Bastien, L., Tétreault, É., & Bernier, A. (in press). Disentangling the direction of associations between sleep and temperament in toddlers. *Behavioral Sleep Medicine.*

Abstract

Objectives/Background: Although much research has investigated the associations between children's sleep and their temperament, the direction of these associations remains unclear, largely due to a lack of longitudinal studies with repeated assessments of both sleep and temperament. Aiming to clarify the temporal precedence of these two constructs, the current study investigated reciprocal associations between toddlers' sleep and temperament with a longitudinal design. *Participants*: The sample consisted of 82 toddlers (39 girls) assessed twice. *Methods*: At both 2 (*M* = 25.23 months; *SD* = 1.11) and 3 years of age (*M* = 36.81 months; *SD* = 0.91), toddlers' sleep duration and quality were assessed using actigraphy and their temperament was reported by their mothers with the Toddler Behavior Assessment Questionnaire. *Results*: Shorter nighttime sleep duration (ß = -.28, *p* = .03) and lower sleep efficiency (ß = -.33, *p* = .01) at 2 years predicted more temperamental proneness to anger at 3 years, while greater temperamental social fear at 2 years was predictive of shorter 24-hour (ß = -.44, *p* = .02) and nighttime (ß = -.36, *p* = .04) sleep duration at 3 years. Associations between temperamental activity level and sleep variables were non-significant. C*onclusion*: The direction of the associations between toddlers' sleep and their temperament may vary according to which dimension of temperament is considered. These findings should encourage practitioners to identify the beginning of the causal chain leading to sleep or temperamental difficulties so as to develop well-tailored intervention plans.

Keywords: toddlerhood, sleep, temperament, directionality, actigraphy.

Disentangling the direction of associations between sleep and temperament in toddlers

During childhood, sleep plays a significant role in multiple areas of child health and development, including brain maturation, physical growth and health, as well as social, emotional, behavioral, and cognitive adjustment (El-Sheikh & Sadeh, 2015). However, 10 to 30% of children will have sleep problems (Scher, Zukerman, & Epstein, 2005), which may persist for years if left untreated (Mindell, 2005). It is therefore important to identify factors that can lead to sleep problems so as to intervene early and reduce the risks of chronicity.

Temperament, which can be conceptualized in terms of individual differences in tendencies to feel and express primary emotions (Goldsmith & Campos, 1990), is one of the factors most often proposed as likely to influence children's sleep (Molfese et al., 2015; Wolfson & Montgomery-Downs, 2013). De Marcas, Soffer-Dudek, Dollberg, Bar-Haim, and Sadeh (2015) suggested that child temperament may influence sleep in that reactivity to stimuli is a central aspect of temperament (Rothbart & Derryberry, 1981). Accordingly, a more temperamentally reactive child will be more easily distracted and have more difficulty disengaging from internal and external stimuli (e.g., darkness, noise). These difficulties, in turn, may make sleep more difficult to initiate and maintain (De Marcas et al., 2015).

Some studies support that direction of association, by uncovering relations between young children's difficult temperament (mostly consisting of negative emotionality; Thomas & Chess, 1977) evaluated by parents and subsequent sleep. Scher and Asher (2004) noted that difficult temperament at 8 months predicted more sleep problems at 12 months (assessed with actigraphy and through maternal report). With parental reports of sleep, Weissbluth (1984) found that infants with a difficult temperament at 8 months slept less at 3 years. Weinraub and colleagues (2012) observed that difficult temperament at 6 months was associated with more nocturnal

awakenings at 21 months. These findings are consistent with the hypothesis that temperament may influence infants' and toddlers' sleep, particularly its consolidation and duration.

Other studies tend support the inverse relation, according to which sleep would predict subsequent temperament. Halpern, Anders, Garcia-Coll, and Hua (1994) observed that infants who spent most of the night awake at 3 weeks (recorded by videosomnography) were perceived by their parents as more irritable at 3 months. Judge, Chang, and Lammi-Keefe (2015) found that a longer time spent in a transitional sleep state (between sleep and wakefulness) during the first two days of life evaluated by actigraphy predicted more difficult temperament at 6 months. Finally, Novosad, Freudigman, and Thoman (1999) reported that several sleep variables (e.g., duration, restlessness) during the first two days after birth predicted temperament at 8 months of age.

