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The longitudinal associations between temperament and sleep during the first year of life

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ABSTRACT

Temperament and sleep in infants are related but also distinct concepts. The longitudinal effects of temperament on sleep in infancy remain unclear, although this information is potentially important for the prevention and treatment of early sleep problems. We examined how various temperament features influence sleep development during the first year of life in a large birth cohort. This study comprised mother-infant dyads with complete longitudinal data on sleep, temperament and sociodemographic measurements at six and 12 months (N = 1436). We observed that higher infant Negative Affectivity was related to several sleep problems, and that many subscales of Negative Affectivity and Orienting/Regulation predicted worse sleep and deterioration in sleep problems from six to 12 months. Few associations between Surgency and sleep were found. Our findings highlight especially Negative Affectivity as a risk factor for persistent and increasing sleep problems, and also the specific importance of the fine-grained aspects of temperament in predicting infant sleep development.

1. Introduction

Extensive variability among infants has been observed in the normative development of sleep, suggesting that several factors influence individual differences in sleep patterns (Paavonen et al., 2020). Temperament is considered one such key factor (Sadeh & Anders, 1993). Temperament refers to the constitutionally based individual differences in reactivity and self-regulation already present in early childhood (Rothbart & Derryberry, 1981). In Rothbart's theory, infant temperament comprises three main dimensions: negative affectivity and surgency/positive affectivity, referring mainly to the aspects of reactivity, and orienting/regulation, referring

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to the emerging self-regulation abilities (Weissbluth, 1989).

There is evidence suggesting that temperament is an endogenous factor affecting infants sleep quality, already from the earliest stages of life onward (De Marcas, Soffer-Dudek, Dollberg, Bar-Haim, & Sadeh, 2015; Jian & Teti, 2016). For instance, child emotional intensity, which is one aspect of temperament, is negatively associated with the amount and quality of children's sleep (El-Sheikh & Buckhalt, 2005), and infants, toddlers and young children with sleep problems are related to specific temperament profiles (Owens-Stively et al., 1997; Schaefer, 1990). There is a wealth of cross-sectional studies reporting associations between especially the reactive aspects of temperament, and worse sleep in children (Bagley & El-Sheikh, 2014; De Marcas et al., 2015; Kelmason, 2013). Most of these studies demonstrate that higher negative affectivity/difficult temperament in infants is cross-sectionally associated with shorter sleep duration (Kaley, Reid, & Flynn, 2012; Loutzenhiser & Sevigny, 2008; Sadeh & Anders, 1993), night awakenings (Morrell & Steele, 2003; Scher, Zukerman, & Epstein, 2005; Touchette et al., 2005; Weissbluth, Christoffel, & Davis, 1984) and sleep problems in general (Atkinson, Vetere, & Grayson, 1995; Jimmerson, 1991; Minde et al., 1993). A few studies have examined the association between self-regulation and early sleep patterns (Turnbull, Reid, & Morton, 2013; Williams & Sciberras, 2016), and suggest that also certain aspects of infant self-regulation, such as higher infant persistence, adaptability, soothability, and rhythmicity, and in turn lower infant distractibility are cross-sectionally linked with higher quality of infant/toddler sleep (Kelmanson, 2004; Sadeh, Lavie, & Scher, 1994; Scher, Epstein, Sadeh, Tirosh, & Lavie, 1992; Scher, Tirosh, & Lavie, 1998). In addition, a recent study conducted in toddlers suggests that the motivational–emotional (i.e., the "hot" system) and the cognitive (i.e., the "cool" system) systems of self-regulation may differentially underlie sleep problems throughout early childhood (Jusienė & Breidokienė, 2019).

However, there is still a paucity of studies focusing on the longitudinal relations between temperament and sleep in infancy. This information is essential, for example, in our attempts to ultimately prevent and treat early sleep problems. So far, the existing longitudinal studies indicate that higher negative affectivity in infants, such as distress to limitations and fear, difficult temperament and/or fussiness, is associated with more parent-reported sleep problems (Sorondo & Reeb-Sutherland, 2015), night awakenings (Weinraub et al., 2012), and disruption in sleep-wake states (such as less sleep duration, more difficulties to get down to sleep, and less quiet, deep sleep) over the first four months of life (Keefe, Kotzer, Froese-Fretz, & Curtin, 1996). In addition, a recent longitudinal study using actigraph-based sleep measures reported that both hypersensitive and hyposensitive infants were at risk for poorer sleep, compared to infants with sensory reactivity in the average range (De Marcas et al., 2015).

However, there is a lack of longitudinal data focusing on the different aspects of temperament, thus it is not known if temperament increases risk for persistent sleeping problems. As sleep is an utmost necessity for optimal daily functioning, further research in this field disentangling the interrelations between temperament and sleep and especially on the role of temperament in predicting longitudinal changes in sleep are of high importance. Although sleep and temperament likely share some underlying central nervous systems (Dahl, 2005), they are not interchangeable. For instance, amygdala connectivity and size have been implicated to underlie infant negative affectivity in early life (Graham et al., 2017; Thomas et al., 2018), and connectivity between amygdala and prefrontal cortex and fronto-parietal network, default mode and dorsal attention network is reportedly predictive of self-regulation capacity across age groups (Gao et al., 2009; Graham et al., 2015; Kelly, Uddin, Biswal, Castellanos, & Milham, 2008; Stevens, Tappon, Garg, & Fair, 2012). Instead, the sleep-wake cycle is associated primarily to the circadian timing system, which is located in the suprachiasmatic nuclei of the anterior hypothalamus in flies (Panda, Hogenesch, & Kay, 2002) and in human infants (Rivkees, 2003), but also to aminergic neurons of the brainstem and the midbrain already during the first months of a child's life (Segawa, 2006). However, sleep-wake cycle development is also linked with the activation of visual cortex and limbic regions, coupled with deactivation of prefrontal cortex in the developing animal (Brown, Basheer, McKenna, Strecker, & McCarley, 2012), emphasizing also the existence of common neural systems across sleep and temperament.

