Distinct Developmental Trends in Sleep Duration During Early Childhood

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KEY WORDS
sleep, trajectories, quality of life

ABBREVIATIONS
AIC—Akaike's Information Criterion
BIC—Bayesian Information Criterion
BLRT—bootstrap likelihood ratio test
GMM—growth mixture modeling
LSAC—Longitudinal Study of Australian Children
OR—odds ratio
PedsQL—Pediatric Quality of Life Inventory
QoL—quality of life

Dr Magee conceptualized the study, conducted the analyses, and drafted the initial manuscript; Dr Gordon contributed to the conceptualization of the study, provided input into the analyses, and reviewed and revised the manuscript; Dr Caputi contributed to the conceptualization of the study and the analytic approach and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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WHAT'S KNOWN ON THIS SUBJECT: A limited number of studies have identified distinct patterns of child sleep duration, which appear to have implications for health and well-being.

WHAT THIS STUDY ADDS: This article identifies distinct patterns of sleep duration during early childhood and demonstrates that these have important implications for health-related quality of life.

abstract

BACKGROUND AND OBJECTIVES: Sleep is important to child development, but there is limited understanding of individual developmental patterns of sleep, their underlying determinants, and how these influence health and well-being. This article explores the presence of various sleep patterns in children and their implications for health-related quality of life.

METHODS: Data were collected from the Longitudinal Study of Australian Children. Participants included 2926 young children followed from age 0 to 1 years to age 6 to 7 years. Data on sleep duration were collected every 2 years, and covariates (eg, child sleep problems, maternal education) were assessed at baseline. Growth mixture modeling was used to identify distinct longitudinal patterns of sleep duration and significant covariates. Linear regression examined whether the distinct sleep patterns were significantly associated with health-related quality of life.

RESULTS: The results identified 4 distinct sleep duration patterns: typical sleepers (40.6%), initially short sleepers (45.2%), poor sleepers (2.5%), and persistent short sleepers (11.6%). Factors such as child sleep problems, child irritability, maternal employment, household financial hardship, and household size distinguished between the trajectories. The results demonstrated that the trajectories had different implications for health-related quality of life. For instance, persistent short sleepers had poorer physical, emotional, and social health than typical sleepers.

CONCLUSIONS: The results provide a novel insight into the nature of child sleep and the implications of differing sleep patterns for health-related quality of life. The findings could inform the development of effective interventions to promote healthful sleep patterns in children. *Pediatrics* 2014;133:e1561–e1567

Poor sleep during early childhood is linked with adverse outcomes including child anxiety, behavioral problems, impaired cognitive development, obesity,[1,2] and maternal fatigue and depression.[3] Although potential determinants and consequences of child sleep have been investigated, most research has examined sleep at 1 or 2 time points, which is not sufficient to capture developmental changes in sleep that occur during childhood.[4,5] Therefore, extant research provides only partial insights into the nature and consequences of child sleep.

Two recent studies have investigated child sleep duration across 4 or 5 time points and identified distinct developmental trajectories of sleep duration. Touchette et al[2] identified 4 distinct sleep trajectories in children followed across 5 time points from age 2.5 years to 6 years: short persistent sleep (5.2%), short increasing sleep (4.7%), 10-hour persistent sleep (50.7%), and 11-hour persistent sleep (39.4%). Seegers et al[6] identified 3 distinct trajectories of time spent in bed (a proxy of sleep duration) in children followed from age 10 to 13 years: short sleepers (15%), 10.5-hour sleepers (68%), and 11-hour sleepers (17%). Both studies found that children in the shorter sleep trajectories were more likely to be overweight.

These studies provide insights into the nature of child sleep, but additional research is needed to more comprehensively investigate these trajectories. This research should examine factors predicting these trajectories and clarify the implications of these trajectories for health and well-being more broadly. Using a growth mixture modeling approach, the present study investigated the presence and nature of distinct sleep duration trajectories during early childhood, their underlying determinants, and their implications for physical, emotional, and social health-related quality of life (QoL).