These findings, suggesting that young children's sleep may influence their temperament, can perhaps be attributed to the regulatory component of temperament (Rothbart & Derryberry, 1981). Although temperament has an innate basis, it also develops across time, particularly its regulatory component during early childhood (Rothbart & Bates, 2006). Hence, some propose that temperament could be influenced by early life experiences such as sleep problems (Wolfson & Montgomery-Downs, 2013). In particular, fatigue, caused by lack of sleep or poor sleep quality, is a physiological stressor for children. This can result in a biochemical stress response likely to interfere with emotion regulation, and could thereby worsen temperamental difficultness (Weissbluth, 1989).

Overall, after many years of research on the links between young children's sleep and temperament, the direction of these links remains unclear (e.g., Sorondo & Reeb-Sutherland, 2015) and indeed, both directions are theoretically plausible. The sleep variables and

temperament dimensions examined differ from one study to another, making it difficult to compare results across studies. Importantly, extant studies are either cross-sectional or longitudinal with only one assessment each of sleep and temperament, which does not allow one to disentangle the direction of the association between these two constructs. One way to clarify this issue is with the use of longitudinal cross-lagged designs entailing two assessment time points of both sleep and temperament. Although such non-experimental designs cannot firmly demonstrate causality, they are useful in suggesting directionality of associations. The present longitudinal study aimed to contribute knowledge on the reciprocal associations between sleep and temperament among toddlers by assessing several dimensions of each at both 2 and 3 years of age, using a behavioral sleep measure and maternal reports of temperament. In line with recommendations (e.g., Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010; Diaz et al., 2017; Philbrook, Hinnant, Elmore-Staton, Buckhalt, & El-Sheikh, 2017), we focus on indices of sleep duration and quality, as well as distribution over the 24-hour period (Sadeh, 2015). Due to the lack of previous studies jointly considering the same dimensions of sleep and temperament as assessed here, no a priori hypotheses were formulated and analyses were exploratory.

Method

Participants

Participating families were recruited randomly using government-provided birth lists of the city of Montreal, Canada, and criteria for participation were full-term pregnancy and the absence of any known physical or intellectual disability in the child. The study protocol was approved by the university's institutional review board. Upon recruitment (when children were 8 months old), mothers were between 20 and 44 years (M = 31.91, SD = 4.49), had an average of 16 years of education (SD = 2.2) and were mostly Caucasian (90.2%). Fathers were between 21

and 47 years (*M* = 33.87, *SD* = 5.03), had an average of 15 years of education (*SD* = 2.76) and were generally Caucasian (79.3%). The average annual family income was in the $60,000 to $79,000 bracket.

At 2 years, the initial sample consisted of 82 subjects (39 girls). Valid sleep data were available for the 82 toddlers and 73 (33 girls) mothers provided assessments of toddler temperament (described below). At 3 years, temperament was available for 55 toddlers (28 girls) and sleep for 63 toddlers (32 girls). Children with missing sleep or temperament data at 3 years did not differ from others on socio-demographic or 2-year sleep or temperament data (*p*s > .50).

Procedure

Temperament and sleep were assessed when children were aged 2 (*M* = 25.23 months; *SD* = 1.11) and 3 years (*M* = 36.81 months; *SD* = 0.91). At each time point, home visits took place and mothers were asked to complete the Toddler Behavior Assessment Questionnaire (TBAQ; Goldsmith, 1996) to report on their toddler's temperament. During the visits, the assistant gave the parents an actigraph, instructing them to place it on the toddler's ankle or wrist for three consecutive days during which their toddler had a fairly usual routine. The three-night period was chosen based on prior actigraphy research with same-age children (e.g., Ward, Gay, Anders, Alkon, & Lee, 2008) and to reduce family burden.

To cross-check actigraphy data, mothers were also instructed to complete a diary of their toddler's sleep during the same period. They indicated bedtime, rise time, any event that might have disturbed their toddler's sleep (e.g., illness, medication taking, visitors at home), and times where the toddler did not wear the actigraph. This last piece of information is needed to ensure that moments without motor activity are attributable to sleep, rather than to the actigraph not being worn. To minimize memory biases, mothers were asked to complete the sleep diary in real

time rather than retrospectively at the end of the three-day period. When there was poor correspondence between the actigraphic data and the sleep diary, the nights in question were discarded. Possible causes of poor correspondence are the mother's lack of diligence in completing the sleep diary or technical problems with the actigraph. Two subjects were excluded for unsatisfactory correspondence at 2 years, and three at 3 years (resulting in the *N*s = 82 and 63 provided above). Following the three-day period of actigraphy assessment, a financial compensation (CND $20) was provided to the family. The full financial compensation was given regardless of the number of completed days, in order to reduce the probabilities of parents filling out diaries at the last minute, retrospectively, to receive the compensation.