To conclude, a better characterization of the specific temperamental factors interfering or underlying sleep development in children would help to design better targeted interventions, where not only sleep problems as such, but also child's intrinsic reactivity and regulatory capacity and the developmental phase are considered. For instance, many parents report temporary child sleep problems that may be part of a normal development; however, for some young children, the sleep problems become more persistent and clinically significant. Thus, it is crucial to understand the risk factors especially for the persistent sleep problems, to be able to allocate interventions effectively.

Here, we aimed to extend the existing research by examining how temperament traits in infancy are related to the risk for longitudinal and increasing sleep problems over the first year of life. We also wanted to focus on the important self-regulatory aspects of temperament in addition to the more widely studied aspects of temperamental reactivity. More specifically, this study assessed the longitudinal associations of the main temperament dimensions in infancy (i.e., Negative Affectivity, Orienting/Regulation, and Surgency/Positive affectivity) with several sleep problems during the first year of life (i.e., six and 12 months), in a large birth cohort of infants. In terms of temperament scale Negative Affectivity, which was the only temperament scale including items clearly related to sleep, we also conducted a sensitivity analysis excluding these items to verify whether temperament and sleep are still related. Finally, we examined the different subscales of each temperament domain separately, with a specific focus on the self-regulatory aspects of temperament (Cuddliness, Duration of Orienting and Low Intensity Pleasure). This was based on the evidence that specific aspects of temperament may have unique associations with later outcomes, and may follow different developmental trajectories compared to the respective main dimension (e.g. fear reactivity vs. overall negative emotionality, or approach vs. overall positive affectivity) (Clifford, Hudry, Elsabbagh, Charman, & Johnson, 2013; Kochanska, Aksan, Penney, & Doobay, 2007; Rothbart, 2011). Based on previous studies in toddlers (Molfese et al., 2015), preschoolers (Atkinson, Vetere, & Grayson, 1995) and adolescents (Moore, Slane, Mindell, Burt, & Klump, 2011), we hypothesized that higher negative reactivity and poorer capacity for self-regulation as well as its fine-grained aspects, such as lower duration of orienting (e.g., higher distractibility) would be longitudinally related to short sleep duration and worse sleep quality during the first year of life. Finally, and following previous research (Jian & Teti, 2016), we did not make assumptions of finding associations between Surgency/Positive affectivity or its subscales and sleep development in this age group, but wanted to include also this domain in the analyses, given the generally less studied longitudinal relations between all temperament features and sleep.

2. Methods

2.1. Participants

This study was based on a large birth cohort study, and details of the recruitment process have been previously reported (Karlsson et al., 2018). Initially, 5790 pregnant mothers were informed about the study, with a total of 3808 mothers and 2623 fathers agreeing to participate. For this study, only mother-infant dyads with complete sleep and temperament measurements at both six and 12 months were chosen (N = 1436). Of these, a total of 34 cases (31 infants at six months, and 27 at 12 months) had been previously excluded due to medical conditions that may have interfered with the final results (i.e., early preterm, heart structural defects, heart arrhythmias, epilepsy, or renal failure). Larger samples (N = 1611–1972) reported infant sleep and temperament at six and 12 months separately, which refer to the cross-sectional time points (see demographic data and the findings in Supplement material, Table 1).

The parents gave written informed consent on their own and their child's behalf. The study was approved by the ethics committee of the participating hospital district.

2.2. Measures

The Brief Infant Sleep Questionnaire (BISQ) was developed to measure infant sleep quality (Sadeh, 2004). It includes several items to be completed by the parents that refer to their child's sleep during the past week. For the purposes of this study we restricted the variables of interest from the BISQ scale to: i) total number of sleep hours per day; ii) sleep onset latency; iii) number of nocturnal awakenings; iv) method of falling asleep; and v) sleep difficulties (i.e., none, mild, moderate, severe). Taking into account that the purpose of this study was to investigate how temperament traits in infancy are related to the risk for longitudinal and increasing sleep problems over the first year of life, we created dichotomous sleep variables representing specific sleep problems, instead of continuous variables, as follows: i) short sleep, total duration (25th percentile: cut-off $\leq$ 13 h at six months; and $\leq$ 12 h at 12 months); ii) high frequency of nocturnal awakenings (cut-off of three or more nocturnal awakenings, both at six and 12 months); iii) long sleep onset latency (75th percentile: cut-off $\geq$ 30 min., both at six and 12 months); iv) likelihood to fall asleep alone on his/her own bed (which is considered an indirect measure of self-soothing ability in children); and v) sleep difficulties (obtained from the item concerning the existence of sleep difficulties: 0 = none; 1=mild/moderate/severe).

The Infant Behavior Questionnaire-Revised Short Form (IBQ-R-SF) is a widely-used parent-reported measure developed to assess the dimensions of temperament in infants between three and 12 months of age (Putnam, Helbig, Gartstein, Rothbart, & Leerkes, 2014), which consists of 91 items asking the mother to rate her infant's behavior during the past week or two weeks. The questionnaire comprises three main dimensions and their subscales, including (1) Surgency/Extraversion (SUR), consisting of the subscales Approach, Vocal Reactivity, High Intensity Pleasure, Smiling and Laughter, Activity Level, and Perceptual Sensitivity; (2) Negative Affectivity (NEG), consisting of the subscales Sadness, Distress to Limitations, Fear, and Falling Reactivity/Rate of Recovery from Distress; and (3) Orienting/Regulation (REG), consisting of the subscales Low Intensity Pleasure, Cuddliness, Duration of Orienting, and Soothability. Cronbach's alpha coefficients ranged from 0.852 to 0.906 for the IBQ full scale, from 0.823 to 0.880 for the main domains (i.e., 880–.873 for SUR, .849–.850 for NEG, and .823–.854 for REG), from 0.604 to 0.811 for the NEG subscales, and from 0.589 to 0.848 for the REG subscales. Given that some of the IBQ-R subscales (Falling Reactivity from NEG and Soothability from REG) share similar items with sleep questionnaires, our focus was especially on the potential of other aspects of the IBQ-R NEG and REG subscales to predict sleep problems longitudinally.