METHODS

Participants

The Longitudinal Study of Australian Children (LSAC) commenced in 2004 and tracks a cohort of infants (followed from birth) and a cohort of children (followed from age 4 years). These cohorts were randomly selected through the Medicare Australia database (the most comprehensive database of the Australian population) using geographic stratification; follow-up data are collected every 2 years. This study focused on the infant cohort for the first 4 waves when children were aged 0 to 1 years (Wave 1), 2 to 3 years (Wave 2), 4 to 5 years (Wave 3), and 6 to 7 years (Wave 4). This cohort included 5107 children at Wave 1 and 4242 children at Wave 4 (attrition rate of 16%); 1315 children had missing sleep data across 3 or more time points, 105 had extreme values for sleep duration (informed by Cook's distance and influence statistics), and 761 had missing data on relevant covariates. The final sample thus consisted of 2926 children. Missing sleep duration data across 1 or 2 time points were handled using full information maximum likelihood.[7] Parents provided informed written consent for their child to participate in LSAC, and this study received ethical approval from the appropriate university human research ethics committee.

Measures

Sleep Duration

In Waves 1 to 3, sleep duration was assessed via parent-completed 24-hour time use diaries. Two diaries (1 weekday and 1 weekend day) were completed for each child at every wave. Each diary involved the parent indicating what the child was doing in each 15-minute interval during the 24-hour period by selecting from a list of 26 activities ("sleeping" was one of the options). In Wave 4, sleep duration was determined from interview questions assessing the time the child fell asleep and woke up on a weekday and weekend night. A weighted average of weekday and weekend sleep duration was calculated and included in the analyses as an estimate of weekly sleep duration to enable comparisons with previous research.

Quality of Life

The Pediatric Quality of Life Inventory (PedsQL)[8,9] is a 23-item parent-completed scale assessing how often a child experiences problems in 4 domains: physical functioning (eg, problems with walking), emotional functioning (eg, feeling sad), social functioning (eg, problems socializing), and school functioning (eg, missing school because of illness). Parents indicated how frequently the child had experienced each problem during the past month on a 5-point Likert scale (*never a problem* to *almost always a problem*). The LSAC first assessed QoL at Wave 2 and then at each subsequent wave. The exception was school functioning, which was not assessed until the children had commenced school and thus was not included in this study.

Covariates

Several covariates assessed at Wave 1 were included. Parents provided information on the child's gender, birth weight (low birth weight, <2500 g; normal birth weight, 2500–4000g; and, high birth weight, >4000 g),[10] and any medical conditions. Parents indicated whether their child experienced sleep problems (eg, wheezing or coughing, difficultly falling asleep, waking during the night, and restless sleep) on 4 or more nights a week. Responses were combined to provide an indication of frequent sleep problems ("yes" versus "no"). Information was collected on family type (ie, single- versus dual-parent family), household size, and

maternal education (less than high school, completed high school, or completed a tertiary qualification [diploma, certificate, or university degree]). Maternal employment status at Wave 1 (not employed, employed on a causal basis or part-time, or employed full-time) was also included.

Child temperament was assessed using the Approach, Cooperation–manageability, and Irritability subscales of the Infant Temperament Questionnaire.[11,12] The Approach subscale (4 items) assesses infant reactions to new people and changing environments (eg, accepts strangers at home). The Irritability subscale (4 items) assesses how fretful the infant is and whether he or she settles with soothing (eg, fretful on waking or going to sleep). The Cooperation–manageability subscale (4 items) assesses whether the child is easy to groom and remains happy when being changed or dressed (eg, accepts grooming without protest).

The study also included the Family Hardship Scale, which was designed specifically for the LSAC. This scale includes 7 indicators of household hardship (eg, inability to pay bills), which are summed to provide a total number of household hardships. This variable was included because financial hardships could reflect family stress and socioeconomic status, which have been related to child sleep.[13]

Statistical Analysis

Distinct sleep duration trajectories were assessed by using growth mixture modeling (GMM), which identifies subpopulations with similar trajectories over time.[14] The analyses followed existing recommendations[14–17] and involved 3 steps: identifying the number of distinct trajectories, examining covariates associated with the trajectories, and then testing a final GMM that included relevant covariates.

