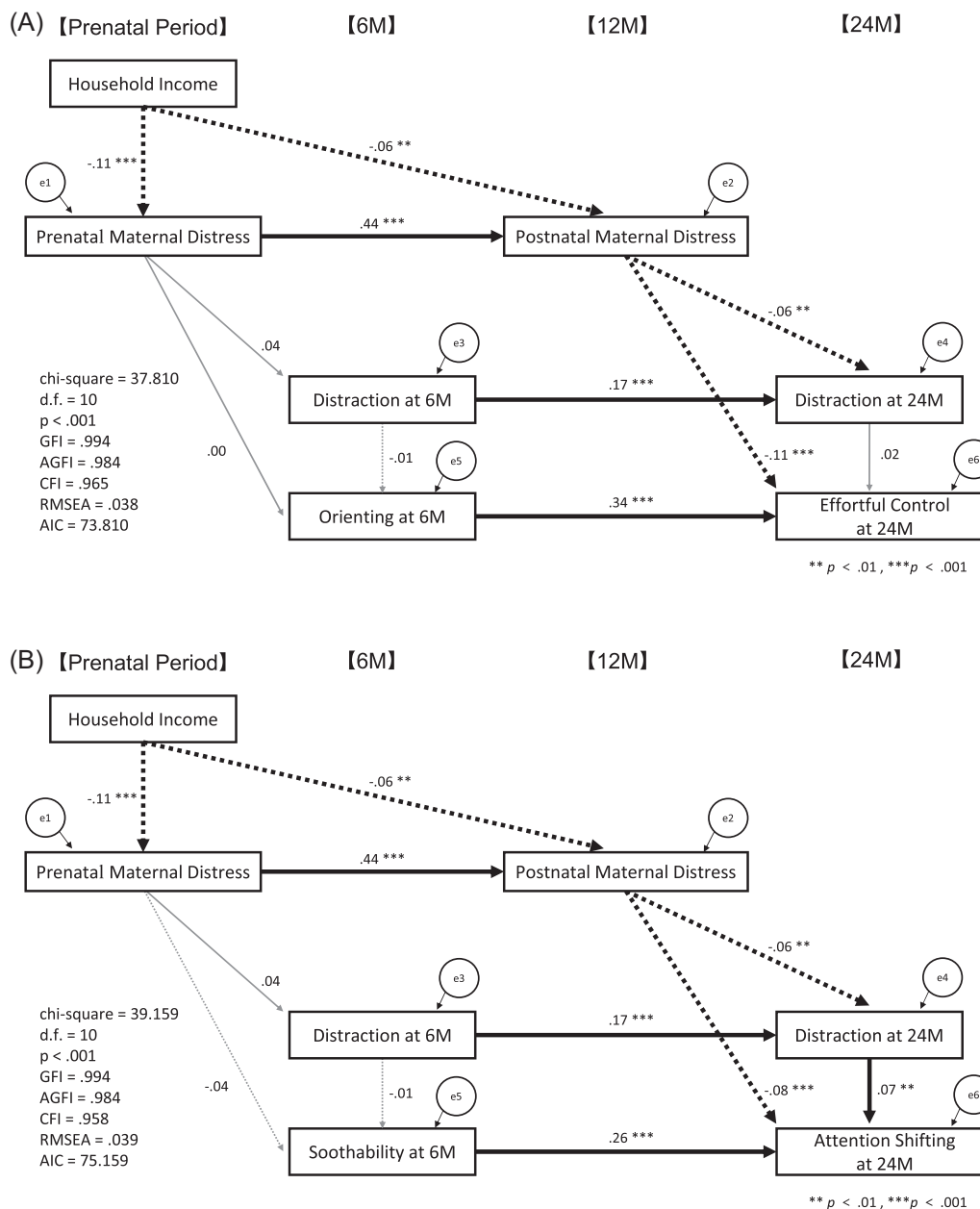
In response, we applied attention-related subscales, i.e., Soothability and Attention Shifting at 6 and 24 months, respectively (Figure 2B) instead of temperamental regulation factors (Figure 2A). In Figure 2B, Household Income as a control factor negatively influenced maternal distress during mid- to late pregnancy and 12 months after birth ( $\beta = -0.11$   $p < 0.001$ ;  $\beta = -0.06$   $p = 0.002$ ). Results also revealed that the higher the postnatal maternal distress, the lower the tendency to use distraction soothing methods