The following socio-demographic variables were used as covariates, both at six and 12 months: gestational age (weeks), maternal age at delivery (years), total duration of breastfeeding (months), mother's level of education, gender of the child, and parity (i.e., number of deliveries). Mother's education level was categorized into three levels: 1=low: primary education; 2=medium: secondary education; 3=high: higher education. Parity was treated as a dichotomous variable (Primiparous/Multiparous).

2.3. Statistical analysis

Statistical analyses were performed with IBM SPSS Statistics V22.0. First, the descriptive statistics were run to obtain the means, standard deviations (SD), frequencies, and percentages of the variables of interest. Second, the zero-order associations, examined using Pearson correlations (for continuous variables) and Analysis of Variance (ANOVA), T-test or χ^2 test (for categorical and dichotomous variables) between our key variables (temperament and sleep measures) and the socio-demographic variables of interest were conducted to define potential covariates used in the subsequent analyses and to evaluate the potential impact of these covariates. All the covariates associated with either sleep or temperament were included in the consequent analyses.

To test the hypothesis that higher Negative Affectivity and lower Regulation, but not Surgency at six months are longitudinally related to sleep problems at 12 months of age, logistic regression analyses were conducted. The independent variables were the three continuous temperament domains, while the dependent variables included the five sleep problems, which were treated as dichotomous, as previously described. Each variable of interest, together with the covariates (i.e., gestational age, maternal age at delivery, total duration of breastfeeding, mother's level of education, gender of the child, and parity) were studied in a separate model to test whether temperament at six months is associated with sleep problems at 12 months. In addition to the previous confounding factors, the respective sleep problem at six months was controlled in the second step of the model, to test the contribution of each temperament domain to change in sleep problems.

Finally, we analyzed which IBQ-R subscales from each main temperament dimensions were longitudinally related to each sleep problem, following similar procedure as described in the previous paragraph. To do this, we included all the subscales of a certain temperament dimension simultaneously into each model, for each sleep domain. To test whether the associations were independent of overlapping sleep-related questionnaire items, sensitivity analyses were conducted using IBQ-R subscales that were calculated without the sleep-related items, which concerned the main dimension of Negative Affectivity (9 sleep items were removed out of 25 items) and its subscales Distress (4 items out of 7), Falling Reactivity (4 items out of 6) and Sadness (1 item out of 5). Further, we did not remove the items related to soothability from the sensitivity analyses. Although these items have some overlap with the aspects of sleep, we considered them an essential regulation-related aspect of temperament, and not overlapping enough to justify removal.

3. Results

3.1. Descriptive variables

Table 1 describes the sociodemographic characteristics of the sample, sleep variables, and temperament domains at six and 12 months. Information regarding the cross-sectional associations between temperament and sleep at six and 12 months can be found in the supplementary material (Tables 2 and 3). Briefly, we observed that higher NEG was cross-sectionally related to all sleep problems at both time points, and lower REG was associated with short sleep, long sleep-onset latency and sleep difficulties at six and 12 months; while lower SUR was only related to sleep difficulties at six months. Concerning the NEG and REG subscales, we found that lower falling reactivity and lower soothability were the two most relevant aspects of temperament that associated with most of the sleep problems at both time points. Further, correlations between socio-demographic variables and our measures of central interest (i.e. temperament and sleep variables) are reported in Table 2.

3.2. Longitudinal associations between main temperament domains and sleep

Table 3 shows all the results concerning the longitudinal logistic regressions between temperament at six months and sleep at 12 months. All the temperament domains had a contribution to short sleep at 12 months; lower SUR and REG predicted short sleep duration at 12 months, whereas higher NEG predicted short sleep at 12 months. However, after controlling for short sleep at six

Table 1
Descriptive variables of the infants in the longitudinal analyses (N = 1415, infants with at least one sleep outcome reported at both 6 and 12 months included).

	Sociodemographic variables (at 6 months)	
	Mean	*SD*
Parity (number of deliveries)	2.37	0.72
Gestational age (weeks)	39.82	1.51
Maternal age at delivery (years)	30.86	4.35
Birth weight (g)	3552.16	504.15
Birth length (cm)	50.57	2.19
Total duration of breastfeeding (days)	131.61	49.91
	Frequency	*%*
Gender (Female)	662	46.8
Maternal level of education (Primary/Secondary/Higher)	436 / 415 / 564	30.8 / 29.3 / 39.9
Visited doctor at 6 months (Yes)	187	13.2
Parity (Primiparous)	777	54.9

	Sleep at 6 months		Sleep at 12 months	
	Mean	*SD*	*Mean*	*SD*
Total sleep duration (hours)	13.62	1.49	12.78	1.13
Number of night time awakenings/night	2.49	1.79	1.79	1.52
Sleep onset latency (hours)	0.43	0.35	0.36	0.34
	Frequency	*%*	*Frequency*	*%*
Short sleep, total (<25 pc)	524	37.0	401	28.3
High frequency of night wakening (≥3/night)	541	38.2	316	22.3
Long sleep onset latency (>75 pc)	592	41.8	430	30.4
Falling asleep alone, own bed	550	38.89	758	53.6
Sleep difficulties	418	29.5	429	30.3

	Temperament at 6 months	
	Mean	*SD*
Surgency/Extraversion	4.72	0.71
Negative Affectivity	3.01	0.76
Orienting/Regulation	5.26	0.65

Table 2
Zero-order associations between sleep, temperament and covariates (N = 1415).