In Step 1, a series of GMMs was tested (without covariates) specifying different numbers of classes to identify the number of distinct trajectories. The optimal number of latent classes was informed by bootstrap likelihood ratio tests (BLRTs), which compare the fit between 2 subsequent models (eg, 3 latent classes and 2 latent classes). A significant BLRT indicates that the model with 1 more latent class provides an improved model fit.[16,18] Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), and sample-size adjusted BIC also informed model selection. These criteria are used to compare model fit between competing models, taking into account model complexity. A model with smaller relative values indicates a good-fitting and parsimonious model.[19] Classification accuracy (entropy) and the size of the latent classes were also considered.

Step 2 involved conducting multinomial logistic regressions to identify covariates significantly associated with the trajectories. In Step 3, the full GMM was tested by specifying the number of classes from Phase 1 and including significant covariates from Step 2 as time-invariant predictors. Logistic regressions in the full model investigated how the covariates were associated with each trajectory.

Additional analysis examined whether these trajectories were associated with health-related QoL at age 6 to 7 years (controlling for QoL at 2–3 years of age) by using linear regression. Each QoL subscale was modeled as a latent variable to reduce measurement error.[20] Separate models were tested for each QoL scale, with the covariates identified in Step 2 controlled for. All analyses were performed with Mplus version 6.11 (Muthén and Muthén, Los Angeles, CA).[21]

RESULTS

Identification of Distinct Sleep Trajectories

The results of the initial models are shown in Table 1. The 4-class model had a significant BLRT and lower AIC, BIC, and sample-size adjusted BIC scores compared with the previous models. The specification of a fifth class did not lead to a significant improvement in model fit as reflected by the BLRT and information criteria. Therefore, the 4-class model was considered optimal in this study.

Logistic regression indicated that child gender, sleep problems, temperament (irritability), household size and financial hardship, and maternal employment status were significant correlates of these classes. The GMM was tested again, specifying 4 classes, and included these covariates. The subsequent trajectories are shown in Fig 1, with Table 2 showing the functions for each trajectory and Table 3 presenting the characteristics of each trajectory. Sleep duration data reported by Jenni et al[5] and Iglowstein et al,[4] who examined patterns of sleep duration in normal, healthy children during the first 10 and 16 years of life, respectively, were used

TABLE 1 Information Criteria and Model Fit for GMMs With 1 to 5 Classes

Number of Classes	AIC	BIC	ABIC	BLRT[a]	Entropy
1	26 955.30	27 009.14	26 980.54	—	—
2	26 930.83	27 008.60	26 967.30	−13 468.65*	0.93
3	26 906.42	27 008.12	26 954.11	−13 452.42*	0.64
4	26 879.63	27 005.26	26 938.54	−13 436.21*	0.56
5	26 877.65	27 027.21	26 947.78	−13 418.82	0.54

* $P < .05$. AIC, Akaike's Information Criterion; ABIC, sample-size adjusted Bayesian Information Criterion.

[a] BLRT compares a model with n classes to a model with $n-1$ classes. Therefore, BLRT values are not available for a 1-class model.

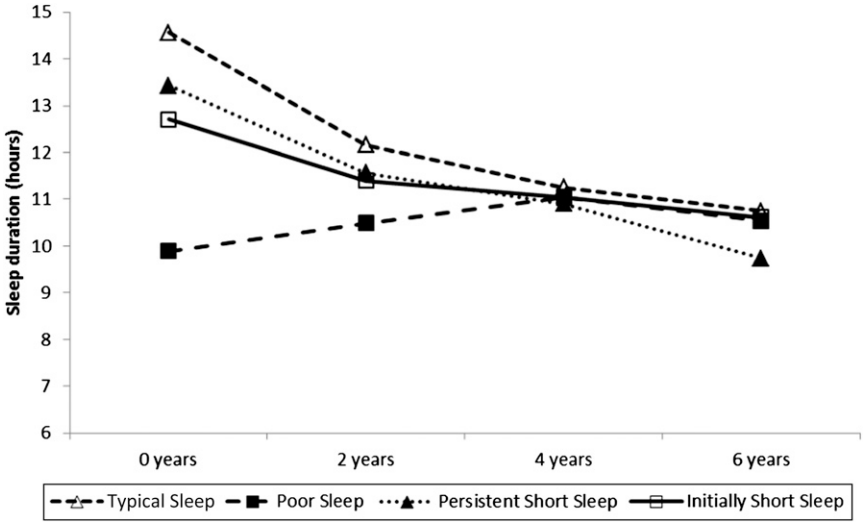

FIGURE 1
Average sleep durations for each of the 4 sleep trajectories in this sample of Australian children followed from age 0 to 1 years to 6 to 7 years.