**TABLE 3** Results of correlation analysis of potential covariates and variables used in structural equation modeling.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Prenatal maternal distress																
2 Postnatal maternal distress	0.51***															
3 Child sex	-0.03	-0.03														
4 Mother's highest level of education	-0.08***	-0.07**	-0.03													
5 Partner's highest level of education	-0.08**	-0.03	-0.04	0.39***												
6 Maternal age	-0.07**	-0.04	-0.02	0.10***	0.08***											
7 Annual household income	-0.11***	-0.12***	-0.05	0.28***	0.25***	0.16***										
8 Maternal smoking habit	0.11***	0.03	0.03	-0.23***	-0.25***	-0.03	-0.15***									
9 Existence of child siblings	-0.05*	-0.02	-0.02	-0.07**	-0.04	0.14***	-0.08**	0.02								
10 Pregnancy weeks	0.00	0.03	0.05*	0.01	0.00	-0.07**	0.03	0.02	-0.14***							
11 Child's birth weight	0.00	0.00	-0.17***	0.01	0.01	0.01	0.04	0.02	0.06*	0.41***						
12 Distraction at 6 M	0.03	0.02	-0.04	-0.02	-0.02	-0.05*	-0.02	0.04	0.06**	0.01	0.05*					
13 Orienting at 6 M	-0.01	-0.11***	0.02	-0.02	-0.02	-0.05*	-0.01	0.06**	-0.03	0.03	0.01	-0.01				
14 Soothability at 6 M	-0.05*	-0.14***	0.03	-0.02	0.01	-0.01	-0.01	0.04	0.06**	-0.02	0.03	-0.01	0.63***			
15 Distraction at 24 M	-0.04	-0.05*	-0.04	0.03	0.02	-0.01	0.04	0.00	-0.05*	0.00	0.01	0.17***	0.01	-0.02		
16 Effortful control at 24 M	-0.12***	-0.18***	0.07**	0.02	0.05*	0.02	0.02	-0.01	0.06*	-0.01	0.03	-0.01	0.35***	0.30***	0.03	
17 Attention shifting at 24 M	-0.07**	-0.14***	0.00	-0.02	0.04	-0.06*	0.00	0.03	-0.04	0.04	0.05*	0.01	0.31***	0.27***	0.07**	0.64***

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$





**FIGURE 2** Standardized coefficients of structural equation modeling (SEM) for hypothesized model of relationships between maternal distress, mother's soothing techniques, and infant temperamental regulation (A) or the infant temperamental attentional subscale (B). Significant paths are indicated by thick lines and nonsignificant paths by grayscale. Positive effects are indicated by solid lines and negative effects by dashed lines.

( $\beta = -0.06$ ,  $p = 0.006$ ) as well as the score in attention shifting ( $\beta = -0.08$ ,  $p < 0.001$ ). Moreover, the distraction soothing method used by mothers had a significant positive correlation with attention shifting in toddlers ( $\beta = 0.07$ ,  $p = 0.002$ ): the higher the mother's tendency to use a visual distraction soothing method, the higher the score on attention shifting. However, no such relationship between distraction method and infants' soothability was found at 6 months. Fit indices showed that this model was an overall good fit:  $\chi^2(10) = 39.159$ ,  $p < 0.001$ ; GFI = 0.994; AGFI = 0.984; CFI = 0.958; RMSEA = 0.039; AIC = 75.159.

## 4 | DISCUSSION

Inspired by attention theory<sup>5</sup> and by evidence that therapeutic intervention for mothers with postpartum depression (PPD) improves the temperamental self-regulation of their offspring,<sup>19</sup> this study examined the hypothesis that the degree of psychological distress in mothers is related to how they soothe their infant, which may be associated with temperamental self-regulation of toddlers in later years. Although investigated through questionnaires, the results (Figure 2B) demonstrated that soothing methods, especially



distraction, may be related to maternal distress and that the amount of visual attention distraction experienced as soothing promotes temperamental attention shifting, a subscale of the Self-regulation factor. This is consistent with our original hypothesis that visual attention distraction methods used for soothing may be associated with the early development of attentional control networks.

It has been pointed out that there may exist a relationship between visual attention distraction soothing method and the early development of emotional regulation,<sup>6</sup> even though few empirical studies have examined this possibility in infancy. The present study provides the first evidence outside the laboratory that the experience of toddlers' attention being drawn to novel objects as a palliative to current distress is associated with temperamental attention shifting. However, this trend was observed at 24 months but not at 6 months. One reason for the absence of such a relationship at 6 months may be that as neural networks for disengagement dramatically improve from around 3 months,<sup>36</sup> the soothing techniques used do not necessarily provide the desired effect of emotional distraction in infants as a result of different maturational rates of behavioral and neurobiological capabilities contributing to attentional disengagement.