Instruments

Toddler temperament. At 2 and 3 years, mothers were asked to complete the TBAQ (Goldsmith, 1996), translated and validated in French by Lemelin and colleagues (2007). This questionnaire is intended for children aged between 15 to 36 months and evaluates five dimensions of temperament (activity level, tendency to express pleasure, social fear, proneness to anger and interest/persistence). Because they have been more often associated with sleep problems, only the negative dimensions were assessed in the current study, namely proneness to anger, social fear, and activity level. This last dimension refers to the general level of emotional arousal in children and serves to capture the role of action in expressing a strong emotion (Goldsmith, 1996). Mothers rated the items on a seven-point scale ranging from (1) "Never" to (7) "Always" to describe their toddler’s reactions in the last month.

The TBAQ shows good reliability and convergent validity (Goldsmith, 1996). In the current study, internal consistency was very good at both 2 (social fear: α = .79, proneness to anger: α = .88, activity level: α = .77) and 3 (social fear: α = .90, proneness to anger: α = .74,

activity level: α = .83) years. This instrument shows satisfactory convergent validity with other temperament questionnaires such as the Infant Characteristics Questionnaire (Bates, Freeland, & Lounsbury, 1979) and the Infant Behavior Questionnaire (Rothbart, 1986).

Toddler sleep. When children were 2 and 3 years old, sleep data were collected using an actigraph consisting of a small wireless watch-like device (Mini-Mitter® Actiwatch Actigraph, Respironics, OR; AW-64). Actigraphy evaluates sleep from motor activity through an accelerometer that continuously records child movements. Motor activity data are subsequently converted into estimates of sleep and wake periods. Activity level was recorded in 30-s epochs. Because actigraphy tends to overestimate night awakenings due to young children's higher level of motor activity during sleep (Meltzer, Walsh, Traylor, & Westin, 2012), data were analyzed initially with the manufacturer's low sensitivity threshold algorithm (80 activity counts per epoch; more appropriate for toddlers' enhanced motor activity). However, even this more appropriate algorithm tends to overestimates awakenings (Bélanger, Bernier, Paquet, Simard, & Carrier, 2013). Consequently, a secondary "smoothing" algorithm was applied to the nighttime data. This algorithm was developed specifically to address the problem of overestimation of night waking. The smoothing method requires a minimum 2-min awakening period following sleep onset to score an awakening (Sitnick, Goodlin-Jones, & Anders, 2008). Data obtained with this algorithm are highly consistent with those gathered with videosomnography (Sitnick et al., 2008) and home-based polysomnography (Bélanger et al., 2013). The actigraph model used in this study shows adequate validity for the assessment of sleep in children aged 2 to 5 years (Bélanger et al., 2013). An experienced research assistant scored all actigraphic data using Actiware software version 6.0.9 (Philips Respironics, Bend, OR). Sleep onset and sleep offset

were defined manually by the research assistant, based on visual examination of the actogram guided by the bed and rise times indicated on the sleep diary.

In the current study, sleep variables were (a) nighttime sleep duration (number of minutes between nighttime sleep onset and offset that were scored as sleep); (b) total 24-hr sleep duration (the sum of nighttime and daytime sleep duration); (c) proportion of nighttime sleep (percentage of total daily sleep occurring at night); and (d) sleep efficiency (sleep minutes at night/ [sleep minutes at night + wake minutes at night] x 100). For each sleep variable, the average over the three days of assessment was used when available. The majority of toddlers had, at each age, 3 days of valid data. At 2 years, 66 toddlers had 3 days of data, 10 had 2 days, and 6 had 1 day. At 3 years, 44 toddlers had data for 3 days, 15 for 2 days, and 4 toddlers had 1 day of data.

Results

Preliminary analyses

Table 1 presents descriptive statistics for temperament dimensions and sleep variables. All variables presented satisfactory variability and normal or near-normal distributions. Three socio-demographic variables (child sex, maternal ethnicity and education) were associated with some sleep variables or temperament dimensions and were therefore co-varied in the final regression analyses.

Main analyses

Bivariate correlations were computed to examine associations between sleep at 2 years and temperament at 3 years, and vice-versa (see Table 2). First, results indicated that several sleep variables measured at 2 years were associated with temperamental anger at 3 years. Toddlers with shorter nighttime (but not total) sleep duration, lower percentage of nighttime

sleep, and lower sleep efficiency at 2 years showed greater proneness to anger at 3 years. Sleep variables at 2 years were not associated with the other dimensions of temperament (activity level and social fear) at 3 years. We then examined the opposite relation between initial temperament and subsequent sleep. Toddlers who were more socially fearful at 2 years slept less over the 24-hour period, had lower sleep efficiency, and marginally lower percentage of nighttime sleep at 3 years. In contrast, temperamental level of activity and anger proneness at 2 years were not associated with 3-year sleep.