Correlations between the continuous variables (Pearson)	1	2	3	4	5
1 SUR at 6 m					
2 NEG at 6 m	.08**				
3 REG at 6 m	.46**	−.24**			
4 Gestational age	.09**	.05	−.09**		
5 Maternal age	−.02	−.02	.04	−.08**	
6 Duration of breastfeeding	−.03	.07**	−.00	.09**	.09**

Associations between sleep at 6 and 12 months, temperament at 6 months and the continuous covariates (*t* -test or ANOVA)	SUR at 6 m	NEG at 6 m	REG at 6 m	Gest. age	Maternal age	Breastfeeding
7 Short sleep at 6 m	n.s.	Yes > No	Yes < No	n.s.	n.s.	n.s.
8 Night awake at 6 m	n.s.	Yes > No	Yes < No	Yes > No	n.s.	Yes > No
9 Long sleep onset at 6 m	n.s.	Yes > No	Yes < No	n.s.	n.s.	n.s.
10 Fall asleep alone at 6 m	n.s.	Yes < No	n.s.	n.s.	Yes < No	Yes < No
11 Sleep difficulties at 6 m	Yes < No	Yes > No	Yes < No	n.s.	Yes > No	Yes > No
12 Short sleep at 12m	Yes < No	Yes > No	Yes < No	n.s.	n.s.	n.s.
13 Night awake at 12m	n.s.	Yes > No	n.s.	n.s.	Yes > No	Yes > No
14 Long sleep onset at 12m	n.s.	Yes > No	n.s.	n.s.	n.s.	n.s.
15 Fall asleep alone at 12m	n.s.	Yes < No	Yes > No	n.s.	Yes < No	Yes < No
16 Sleep difficulties at 12m	n.s.	Yes > No	Yes < No	n.s.	Yes > No	Yes > No
17 Maternal education	High < Mid, Low	n.s.	High < Mid	n.s.	High > Mid > Low	High > Mid > Low
18 Parity	n.s.	n.s.	n.s.	n.s.	Multi > Prim	Multi > Prim
19 Child gender	n.s.	Girls > Boys	n.s.	n.s.	n.s.	n.s.

Associations between sleep at 6 and 12 months and the categorical covariates (χ^2-test)	Short sleep		Night awake		Late sleep onset		Fall asleep alone		Sleep difficulties	
	6 m	12m	6 m	12m	6 m	12m	6 m	12m	6 m	12m
Maternal education	n.s.	n.s.	High>Mid/ Low	High>Mid/ Low	n.s.	n.s.	n.s.	n.s.	High > Mid/Low	Low<Mid, High
Parity	n.s.	n.s.	n.s.	Multi>Prim	Prim>Multi	n.s.	Prim>Multi	Prim > Multi	n.s.	n.s.
Child gender	n.s.	n.s.	n.s.	n.s.	n.s.	Girls > Boys	n.s.	n.s.	n.s.	n.s.

The associations at $p < .05$ are reported as significant. ** $p < .001$.
SUR = Surgency/Extraversion, NEG = Negative Affectivity, REG = Orienting/Regulation).

months, only higher NEG contributed to increased short sleep between the latter half of the first year. Higher NEG was also the only temperament dimension predicting high frequency of night awakenings, long sleep-onset latency, and sleep difficulties at 12 months, both before and after controlling for baseline in each corresponding sleep problem at six months. Thus, higher NEG predicted the onset of overall sleep problems over the latter half of the first year. Additionally, lower REG was associated with sleep difficulties at 12 months, but did not contribute to change in these difficulties during the follow-up.

Apart from this pattern, SUR and REG contributed to the ability to fall asleep alone at 12 months. Lower REG predicted the ability to fall asleep alone both before and after controlling for baseline ability, whereas lower SUR was only related to the change towards the ability to independently fall asleep. Vice versa, lower NEG predicted the ability to fall asleep alone at 12 months but had no influence on the change of this ability during the follow-up.

The sensitivity analyses utilizing IBQ-R without the sleep-related items are presented in Supplementary Table 4. The analyses remained mostly similar, as NEG still predicted all other subscales but the ability to fall asleep alone before six-month sleep was adjusted. After the adjustment of six-months sleep, NEG significantly predicted high frequency of night awakenings, long sleep onset latency and ability to fall asleep independently. The association between NEG and short sleep duration and sleep difficulties did not remain significant; however, even these associations remained at a trend level when utilizing IBQ-R without the sleep-related items.

3.3. Longitudinal associations between temperament subscales and sleep

The associations between temperament subscales at six months and sleep problems at 12 months are presented in Table 4. Expectedly, very few SUR subscales were statistically significantly associated with sleep problems at 12 months or change of sleep problems during the first year. Higher Activity level was associated with high frequency of night awakenings, overall sleep difficulties and longer sleep-onset latency at 12 months, as well as with increase in sleep difficulties and long sleep-onset latency when baseline of these problems was controlled for.

Regarding the effects of NEG subscales at months on sleep problems at 12 months, we expectedly found that lower Falling Reactivity at six months was associated with all types of sleep problems at 12 months and change in short sleep, long sleep-onset latency, and sleep difficulties across the follow-up when the corresponding baseline sleep problem was controlled for. Interestingly, higher level of Fear at six months was also associated with high frequency of nocturnal awakenings at 12 months before and after

Table 3
Longitudinal results concerning logistic regression analysis between IBQ domains at six months and sleep quality problems at 12 months.