TABLE 2 Intercept, Linear, and Quadratic Functions for Each Sleep Trajectory (Final GMM)

	Intercept		Linear		Quadratic	
	M	SE	M	SE	M	SE
Typical sleepers	14.31*	0.14	−2.48*	0.14	0.43*	0.04
Poor sleepers	10.30*	0.44	0.88	0.53	−0.27*	0.14
Persistent short sleepers	13.23*	0.22	−1.61*	0.19	0.18*	0.05
Initially short sleepers	12.83*	0.29	−1.36*	0.22	0.21*	0.04

* $P < .05$.

to guide interpretation of the present trajectories.

The first trajectory (n = 1190, 40.6%) was characterized by a gradual decline in sleep duration from baseline (14:34 hours) to age 6 to 7 years (10:45 hours); the rate of this decline slowed with age. The amount and pattern of change over time are consistent with population data tracking sleep duration during childhood.[4,5] Therefore, this trajectory was labeled typical sleepers and was used as the referent category.

The second trajectory was the smallest (n = 74; 2.5%) and characterized by short sleep durations at 0 to 1 years of age (9:54 hours), which gradually increased with age. These children had sleep durations that were 4:40 hours and 1:41 hours less than those of typical sleepers at 0 to 1 and 2 to 3 years of age, with these differences less pronounced at ages 4 to 5 years and 6 to 7 years. This trajectory also had a very high rate of sleep problems compared with the other trajectories (Table 3). Therefore, this trajectory was labeled poor sleepers.

The third trajectory (n = 339; 11.6%) showed a gradual reduction in sleep duration from 13:25 hours at 0 to 1 years of age to 9:44 hours at 6 to 7 years of age. This pattern was similar to that of typical sleepers, but the amount of sleep duration was consistently lower. For instance, this trajectory had sleep durations 0:20 hours to 1:09 hours less than typical sleepers across all waves. Because this trajectory had consistently shorter sleep than typical sleepers, it was labeled persistent short sleepers.

The final trajectory accounted for 45.2% of the sample (n = 1323). This trajectory was characterized by short sleep at 0 to 1 years of age relative to typical sleepers (difference of 1:52 hours), but only minor differences in sleep duration were observed at age 4 to 5 years and 6 to 7 years (0:08–0:13 hours' difference). This suggests these children had lower amounts of sleep in the first few years of life but typical levels from age 4 to 5 years. This trajectory was labeled initially short sleepers.

Determinants and Consequences of the Sleep Trajectories

Compared with typical sleepers, poor sleepers had higher levels of irritability (odds ratio [OR] = 7.04, $P < .001$), had more sleep problems (OR = 17.12, P = .018), came from larger households (OR = 2.08, P = .013) with more financial difficulties (OR = 2.44, P = .002), and had mothers who worked full-time compared with part-time (OR = 10.60, P = .023) (Table 3). Initially short sleepers had higher levels of irritability (OR = 2.66, P = .008) and a greater likelihood of sleep problems (OR = 5.19, $P < .001$) compared with typical sleepers. Persistent short sleepers were more likely to be irritable (OR = 2.77, P = .035), have a sleep problem (OR = 3.72, P = .029), belong to a household with more financial difficulties (OR = 1.59, P = .013), and have a mother who works full-time (OR = 6.23, P = .046) compared with typical sleepers.

The regression results (see Table 3 and Fig 2) indicated that persistent short sleepers had significantly lower physical (β = −0.17, P = .005), emotional (β = −0.20, $P < .001$), and social (β = −0.16, P = .006) health-related QoL compared with typical sleepers. In addition, the poor sleepers (β = −0.35, P = .003) and initially short sleepers (β = −0.13, P = .004) had poorer physical health-related QoL compared with typical sleepers.