To explore these associations further, hierarchical regression analyses were used to examine whether initial sleep could predict subsequent temperament, and vice-versa, while controlling for covariates. To reduce the number of models run and as per the analyses above, only 2-year social fear and 3-year anger proneness were considered for temperament.

Table 3 illustrates that nighttime sleep duration and sleep efficiency measured at 2 years significantly predicted anger proneness at 3 years, after controlling for child sex as well as maternal ethnicity and education. Toddlers with shorter or less efficient nighttime sleep at 2 years were considered more prone to anger by their mothers at age 3. In addition, both the percentage of nighttime sleep and 24-hour sleep duration at 2 years were marginally predictive of 3-year anger proneness (see Figure 1).

Results of a second series of regressions revealed that, above and beyond child sex, maternal ethnicity and education, social fear at 2 years predicted 24-hour sleep duration as well as nighttime sleep duration at 3 years (see Table 4). Toddlers who were considered more socially fearful by their mothers at age 2 slept less one year later. In addition, social fear at 2 years was marginally associated with 3-year sleep efficiency, but unrelated to the percentage of nighttime sleep (see Figure 2).

In a last step of analyses, we examined whether 2-year sleep predicted *changes* in proneness to anger between ages 2 and 3, by covarying age-2 anger along with the other covariates (results not displayed in a table). Results showed that 2-year sleep did not significantly predict changes in anger proneness between ages 2 and 3, although two trend-level predictions were observed: shorter nighttime sleep duration (ß = -.21, p = .08) as well as lower sleep efficiency (ß = - .22, p = .07) marginally predicted an increase in anger proneness between 2 and 3 years of age. Similar analyses were conducted to investigate whether 2-year social fear predicted changes in sleep between 2 and 3 years. Results revealed that social fear did not predict changes in sleep, although one trend-level prediction was found: greater temperamental social fear marginally predicted a decrease in nighttime sleep duration between age 2 and age 3 (ß = -.48, p = .05).

Discussion

The aim of this study was to investigate the directionality of associations between sleep and temperament among toddlers. Results suggested that the direction of associations between the two constructs may vary by dimension of temperament considered. This is broadly consistent with the consensus that temperament is multidimensional (Goldsmith & Campos, 1990; Rothbart & Derryberry, 1981) and that different dimensions have distinct implications for child functioning (Rettew, Copeland, Stanger, & Hudziak, 2004). In contrast, the results did not vary much according to which aspect of sleep was considered and accordingly, are discussed below by temperament dimensions.

Proneness to anger

After accounting for covariates (child sex, mother ethnicity and education), lower sleep efficiency and shorter nighttime sleep duration at 2 years predicted more anger proneness at 3

years (and marginally predicted *increases* in anger proneness between ages 2 and 3). Furthermore, lower percentage of nighttime sleep and shorter sleep duration over a 24-hr period at 2 years were marginally associated with greater temperamental anger at 3 years of age. These relations between sleep and subsequent anger proneness are consistent with previous studies that found associations between sleep difficulties and anger-related constructs such as aggression (Bélanger, Bernier, Simard, Desrosiers, & Carrier, 2015) and irritability (Clinkinbeard, Simi, Evans, & Anderson, 2010).

Most of the literature on sleep and anger has focused on adolescents and adults (e.g., Ottoni, Lorenzi, & Lara, 2011; Shin et al., 2005). Despite the cross-sectional nature of much of this research, study authors often propose that anger would impact sleep, although the inverse relation has also been proposed (Kamphuis, Meerlo, Koolhaas, & Lancel, 2012; Krizan & Herlache, 2016; Krizan & Hisler, 2016). In fact, Krizan and Hisler (2018) recently observed through an experimental design that sleep loss plays a causal role in shaping anger among adults. The authors propose that sleep deprivation may enhance the awareness of aversive and negative stimuli which, combined with the propensity of sleep disruption to impair the regulation of negative emotions (Mauss, Troy, & LeBourgeois, 2013), could contribute to feelings of anger. Experimental designs with young populations are needed to confirm adult findings, but the results of the current longitudinal study also suggest that poor sleep may precede anger manifestations in toddlers, more so than the converse. Irritability is conceptualized as children's aberrant response to frustration that is often manifested as increased proneness to anger (Leibenluft, 2017) and has been observed to relate to disturbed sleep in young children (Halpern et al., 1994). Hence, irritability may provide a vehicle between

poor sleep and anger in toddlers, akin to the role of awareness of aversive stimuli proposed in adults by Krizan and Hisler (2018).