	Model 1, adjusted for background covariates			Model 2, additionally adjusted for six-month sleep		
	B	*p*	AOR (95 % C.I.)	B	*p*	AOR (95 % C.I.)
SUR at 6 m	**−0.186**	**0.03**	**0.831 (0.701 to 0.984)**	−0.168	0.06	0.845 (0.710 to 1.006)
NEG at 6 m	**0.291**	**<0.001**	**1.338 (1.144 to 1.564)**	**0.214**	**0.01**	**1.238 (1.053 to 1.456)**
REG at 6 m	**−0.207**	**0.025**	**0.813 (0.678 to 0.975)**	−0.154	0.11	0.857 (0.710 to 1.035)
High frequency of night awakening/night (≥3) at 12 months						
	B	*p*	AOR (95 % C.I.)	B	*p*	AOR (95 % C.I.)
SUR at 6 m	0.068	0.47	1.071 (0.889 to 1.289)	0.083	0.40	1.086 (0.897 to 1.315)
NEG at 6 m	**0.488**	**<0.001**	**1.629 (1.367 to 1.941)**	**0.363**	**<0.001**	**1.438 (1.199 to 1.724)**
REG at 6 m	−0.041	0.69	0.960 (0.785 to 1.174)	0.076	0.47	1.079 (0.877 to 1.327)
Long sleep onset at 12 months (≥30 min, 75th percentile)						
	B	*p*	AOR (95 % C.I.)	B	*p*	AOR (95 % C.I.)
SUR at 6 m	−0.024	0.78	0.976 (0.827 to 1.152)	−0.011	0.90	0.989 (0.830 to 1.179)
NEG at 6 m	**0.497**	**<0.001**	**1.645 (1.405 to 1.925)**	**0.244**	**0.005**	**1.277 (1.076 to 1.515)**
REG at 6 m	−0.072	0.429	0.930 (0.777 to 1.113)	0.003	0.97	1.003 (0.829 to 1.214)
Fall asleep alone, own bed at 12 months						
	B	*p*	AOR (95 % C.I.)	B	*p*	AOR (95 % C.I.)
SUR at 6 m	−0.123	0.12	0.885 (0.758 to 1.033)	**-0.177**	**0.04**	**0.838 (0.707 to 0.992)**
NEG at 6 m	**−0.144**	**0.05**	**0.866 (0.750 to 1.000)**	0.043	0.60	1.044 (0.890 to 1.223)
REG at 6 m	**−0.180**	**0.04**	**0.835 (0.707 to 0.987)**	**-0.260**	**0.005**	**0.771 (0.642 to 0.926)**
Sleep difficulties at 12 months						
	B	*p*	AOR (95 % C.I.)	B	*p*	AOR (95 % C.I.)
SUR at 6 m	−0.075	0.376	0.928 (0.787 to 1.095)	−0.020	0.82	0.980 (0.825 to 1.164)
NEG at 6 m	**0.519**	**<0.001**	**1.68 (1.435 to 1.996)**	**0.284**	**0.001**	**1.329 (1.121 to 1.575)**
REG at 6 m	**−0.241**	**0.008**	**0.786 (0.658 to 0.939)**	−0.073	0.45	0.930 (0.771 to 1.122)

*Dependent variables = sleep variables (cut-offs); Independent variables = IBQ dimensions (SUR = Surgency/Extraversion, NEG = Negative Affectivity, REG = Orienting/Regulation);
Covariates, Model 1: Gestational age, maternal age at delivery, total duration of breastfeeding, gender, maternal educational level, parity.
Covariates, Model 2: The previous covariates and additionally the respective aspects of sleep at six months.
All the analyses have been conducted in separate models.

controlling for the degree of the night awakenings at six months. Further, higher level of Sadness at six months was related to the better ability to fall asleep alone and change in this aspect of sleep throughout the first year of life. Higher levels of Distress to Limitations only predicted change in long sleep-onset latency after controlling for baseline at six months, but were unrelated to other sleep outcomes. The sensitivity analyses using IBQ-R NEG subscales excluding the sleep-related items are displayed in Supplementary Table 5. The findings remained similar as when utilizing original IBQ-R with the exception of Falling Reactivity that remained a significant predictor for short sleep duration, but not other sleep outcomes.

Finally, we found several individual associations between the aspects of REG at six months and some sleep problems at 12 months. We observed that lower levels of Low Intensity Pleasure at six months were associated with sleep difficulties at 12 months and also with sleep difficulties during the follow-up. Further, higher levels of Cuddliness at six months were associated with high frequency of nocturnal awakenings, while lower levels of Cuddliness at six months associated with the ability of falling asleep alone at 12 months, as well as with increased problems in these sleep domains across the follow-up. Longer Duration of Orienting predicted long sleep-onset latency at 12 months. Finally, and expectedly, lower infant Soothability at six months predicted short sleep duration and long sleep-onset latency at 12 months, and increase in long sleep-onset latency when controlling for baseline sleep.

4. Discussion

Our main results indicated that infant Negative Affectivity at six months was most consistently associated with sleep development during the first year of life even after removing the sleep-related items from the Negative Affectivity scale. Although many of the relations between Negative Affectivity and sleep were explained by Falling Reactivity that was most strongly dependent on the sleep-related items, interestingly our findings also indicated that many scales of Negative Affectivity and Orienting/Regulation were longitudinally related to sleep problems and increase in sleep problems independently of the sleep-related items when baseline sleep was controlled for. For instance, higher Fear was related to nocturnal awakenings, and lower level of Low Intensity Pleasure contributed to sleep difficulties at 12 months. However, Cuddliness, a trait related to better regulatory capacity, was also unexpectedly found to predict high frequency of nocturnal awakenings and problems in falling asleep alone. Similarly, higher infant Orienting/Regulation and Surgency, traits which are conventionally related to socioemotional adjustment, predicted poorer ability to fall asleep

Table 4
Longitudinal results concerning logistic regression analysis between SUR, NEG and REG subscales at six months and sleep quality problems at 12 months.