TABLE 3 Sociodemographic and QoL Characteristics of Each of the Sleep Trajectories

	Typical Sleepers (n = 1190)	Poor Sleepers (n = 74)	Initially Short Sleepers (n = 1323)	Persistent Short Sleepers (n = 339)
Gender				
Female	43.9 (522)	45.9 (34)	52.2 (691)	79.9 (271)
Male	56.1 (668)	54.1 (40)	47.8 (632)	20.1 (68)
Children with sleep problems	16.8 (200)	91.9 (68)*	78.9 (1044)*	64.0 (217)*
Sleep duration (hr:min), mean (SD)				
0–1 y	14:34 (1:19)	9:54 (1:14)*	12:42 (1:22)*	13:25 (1:32)*
2–3 y	12:10 (1:08)	10:29 (1:05)*	11:23 (1:11)*	11:34 (1:10)*
4–5 y	11:15 (0:52)	11:03 (0:59)	11:02 (1:01)*	10:55 (0:50)*
6–7 y	10:45 (0.34)	10:32 (0:33)*	10:37 (0.32)*	9:44 (0:26)*
Child irritability	2.03 (0.62)	3.39 (0.90)*	2.80 (0.74)*	2.73 (0.75)*
Household size	3.88 (0.98)	5.41 (1.67)*	3.81 (0.81)	4.59 (1.44)
Household financial hardship	0.49 (0.86)	2.27 (1.62)*	0.66 (1.05)	1.29 (1.47)*
Maternal employment status				
Not employed	45.2 (538)	70.3 (52)	38.0 (503)	66.4 (225)
Part-time work (1–34 h/week)	47.0 (559)	12.2 (9)	42.6 (564)	14.7 (50)
Full-time work (≥35 h/week)	7.8 (93)	17.6 (13)*	19.3 (256)	18.9 (64)*
PedsQL scores at age 6–7 y				
Physical functioning, mean (SD)	82.83 (15.93)	73.93 (21.64)*	80.10 (16.75)*	77.79 (18.07)*
Emotional functioning, mean (SD)	77.52 (13.77)	71.84 (18.69)	73.81 (14.47)	70.51 (17.47)*
Social functioning, mean (SD)	83.00 (15.58)	76.58 (18.08)	81.43 (16.32)	77.94 (18.80)*

Data presented as frequencies (percentages) unless specified otherwise. Percentages do not sum to 100.0% on variables where there are missing data. *Indicates a significant difference ($P < .05$) relative to typical sleepers.

DISCUSSION

This study identified 4 distinct patterns of sleep duration in early childhood: typical sleepers (40.6%), initially short sleepers (45.2%), persistent short sleepers (11.6%), and poor sleepers (2.5%). The differences in sleep duration between trajectories were most obvious at baseline and became less pronounced with age. This is consistent with population data indicating that the interindividual variability in sleep duration decreases over time,[4,5] perhaps reflecting the consolidation of sleep with age.

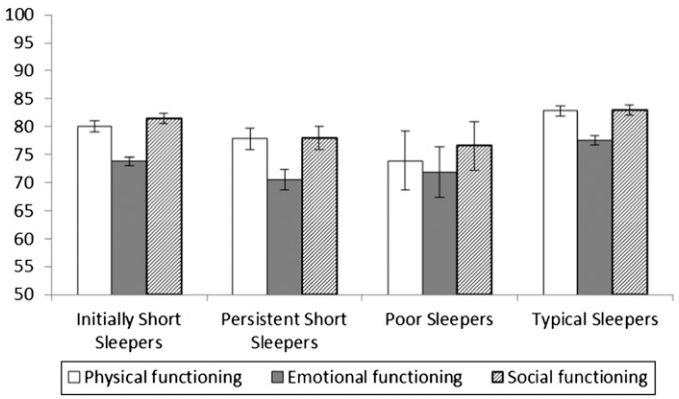

FIGURE 2
Quality of life values at age 6 to 7 years for each of the 4 sleep trajectories; results are presented as means with 95% confidence intervals.