Another likely mechanism for the putative impact of sleep difficulties on anger is related to the prefrontal cortex, a brain region that is still immature during childhood and important for anger control, especially for the inhibition of resulting behaviors (Dahl, 1996; Maski & Kothare, 2013). Poor sleep could disrupt prefrontal cortex inhibitory activity, resulting in inappropriate behavioral responses, such as tantrums (Kamphuis & Lancel, 2015). These responses, in turn, may lead to more anger proneness as observed by parents.

Sleep did not predict dimensions of temperament other than anger. This might be due to the fact that anger is an intense emotion that is particularly difficult to manage and requires more resources to be regulated (Bonanno, 2001). When fatigue, which interferes with emotion regulation (Weissbluth, 1989), is involved, children with greater temperamental anger may be particularly penalized by the negative impact of sleep difficulties, relative to children who struggle with intense activity levels or social fear instead.

Social fear

Toddlers who were more socially fearful at 2 years slept less over a 24-hour period and during the night at 3 years, above and beyond covariates (social fear was also marginally associated with a decrease in nighttime sleep duration between ages 2 and 3). Moreover, higher scores on 2-year social fear were marginally predictive of lower 3-year sleep efficiency. These links are reminiscent of those identified by Zaidman-Zait and Hall (2015), who reported that 29-month-old toddlers with extended night waking showed higher concurrent levels of shyness.

From a biological point of view, social fear could influence sleep in different ways. Social fear is associated with less efficient vagal regulation, which reflects parasympathetic

nervous system activity, important for homeostasis and rest (Damon, Lerner, & Eisenberg, 2006). Less efficient vagal regulation has been associated with sleep disturbances in school-age children (El-Sheikh & Buckhalt, 2005). Thus, social fear may negatively affect sleep through non-optimal vagal regulation. In addition, more socially fearful children experience higher salivary cortisol levels in the morning (Schmidt et al., 1997), which have been found to predict an increase in sleep problems between 2 and 3 years of age (Kiel, Hummel, & Luebbe, 2015). Hence, higher morning cortisol in socially fearful toddlers may affect their sleep quality and duration. Lastly, social fear could influence sleep through the lower sensory threshold that is frequently associated with this dimension of temperament (Coplan, Arbeau, & Armer, 2008). This lower threshold makes children sensitive to stimuli (e.g., light, noise) that they must disengage from in order to fall and to remain asleep (Aron, 2012). Overall, temperamental social fear could detract from sleep duration and sleep efficiency due to its biological substrates.

Socio-emotional pathways are also likely. Fearful toddlers are particularly sensitive to judgment (Kochanska, 1997) and are more likely to feel shame and embarrassment as early as the age of 2 (Rothbart, 2011). Unfortunately, this influences their social interactions and predisposes them to less positive relationships (Rydell, Bohlin, & Thorell, 2005) that in turn, constitute an interpersonal stressor that can negatively impact their sleep (Bell & Belsky, 2008). Thus, social fear may undermine sleep by predisposing toddlers to interpersonal difficulties.

However, one should bear in mind that in the case of both social fear and anger, age-2 variables predicted some age-3 variables, but did not reliably predict changes between these two ages: poor sleep did not reliably predict an *increase* in anger, and social fear did not reliably predict *deteriorations* in sleep over a one-year period. The marginal nature of certain results suggests that insufficient statistical power may be at play with these analyses that required the

inclusion of an additional covariate. However, these results also suggest that part of the associations between sleep and temperament appears before toddlerhood (as suggested by prior studies, e.g., Halpern et al., 1994; Judge et al., 2015), and thus is already in place by age 2. Hence, the unfolding of the developmental process linking children's sleep to their temperament probably starts early, and its precise characterization is likely to require detailed longitudinal studies with frequent assessments of both constructs beginning early in infancy.