SUR at six months					NEG at six months					REG at six months				
Model 1			Model 2		Model 1			Model 2		Model 1			Model 2	
Short sleep total, 12 months					Short sleep total, 12 months					Short sleep total, 12 months				
	B	*p*	B	*p*		B	*p*	B	*p*		B	*p*	B	*p*
Act	−0.044	0.51	−0.069	0.32	Dis	0.139	0.07	0.144	0.09	Lip	−0.076	0.25	−0.089	0.19
Smil	−0.028	0.70	0.010	0.89	Fear	−0.030	0.60	−0.044	0.45	Dura	0.030	0.56	0.044	0.40
Hip	−0.149	0.08	−0.155	0.10	Sad	−0.098	0.19	−0.098	0.20	Cudd	−0.017	0.83	0.003	0.97
Perc	−0.023	0.60	0.023	0.61	Fall	**−0.328**	**<.001**	**−0.260**	**0.001**	Soot	**−0.223**	**0.008**	−0.163	0.06
App	−0.002	0.98	0.010	0.90	——	——	——	——	——	——	——	——	——	——
Voc	−0.037	0.65	−0.066	0.07	——	——	——	——	——	——	——	——	——	——
High night awakenings 12 months					High night awakenings 12 months					High night awakenings 12 months				
	B	*p*	B	*p*		B	*p*	B	*p*		B	*p*	B	*p*
Act	**0.180**	**0.02**	0.120	0.12	Dis	0.153	0.10	0.087	0.35	Lip	−0.104	0.90	−0.079	0.28
Smil	−0.078	0.32	−0.041	0.62	Fear	**0.145**	**0.02**	**0.168**	**0.006**	Dura	0.037	0.52	0.045	0.44
Hip	0.073	0.48	0.071	0.50	Sad	0.027	0.74	0.000	1.00	Cudd	**0.198**	**0.04**	**0.258**	**0.008**
Perc	0.003	0.96	0.023	0.65	Fall	**−0.201**	**0.02**	−0.152	0.07	Soot	−0.135	0.17	−0.081	0.42
App	0.031	0.72	0.021	0.89	——	——	——	——	——	——	——	——	——	——
Voc	−0.006	0.79	−0.009	0.92	——	——	——	——	——	——	——	——	——	——
Long sleep-onset latency, 12 months					Long sleep-onset latency, 12 months					Long sleep-onset latency, 12 months				
	B	*p*	B	*p*		B	*p*	B	*p*		B	*p*	B	*p*
Act	**0.267**	**<.001**	**0.245**	**0.001**	Dis	0.129	0.12	**0.183**	**0.03**	Lip	**−0.125**	**0.05**	−0.083	0.23
Smil	−0.010	0.89	−0.001	1.00	Fear	−0.036	0.52	−0.026	0.66	Dura	**0.148**	**0.004**	**0.106**	**0.05**
Hip	−0.017	0.85	−0.020	0.84	Sad	−0.089	0.23	−0.109	0.16	Cudd	0.083	0.315	0.100	0.25
Perc	**−0.104**	**0.02**	**−0.090**	**0.05**	Fall	**−0.612**	**<.001**	**−0.270**	**0.002**	Soot	**−0.293**	**0.001**	**−0.18**	**0.05**
App	0.134	0.09	0.137	0.10	——	——	——	——	——	——	——	——	——	——
Voc	−0.107	0.18	−0.110	0.20	——	——	——	——	——	——	——	——	——	——
Fall asleep alone, own bed, 12 months					Fall asleep alone, own bed, 12 months					Fall asleep alone, own bed, 12 months				
	B	*p*	B	*p*		B	*p*	B	*p*		B	*p*	B	*p*
Act	−0.072	0.24	−0.055	0.41	Dis	−0.064	0.40	0.004	0.96	Lip	0.011	0.86	−0.090	0.17
Smil	−0.111	0.09	−0.108	0.13	Fear	−0.092	0.07	−0.080	0.15	Dura	−0.034	0.47	0.030	0.56
Hip	0.105	0.22	0.136	0.14	Sad	**0.152**	**0.02**	**0.153**	**0.04**	Cudd	**−0.212**	**0.006**	**−0.195**	**0.02**
Perc	−0.026	0.52	−0.0042	0.33	Fall	**0.231**	**0.001**	0.089	0.24	Soot	−0.046	0.57-	−0.131	0.14
App	**−0.147**	**0.04**	−0.137	0.08	——	——	——	——	——	——	——	——	——	——
Voc	**0.155**	**0.04**	0.087	0.28	——	——	——	——	——	——	——	——	——	——
Sleep difficulties, 12 months					Sleep difficulties, 12 months					Sleep difficulties, 12 months				
	B	*p*	B	*p*		B	*p*	B	*p*		B	*p*	B	*p*
Act	**0.179**	**0.007**	**0.158**	**0.02**	Dis	0.144	0.08	0.096	0.25	Lip	**−0.176**	**0.006**	**−0.130**	**0.06**
Smil	−0.104	0.14	−0.056	0.44	Fear	−0.065	0.25	−0.055	0.33	Dura	0.052	0.31	0.058	0.27
Hip	−0.041	0.65	−0.062	0.50	Sad	0.086	0.23	0.038	0.61	Cudd	−0.038	0.64	0.000	0.99
Perc	0.002	0.96	0.003	0.95	Fall	**−0.409**	**<.001**	**−0.274**	**<0.001**	Soot	−0.099	0.25	0.029	0.75
App	0.096	0.21	0.046	0.56	——	——	——	——	——	——	——	——	——	——
Voc	−0.085	0.28	−0.020	0.81	——	——	——	——	——	——	——	——	——	——

SUR = Surgency; Act = Activity level, Smil = Smiling and laughter, Hip = High Intensity Pleasure, Perc = Perceptual Sensitivity, App = Approach, Voc = Vocal reactivity; NEG = Negative affectivity, Dis = Distress to Limitations, Fear = Fearfulness, Sad = Sadness, Fall = Falling Reactivity; REG = Orienting/Regulation, Lip = low Intensity Pleasure, Dura = Duration of Orienting, Cudd = Cuddliness, Soot = Soothability.
Covariates, Model 1: Gestational age, maternal age at delivery, total duration of breastfeeding, gender, maternal educational level, parity.
Covariates, Model 2: The previous covariates and additionally the respective aspects of sleep at six months.
All the analyses have been conducted in separate models.

alone. Overall, our findings suggest that temperament early in infancy contributes longitudinally to sleep difficulties, and not all the variance is explained by the scales that share similar features with sleep questionnaires.