In our study, the soothing method endorsed by mothers was related to the psychological distress they were experiencing. That is, postnatal maternal distress at 12 months had a negative relationship with the frequency of the distraction soothing methods they used at 24 months. This is consistent with research finding that mothers experiencing depression are less able to regulate or guide their infant.<sup>37,38</sup> Recently, it was found that the ongoing coordination of the parasympathetic nervous system (PSNS) in mother-infant dyads could be the cause of adaptive functioning of the dyadic regulatory system during distress in infants and that PPD can substantially disrupt this process.<sup>39</sup> Although the authors did not elucidate the role of particular mother and infant behaviors in PSNS synchrony, our results suggest that mother's visual attentional distraction method and infant's response to it may be one such behavior.

In addition, we found a negative relationship between postnatal maternal distress and Effortful Control (Figure 2A) or its subscale, Attention Shifting (Figure 2B), at 24 months. However, this significant negative trend was not found at 6 months. Research into the link between maternal prenatal mental health and infant temperament has provided consistent evidence of increased risk of offspring finding it difficult to express smiling or positive emotions, excessive crying or fussiness, poor regulation, and fearfulness.<sup>40,41</sup> However, as self-regulatory factors are rudimentary and limited in infancy, the authors discussed negative reactivity and self-regulation without distinction.<sup>41</sup> Thus, perhaps because it is difficult to capture this temperamental aspect at 6 months, we observed no prenatal effect.

Our results should be interpreted in view of the following limitations. First, since the number of items that could be included in the questionnaire was limited by the constraints of the national longitudinal study, our study used only two items regarding soothing method. In addition, it can be argued that what we measured in this study are the soothing methods endorsed by the mothers, and it is not certain that the

infants and toddlers in question were actually soothed in this way. Future studies should assess individual differences in the outcomes of distraction soothing methods in various ways, including through experimentally-designed observations. Second, prior research also notes that if the mother's depression or anxiety levels are high, the infant's temperament is perceived as difficult to soothe.<sup>42</sup> Moreover, we used mothers' reports of both maternal mental state and infant or toddler reactivity, which may increase the risk of reporting bias. Future studies should strive to avoid such biases in assessing offspring' temperament. Finally, since some of the beta values obtained in the present path analysis were less than 0.10, caution should be exercised in interpreting the results. In addition, future studies should simultaneously measure maternal mental health and the way mothers soothe their offspring.

Our findings demonstrate that the amount of distraction experienced is positively correlated with temperamental regulation in 24-month-old toddlers. Further studies should examine the causal association between maternal distress and soothing method provided as adequate caregiving is a potent effector of brain development.<sup>43,44</sup> In the meantime, our evidence sheds light on how mothers are actively related to the development of their infants' self-regulatory function as well as what may be lacking in the emotional coping cues the child should receive when the mother herself is suffering from distress.

## AUTHOR CONTRIBUTIONS

**Atsuko Nakagawa:** Writing original draft; conceptualization; methodology; funding acquisition; investigation; writing review and editing. **Taishi Miyachi:** Supervision; funding acquisition; writing review and editing; methodology. **Taro Matsuki:** Data curation; formal analysis; writing original draft; validation; resources. **Makiko Tomida:** Visualization; data curation; formal analysis; writing original draft. **Takeshi Ebara:** Writing review and editing; methodology; project administration; resources; validation. **Michihiro Kamijima:** Supervision; project administration; funding acquisition; writing review and editing; resources. All authors have read and approved the final version of the manuscript.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data reported here are unsuitable for public deposition due to ethical restrictions and the Japanese legal framework. It is prohibited by the Act on the Protection of Personal Information (Act No. 57 of 30 May 2003, amendment of 9 September 2015) to publicly deposit data containing personal information. Ethical Guidelines for Medical and Health Research Involving Human Subjects enforced by the Japan Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare also restrict the open sharing of epidemiologic data. All inquiries about access to data should be addressed to: [jecs-en@nies.go.jp](mailto:jecs-en@nies.go.jp). The person responsible for handling inquiries sent to this e-mail address is Dr Shoji F. Nakayama, JECS Programme Office, National Institute for Environmental Studies.

## ETHICS APPROVAL STATEMENT

All procedures involving human subjects in the JECS protocol were reviewed and approved by the Institutional Review Board on Epidemiological Studies of the Ministry of the Environment (Ethical No.100910001) and the Ethics Committees of the Nagoya City University Graduate School of Medical Sciences (Approval No. 60-00-0574).

## TRANSPARENCY STATEMENT

The lead author Atsuko Nakagawa affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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