Activity level

Temperamental activity level was neither predicted by nor predictive of any aspect of sleep. A potential explanation pertains to the theoretical ambiguity surrounding temperamental activity level: for some it is a risk factor, being associated with various behavioral problems (e.g., Fagot, & O'Brien, 1994), for others a favorable factor that confers developmental benefits (e.g., Eaton, McKeen, & Campbell, 2001). In fact, a curvilinear relation between temperamental activity level and child developmental outcomes has been proposed (Zentall & Zentall, 1983): having too high or too low levels of activity would be detrimental to child development, whereas moderate levels would have a negligible influence (Flom, Cohen, & Saudino, 2017). In this study, most toddlers had moderate temperamental activity levels (see Table 1), which may explain why no significant pattern emerged in relation to sleep.

Conclusion

This study presents some methodological limitations that must be considered when interpreting the results. First, the correlational design does not allow for causal inference, limiting the interpretation of the results to the associations between sleep and temperament dimensions. In addition, the modest sample size may have affected statistical power, perhaps contributing to the fact that some results were marginally significant. More specifically,

considering our .05 alpha level, power was 80% if independent variables accounted for at least 10% of unique variance in the regression analyses. The low-risk community sample (mostly college-educated Caucasian parents) also suggests that findings may not replicate in more diverse samples (e.g., characterized by greater socio-economic, biological, or psychosocial risk), limiting the generalization of the results. Also, although the results of several previous studies are based on three nights of actigraphic recording (e.g., Gnidovec, Neubauer, & Zidar 2002; Harrison, 2004; Ward et al., 2008), at least five nights are preferred to maximize reliability of actigraphic data in children (Acebo et al., 1999 – although satisfactory levels of reliability (close or superior to .70) can be obtained with three days of assessment; Acebo et al., 1999). Finally, we used a very precise sleep assessment (based on 30-sec epochs) in conjunction with a broad temperament questionnaire asking mothers about their toddler's reactions in the last month. Future research should investigate whether level of measurement plays a role in the associations observed between sleep and temperament.

This study adds significantly to those of previous longitudinal studies that had entailed only one assessment each of sleep and temperament. It is the first study, to our knowledge, to suggest that the direction of the associations between toddlers' sleep and temperament may vary according to which dimension of temperament is considered. When faced with toddlers with sleep difficulties, practitioners may consider the possibility to intervene differently according to the child's temperament: it may be useful to intervene on temperament first (or also) with toddlers who are more socially fearful, whereas acting directly on sleep may be preferable with toddlers who are prone to anger. However, future studies should investigate whether directionality varies by developmental period, as the directionality of associations uncovered here with toddlers may not generalize to younger or older children.

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Table 1

Descriptive statistics for study variables

Variables	Minimum	Maximum	Mean	Standard deviation
2-year temperamental dimensions				
Activity level	2.68	5.65	3.84	0.64
Anger proneness	2.33	5.70	3.84	0.64
Social fear	1.64	5.19	3.65	0.81
3-year temperamental dimensions				
Activity level	1.88	4.81	3.26	0.79
Anger proneness	2.26	6.21	3.71	0.81
Social fear	1.50	6.07	3.23	1.02
2-year sleep variables				
Nighttime sleep duration (hours)	6.49	11.31	9.42	1.00
Sleep efficiency (%)	67.03	99.57	90.61	7.09
24-hour sleep duration (hours)	9.03	14.19	11.45	1.29
Percentage of nighttime sleep	67.20	98.15	82.33	6.75
3-year sleep variables				
Nighttime sleep duration (hours)	7.77	11.11	9.35	0.75
Sleep efficiency (%)	70.93	100	94	5.52
24-hour sleep duration (hours)	8.46	13.38	11.33	1.02
Percentage of nighttime sleep	69.00	100	83.08	7.09

Note. For each sleep variable, the average of sleep data over the three days was used.

Table 2

Bivariate correlations among all sleep and temperament variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. 2-year AL	---	.48**	.14^{t}	.03	.04	-.09	-.09	.69***	.32**	.03	-.02	.01	-.20	.21
2. 2-year anger		---	.22**	-.14	-.24*	-.14	-.15	.33**	.53***	.14	-.08	-.02	-.22	.07
3. 2-year SF			---	.05	-.09	-.23^{t}	.28*	-.05	.23*	.55***	-.21	-.31*	-.47**	.31^{t}
4. 2-year night sleep				---	.71***	.74***	.27*	-.06	-.32*	-.03	.11	-.21	-.04	.28
5. 2-year efficiency					---	.57***	.11	.05	-.31*	-.15	.22	.05	.09	.19
6. 2-year 24-hour						---	-.45***	.01	-.19	-.15	.18	.00	.21	.02
7. 2-year % night							---	-.27^{t}	-.35*	.05	-.17	-.28	-.31	.23
8. 3-year AL								---	.42***	-.10	-.13	-.01	-.24	.13
9. 3-year anger									---	.36***	-.23	.01	-.27^{t}	.02
10. 3-year SF										---	-.02	-.01	-.42**	.36*
11. 3-year night sleep											---	.57***	.54***	.38**
12. 3-year efficiency												---	.48***	.05
13. 3-year 24-hour													---	-.57***
14. 3-year % night														---