Our findings concerning infant Negative Affectivity were consistent with our initial hypothesis that this temperament domain is longitudinally related to longer sleep onset and nocturnal wakefulness (Sorondo & Reeb-Sutherland, 2015), shorter sleep (Kelmanson, 2004; Weissbluth, 1981), and worse sleep quality (Morrell & Steele, 2003; Sadeh & Anders, 1993; Touchette et al., 2005) independetly of sleep-related questionnaire items, even after controlling for the sleep quality at the age of six months of age. Further, there is evidence supporting the link between infant sleep problems and internalizing problems (Mindell, Leichman, DuMond, & Sadeh, 2017; Sadeh, Tikotzky, & Kahn, 2014; Sivertsen et al., 2015), which might suggest sleep problems as one link bridging fearful temperament and later mental health. However, and interestingly, Sadness in infancy was associated with the ability to fall asleep alone, even when the baseline ability was controlled for, regardless of the fact that Sadness may predict later depression-proneness (Kopala-Sibley et al., 2016). It was unexpected to observe very few links between Distress of Limitations and sleep problems, given that this aspect of temperament has been related to child depressive symptoms (Kopala-Sibley et al., 2016) and more problematic interactions with the caregiver (Vertsberger & Knafo-Noam, 2019). Altogether, the findings provide a more detailed picture about the mechanisms through certain temperament traits are related to specific sleep problems and a risk for later development. However, given the lack of studies with a focus on subscales of temperament, the findings should be replicated in another general population sample to make further conclusions on their implications.

Overall, we found only weak evidence for our hypothesis that Orienting/Regulation main dimension would longitudinally predict better sleep quality. Furthermore, the association found was against our hypothesis that lower Regulation would associate with worse infant sleep quality, as lower Regulation was instead related to better ability to falling asleep alone. Interestingly, this finding was accompanied by a parallel pattern of lower Surgency being also related to the ability to fall asleep alone, and more detailed investigation suggested that this association between regulation and ability to fall asleep alone was likely explained by infant Cuddliness, a measure of affiliation (i.e., sociability) (Rothbart, 2011). Given that high Cuddliness and Surgency both may also reflect infant sociability, and are also reportedly low in children showing autistic spectrum disorder (Clifford et al., 2013), we suggest that our findings reflect temperamental preference for the presence of the parents to calm down in order to fall asleep. This idea was strengthened by further inspection of the subscales, where higher level of Cuddliness at six months was also longitudinally related to high frequency of night awakenings at the age of 12 months. Thus, temperament features underlying both self-regulation and sociability may contribute to more frequent night awakenings in the age where the need for parental soothing is increased. There are no previous studies on temperament and infant ability to learn to sleep independently, but our finding indicates that more studies on the dynamics of temperament that shape sleep behavior in early life are needed. Naturally, also the possibility that the shared temperament features of the children and their parents may be reflected in the parent-reported infant's sleep habits must be taken as one explanation for our findings.

We found also several other fine-grained associations between subscales of Orienting/Regulation and sleep. Again, in contrast to our hypothesis, higher Duration of Orienting predicted longer sleep-onset latency, whereas other Orienting/Regulation subscales expectedly predicted shorter sleep-onset latency. In line with this pattern, there are studies to suggest that long infant duration of attention may have contradictory implications for later development, and short attentional duration may even be beneficial for development (Morales, 2005; Nakagawa & Sukigara, 2013; Todd & Dixon, 2010). More in line with our hypotheses, lower Low Intensity Pleasure was related to more sleep difficulties at 12 months of age. Given that this aspect of temperament is related to better self-regulation by low-level stimuli, including that the infant is typically exposed when going to sleep, this might indicate more persistent sleep problems in infants with less ability to utilize low-intensity cues to self-regulate and get pleasure. Due to the dynamic nature of self-regulation in early childhood, further research is needed on the specific regulatory behaviors and sleep development.

Finally, the lack of associations between Surgency and sleep quality problems is in concordance with our initial hypothesis and previous studies on young infants and adolescents (Jian & Teti, 2016; Moore et al., 2011), suggesting that positive affectivity indeed plays little or no role in the development of sleep. However, high Surgency/Positive Affectivity combined with poorer regulation might be a risk factor for some other developmental outcomes such as social competence (Dollar & Stifter, 2012). This is also true for other combinations of traits, for instance, high negative affectivity combined with poorer regulatory capacity (Ursache, Blair, Stifter, & Voegtline, 2013). Thus, future studies might want to study combination of traits together with environmental exposures (e.g. mother-child interaction) in predicting sleep to get even more detailed about the temperament as a predictor of sleep.

Following our initial hypothesis, we observed in a large and representative cohort that infant Negative Affectivity increases risk for sleep difficulties already in the earliest stages of life independently of sleep-related questionnaire items, which is consistent with previous studies (Loutzenhiser & Sevigny, 2008; Weinraub et al., 2012). Almost all associations between the main dimension Negative Affectivity and sleep remained when sleep-related items were excluded from the temperament scales. However, especially the aspect of Falling Reactivity, which is related to recovery from intense negative emotions, was strongly dependent on sleep-related questionnaire items in the IBQ-R. Furthermore, even though not directly related to sleep, there may still be shared methodological variance in the contexts where temperament is rated and the ratings of infant sleep (e.g. soothability across different situations and sleep) that should be taken into account in the future studies. In the same vein, the same aspects of temperament relevant for recovery from extreme emotional states might be the ones also crucial for sleep development, and may also share the same underlying neural systems. Thus, studies that aim at disentangling the biological systems underlying sleep and temperament from purely conceptual overlap of sleep development and the temperament tendencies that contribute to sleep are clearly needed to get further understanding on the relations between sleep and temperament.