In addition to describing patterns of sleep, this study builds on extant research[2,5,6] by identifying the characteristics underlying each trajectory and examining their implications for health-related QoL. For instance, initially short sleepers had substantially less sleep at 0 to 1 years of age than typical sleepers (12:42 hours versus 14:34 hours) but comparable sleep from age 4 to 5 years, suggesting they gradually caught up with age. Compared with typical sleepers, these children had high rates of sleep problems (78.9%) and irritability, which often co-occur,[22] but they were otherwise similar in terms of sociodemographic profiles. Early sleep problems can reflect factors including maternal depression, parenting styles, child temperament (eg, irritability), and child feeding patterns and can promote shorter sleep.[23,24] These sleep problems often resolve in the first few years of life as sleep becomes consolidated and household routines less disrupted.[23,24] This could explain the pattern of sleep duration observed for the initially short sleep trajectory. This trajectory had significantly poorer physical functioning than typical sleepers, but the magnitude of difference was small and may not be clinically meaningful.[8] However, the remaining 2 trajectories appear to have greater clinical significance.

Persistent short sleepers had short sleep at 0 to 1 years of age compared with typical sleepers, but the pattern of short sleep continued with age, and these children slept 0:20 hours to 1:09 hours less at each wave. Similar to initially short sleepers, this trajectory was characterized by a high rate of sleep problems and high irritability. Other factors also distinguished this trajectory and may explain the prolonged pattern of short sleep. For

instance, persistent short sleepers came from households with high levels of financial hardship, which may contribute to shorter sleep durations via more stressful family environments (eg, greater parental stress).[25,26] Financial hardship could also reflect lower family socioeconomic status, which has been implicated in short and poor child sleep.[13] Maternal full-time work was also associated with persistent short sleep. Longer maternal work hours could promote short sleep by influencing family and child routines (eg, promoting later bedtimes)[27] or by increasing the mother's risk of poor sleep, which subsequently affects their child's sleep.[13] In combination, this suggests that persistent short sleepers could include children from lower socioeconomic families.

Persistent short sleepers had significantly poorer physical functioning, emotional functioning, and social functioning compared with typical sleepers, suggesting these children are at risk for poorer physical and mental health. Consistently short sleep could promote poorer physical functioning by increasing the risk of health problems such as obesity[28] or reducing physical activity.[29] Persistent short sleep could also contribute to poorer social and emotional well-being by contributing to mental health (eg, depression) and behavioral problems in children.[1,30]

Poor sleepers had extreme short sleep duration before age 4 years compared with typical sleepers. This trajectory was characterized by more sleep problems, high irritability, greater household financial hardship, and maternal full-time work. As noted, these factors are potential risk factors for shorter sleep durations in children. Furthermore, children in this trajectory came from larger households, which could contribute to shorter sleep because of increased environmental noise. Overall, these results suggest that this small trajectory is at risk for social disadvantage, contributing to extreme short sleep in the first few years of life. This trajectory could have important clinical implications, as reflected by the significantly poorer scores on the physical functioning scale and a nonsignificant trend toward poorer emotional and social health.

Key strengths of this study include the large, longitudinal sample; incorporation of relevant covariates, which allowed more realistic modeling of the data[15,16]; and inclusion of the PedsQL to assess the implications of these trajectories for QoL. Limitations include the subjective assessment of sleep duration, which generally corresponds well with objective measurements (eg, actigraphy)[31,32] but may lack accuracy and sensitivity to factors such as nocturnal wakings, and sleep quality, which could affect nighttime sleep. There is also no clear consensus on definitions of short and long sleep duration at different ages during childhood. Our interpretations of the trajectories were guided by data reported by Iglowstein et al[4] and Jenni et al,[5] which although useful do not definitively provide an insight into short and long sleep. Other limitations are that the measure of sleep problems was crude and may not reflect the nature or severity of sleep problems, and sleep duration was assessed using a different measure at age 6 to 7 years, which could influence the nature of the trajectories identified. Another consideration is that weekday and weekend sleep were combined to provide an estimate of weekly sleep duration at each wave. Although the difference between weekday and weekend sleep duration was minimal, for some children different trajectories may exist for weekday and weekend sleep duration. These trajectories could be examined in future research.

CONCLUSIONS

Our results provide an important and novel insight into the nature of sleep patterns during childhood, their distinguishing characteristics, and their implications for health and well-being. The findings increase conceptual understanding of child sleep trajectories and suggest that child and household factors could underlie these trajectories; however, additional research is needed to clarify the factors that predict these trajectories. These results could have implications for strategies to promote more healthful sleep patterns, because interventions tailored toward socially disadvantaged children may aid in preventing or minimizing the effects of short sleep in early childhood.

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