Note. AL = activity level; anger = anger proneness; SF = social fear; night sleep = nighttime sleep duration; efficiency = sleep efficiency; 24-hour = 24-hour sleep duration; % night = percentage of nighttime sleep.
For each sleep variable, the average of sleep data over the three days was used.
^{t} $p < .10$. * $p < .05$. ** $p < .01$. ***$p < .001$.

Table 3

Hierarchical regression analyses predicting 3-year anger proneness from 2-year sleep

	R^2	Δ R^2	*F* Change	ß
3-year anger proneness				
1. Child sex	.27		4.74**	.12
M ethnicity				.45**
M education				.39**
2. 2-year 24-hour	.33	.06	3.53t	-.26t
3-year anger proneness				
1. Child sex	.21		4.38**	.10
M ethnicity				.41**
M education				.33*
2. 2-year night sleep	.28	.07	4.81*	-.28*
3-year anger proneness				
1. Child sex	.21		4.38**	.10
M ethnicity				.41**
M education				.33*
2. 2-year efficiency	.32	.11	7.67**	-.33**
3-year anger proneness				
1. Child sex	.27		4.74**	.12
M ethnicity				.45**
M education				.39**
2. 2-year % night	.32	.05	2.96t	-.26t

Note. M ethnicity = maternal ethnicity; M education = maternal education; night sleep = nighttime sleep duration; efficiency = sleep efficiency; 24-hour = 24-hour sleep duration; % night = percentage of nighttime sleep.
t $p < .10$. * $p < .05$. ** $p < .01$.

Table 4

Hierarchical regression analyses predicting 3-year sleep from 2-year temperamental social fear

	R^2	Δ R^2	*F* Change	ß
3-year 24-hour				
1. Child sex	.16		1.96	-.37*
M ethnicity				-.04
M education				.09
2. 2-year social fear	.31	.15	6.70*	-.44*
3-year night sleep				
1. Child sex	.04		.53	.01
M ethnicity				-.17
M education				-.08
2. 2-year social fear	.13	.09	4.53*	-.36*
3-year efficiency				
1. Child sex	.16		2.70t	-.18
M ethnicity				-.08
M education				.32*
2. 2-year social fear	.23	.07	3.84t	-.31t
3-year % night				
1. Child sex	.23		3.13*	.35*
M ethnicity				-.15
M education				-.29t
2. 2-year social fear	.25	.01	.49	.13

Note. M ethnicity = maternal ethnicity; M education = maternal education; night sleep = nighttime sleep duration; efficiency = sleep efficiency; 24-hour = 24-hour sleep duration; % night = percentage of nighttime sleep.
t $p < .10$. * $p < .05$.