Concerning the aspects of self-regulation, which was another main focus of this study, we found that possibly more fine-grained aspects of Regulation rather than the main dimension play more important role in shaping different aspects of sleep in early life, which might explain why fewer studies have tested or reported associations with infant Orienting/Regulation. Finally, and considering that the most profound increases in self-regulation take place in toddlerhood (Rothbart, Sheese, Rueda, & Posner, 2011) and later childhood (Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016), infants' capacity for self-regulation might not be fully developed at six months of age and developmental shifts will take place in the aspects of regulation throughout the early childhood. Therefore, the associations between self-regulation and sleep may be different in older children compared to infants.

This study highlights also some points that should be considered in clinical practice. We replicated the finding of the previous studies that infants with Negative Affectivity are at higher risk for developing persistent sleeping difficulties. However, the main implication of our work is that specific temperament traits are independent of sleep and may be crucial when determining the risk for later specific sleep problems, and a more individualized approach may be needed. Treating sleep problems in children is important because sleep disorders may interfere with physical, cognitive, emotional, and social development (Ednick et al., 2009). Therefore, these interventions should include not only educating parents about sleep, but also about the individual differences in temperament and how these differences might affect their children sleep and also the parental perception of these sleep problems. The complex interactions between normative maturation processes, environment and individual temperament traits should also be kept in mind when planning sleep interventions, emphasizing the idea that traits that may be positive in one regard (e.g. sociability) may also be challenging some sleep patterns in certain developmental stages.

Compared to prior work, this study has several methodological strengths. First, only one previous study has longitudinally examined the links between infant sleep and temperament using Rothbart's psychobiological model of temperament. In contrast to this work of Jian and Teti who focused on infants at one and six months of age (Jian & Teti, 2016), our current study focuses on later infancy (i.e., six and 12 months) in a considerably larger sample of participants. Second, we examined several temperament subscales to determine the specific temperament aspects which might be more crucial for sleep development in very early stages of life. However, the present study also has some limitations. First, sleep measures were only reported using parents' questionnaires, and we did not use objective measures, such as actigraphy. Parental reports and objective reports may disagree in some cases (Molfese et al., 2015); however, parental sleep reports are considered valid in very young children (Gregory, Van der Ende, Willis, & Verhulst, 2008), as they provide relevant information on parental perceptions of several aspects of the child's sleep, which otherwise could not be detected with objective measures. Second, and similarly to sleep assessment, temperament measures in this study were only reported using parental reports. This may bias some of the associations, as the parental rating tendency may affect their responses to the infant (e.g. the ratings of Cuddliness may be linked with parenting style that affects sleep difficulties). For this reason, future studies should include additional sources of information concerning temperament (i.e. observations, physiological markers) when studying predictors of child sleep. Third, in the same vein, other potential contributing factors, such as the parent-infant interactions should be explored in further studies. Fourth, our sample was composed of relatively healthy mothers and infants; thus, generalization of these results should be made cautiously with respect to clinical populations. Fifth, even though we effectively tested that our findings remain regardless of the sleep-related items in the IBQ-R, there may still be some overlap between the IBQ and the BISQ sleep items, which has been noted and discussed critically throughout the earlier sections.

5. Conclusion

In this study, higher levels of Negative Affectivity at six months were longitudinally related to sleep quality problems during the first year of life even independently of sleep-related temperament items. We also showed that several subscales of Negative Affectivity and Orienting/Regulation which were unrelated to sleep predicted aspects of sleep and change in sleep problems throughout the follow-up. For instance, Fear along with Regulation-related scales of Low Intensity Pleasure had expected associations with sleep problems at 12 months of age. As a novel finding, we showed that sociability-related high Cuddliness predicted specific sleep problems which may be related to the increased need of parental presence for sleeping; however, this finding needs to be replicated in future studies. Overall, our study provides support for the contribution of both Negative Affectivity and Regulation, especially their fine-grained aspects, to sleep development in the first year of life. However, further longitudinal studies should extend these findings to later stages, such as toddlers and/or preschool-age children, to determine the long-term effects of early temperament on sleep patterns. Future studies should also seek to disentangle the shared as well as distinct neurobiological mechanisms of temperament and sleep, to better understand their interplay both conceptually and clinically. Our findings suggest that infants' intrinsic reactivity and their regulatory capacity and the developmental phase should be all considered when designing better targeted sleep interventions in early stages of life. This way, a better characterization of the underlying factors interfering with a child's sleep could be also addressed.

Authors' contributions statement

LK, HK and EJP designed the study and wrote the protocol; IMM and SN conducted literature searches and provided summaries of previous research studies; IMM and SN conducted the statistical analysis; and IMM wrote the first draft of the manuscript. All authors contributed to the work and have approved the final manuscript.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

CRediT authorship contribution statement

Isabel Morales-Muñoz: Methodology, Formal analysis, Writing - original draft. **Saara Nolvi:** Methodology, Formal analysis, Writing - review & editing. **Minna Virta:** Methodology, Writing - review & editing. **Hasse Karlsson:** Conceptualization, Writing - review & editing, Project administration, Funding acquisition. **E. Juulia Paavonen:** Conceptualization, Writing - review & editing, Supervision. **Linnea Karlsson:** Conceptualization, Writing - review & editing, Project administration, Funding acquisition, Supervision.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.infbeh.2020.101485.

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