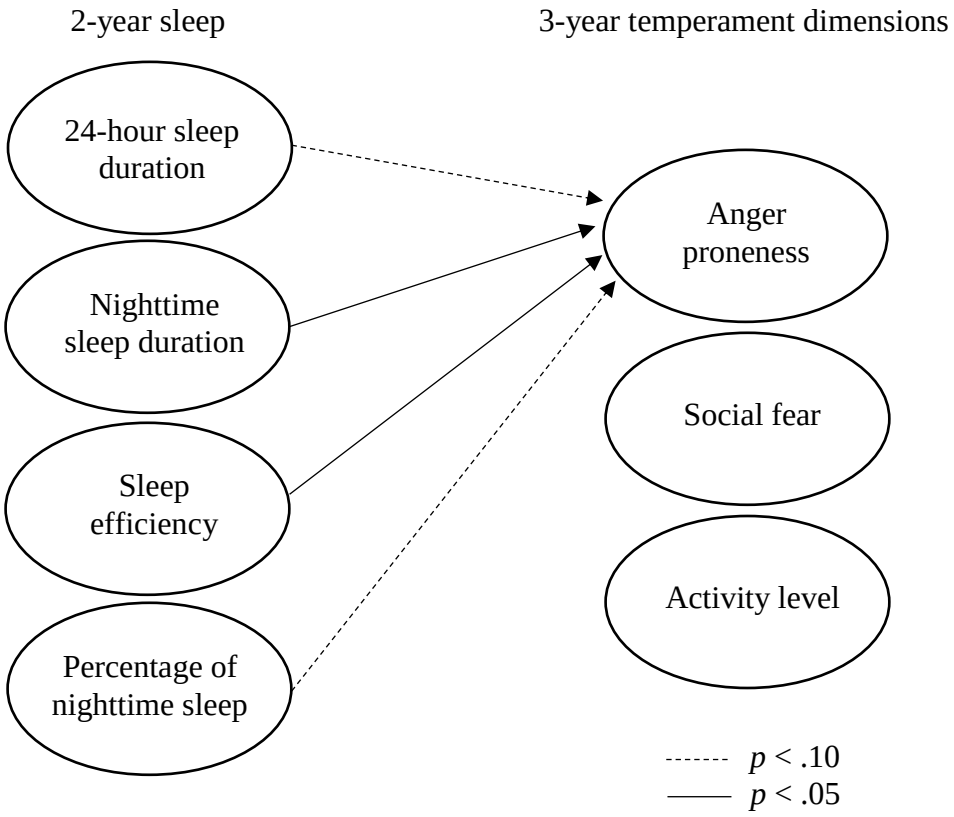

Figure 1. Summary of observed associations between 2-year sleep and 3-year temperament. Nighttime sleep duration and sleep efficiency measured at 2 years significantly predicted anger proneness at 3 years. 24-hour sleep duration and percentage of nighttime sleep at 2 years were marginally predictive of 3-year anger proneness. 2-year nighttime sleep duration and 2-year sleep efficiency were also marginally predictive ($p < .10$) of changes in anger proneness between ages 2 and 3.

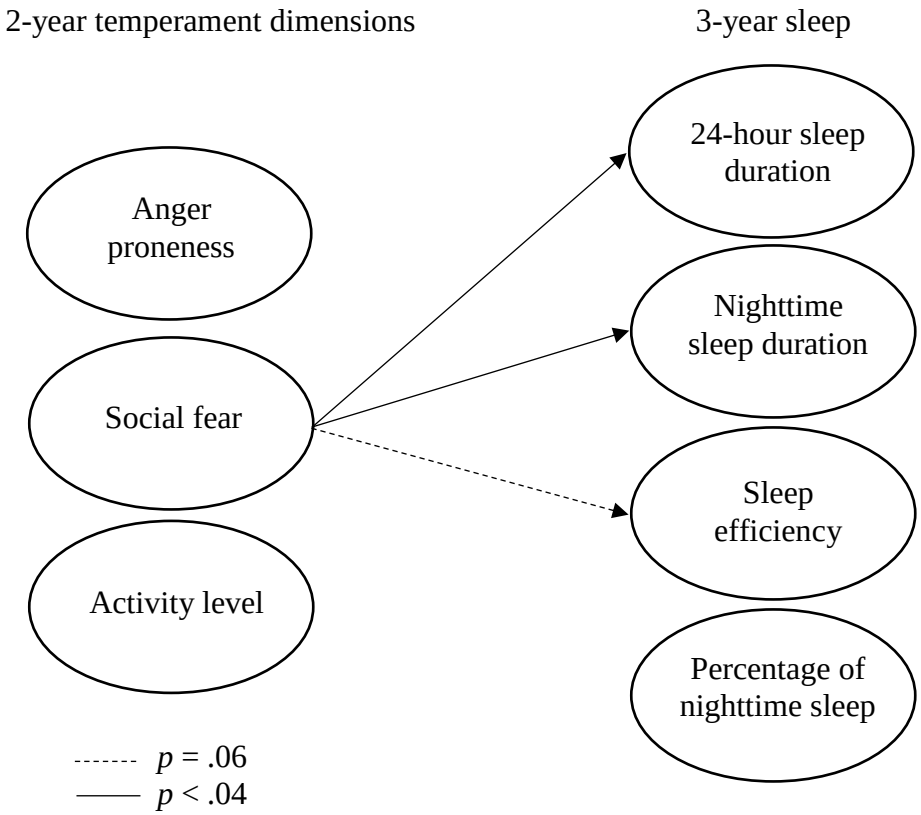

Figure 2. Summary of observed associations between 2-year temperament and 3-year sleep. Age-2 social fear significantly predicted 24-hour sleep duration as well as nighttime sleep duration at 3 years, was marginally associated with 3-year sleep efficiency, and unrelated to the percentage of nighttime sleep. Age-2 social fear also marginally predicted ($p < .10$) changes in nighttime sleep duration between ages 2 and 3.