Infant sleep onset patterns: a case study

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Independent, assisted, short, long… How do babies fall asleep? How do these sleep onset patterns change over time? How can data help caregivers create better bedtime routines for infants? In this whitepaper, we look at what the numbers say about how babies fall asleep. Using longitudinal measurement data from an 11-month period, we explore sleep timing and regularity. Additionally, we identify four distinct styles for infant sleep onset patterns.

Keywords: sleep rhythm, sleep onset pattern, infant, self-soothing, bedtime routines

Different ways of falling asleep

Sleep initiation routines are especially important in supporting an infant's overall sleep (Reuter et al. 2020). Additionally, higher emotional availability during an infant's bedtime, combined with less arousing bedtime activities, has been linked to improved sleep quality (Field 2017). Parental emotional availability encompasses the ability to be emotionally present and responsive to a child's needs, including sensitivity to the child's emotional states, providing support for self-soothing, maintaining consistency, allowing space for exploration, and ensuring interactions are free from anger or frustration.

The transition from wakefulness refers to the process required for calming down and preparing for sleep. Some infants may fall asleep quickly and easily, while others may need more time and soothing to transition into sleep. Over days, weeks, and months, infants learn different ways of falling asleep, which can turn into regular bedtime habits (Reuter et al. 2020). Not all ways of falling asleep are desirable, as their formation can pose challenges to sleep. However, children are unique,

and so are their sleep routines. Longitudinal measurement offers insights into how sleep patterns mature, drawing from data on infants' sleep (Nauha and Kinnunen 2023). This whitepaper's goal was to unobtrusively track an infant's sleep patterns for 11 months using a movement sensor under the crib mattress.

Materials and methods

At the start of the measurement period, the infant was one month old, and by the end, they had reached 12 months. The caregiver provided written consent for the use of the infant's measurement data in this study.

The movement sensor, positioned beneath the mattress of the infant's crib, automatically recorded the infant's body movements without the need for pressing buttons or wearing devices. It began measuring movements as soon as the infant was laid in the bed and ceased recording when the infant was removed.

Measured sleep onset patterns

The initial measurement periods, occurring between 8 PM and 8 AM, were analyzed. Graphs for each session showed the infant's first 60 minutes in bed on the x-axis (time in minutes) and the infant's activity level on the y-axis. The activity level was determined by the highest intensity of movement within each five-second period, with these intensities standardized on a 0 to 100 scale.

The study examined the bedtime timing, regularity, and sleep onset patterns for each month. Particularly, the fifth month received detailed analysis because data for all 30 days of this month were available.

Timing and regularity. Monthly averages for bedtime start times over all 11 months were calculated, along with full-week averages for the fifth month. To estimate the regularity of bedtime start times, monthly standard deviations were determined, as well as standard deviations for full-week bedtime start times during the fifth month. Standard deviation is a common method to estimate sleep regularity (Nauha et al. 2024).

Sleep onset patterns. To understand the different ways of falling asleep as observed in real-time measurements, the sleep onset patterns of a five-month-old infant were visually analyzed. An effort was made to identify the technical features of sleep onset patterns and categorize the sessions based on these features. Furthermore, the sessions were evaluated from a practical standpoint, considering both the viewpoints of the parent and the infant. In addition, over a month-long study period when the

infant was 5 months old, each session was analyzed to determine the predominant style of falling asleep.

Results

Data from 207 sleep sessions were analyzed. Table 1 presents the monthly averages of the infant's bedtime timings and regularity. The timing of bedtime varies across months of age. The earliest average start time was observed during the infant' third month, while the latest average start time occurred in the seventh month. The most consistent bedtime timings were observed from five to seven months. The greatest variability in bedtime start times was during the fourth month.

A weekly analysis of bedtime timings and regularity (Table 2) at five months old shows variations in the start times between weeks. The first week's start time was more irregular compared to the other weeks, featuring both the earliest and latest bedtimes among the four weeks analyzed.

Table 1. *Bedtime timing and regularity of an infant aged 1–12 months, detected by a movement sensor under the crib mattress.*

Dates	Age (months)	Measured days	Average bedtime hh.mm	Regularity* hh.mm
Mar 6 – Apr 5	0	-	-	-
Apr 6 – May 5	1	29	23.32	01.15
May 6 – Jun 5	2	22	23.10	01.15
Jun 6 – Jul 5	3	12	22.03	01.02
Jul 6 – Aug 5	4	14	22.12	02.55
Aug 6 – Sep 5	5	30	22.10	00.39
Sep 6 – Oct 5	6	27	22.51	00.36
Oct 6 – Nov 5	7	24	0.03	01.39
Nov 6 – Dec 5	8	24	22.17	02.06
Dec 6 – Jan 5	9	25	22.07	01.51
Jan 6 – Feb 5	10	23	22.43	02.36
Feb 6 – Mar 5	11	15	23.31	01.42

*Monthly standard deviations of bedtimes; with a higher value indicating greater variability in bedtimes, and a lower value indicating less variability in bedtimes.

Table 2. *Weekly averages of bedtimes and regularity for an infant at five months of age, detected by a movement sensor under the crib mattress.*

Dates	Average bedtime hh.mm [range]	Regularity* hh.mm
Aug 6 – Aug 12	22.18 [20.55–23.57]	1.05
Aug 13 – Aug 19	22.13 [21.23–22.45]	0.31
Aug 20 – Aug 26	22.24 [22.04–23.09]	0.28
Aug 27 – Sep 2	22.12 [21.41–22.30]	0.23

*Weekly standard deviations of bedtimes; with a higher value indicating greater variability in bedtimes, and a lower value indicating less variability in bedtimes.

Visual analysis of the measured sessions identified four types of sleep onset patterns: Kangaroo transition, Short transition, Independent transition, and Long transition. (Figure 3)

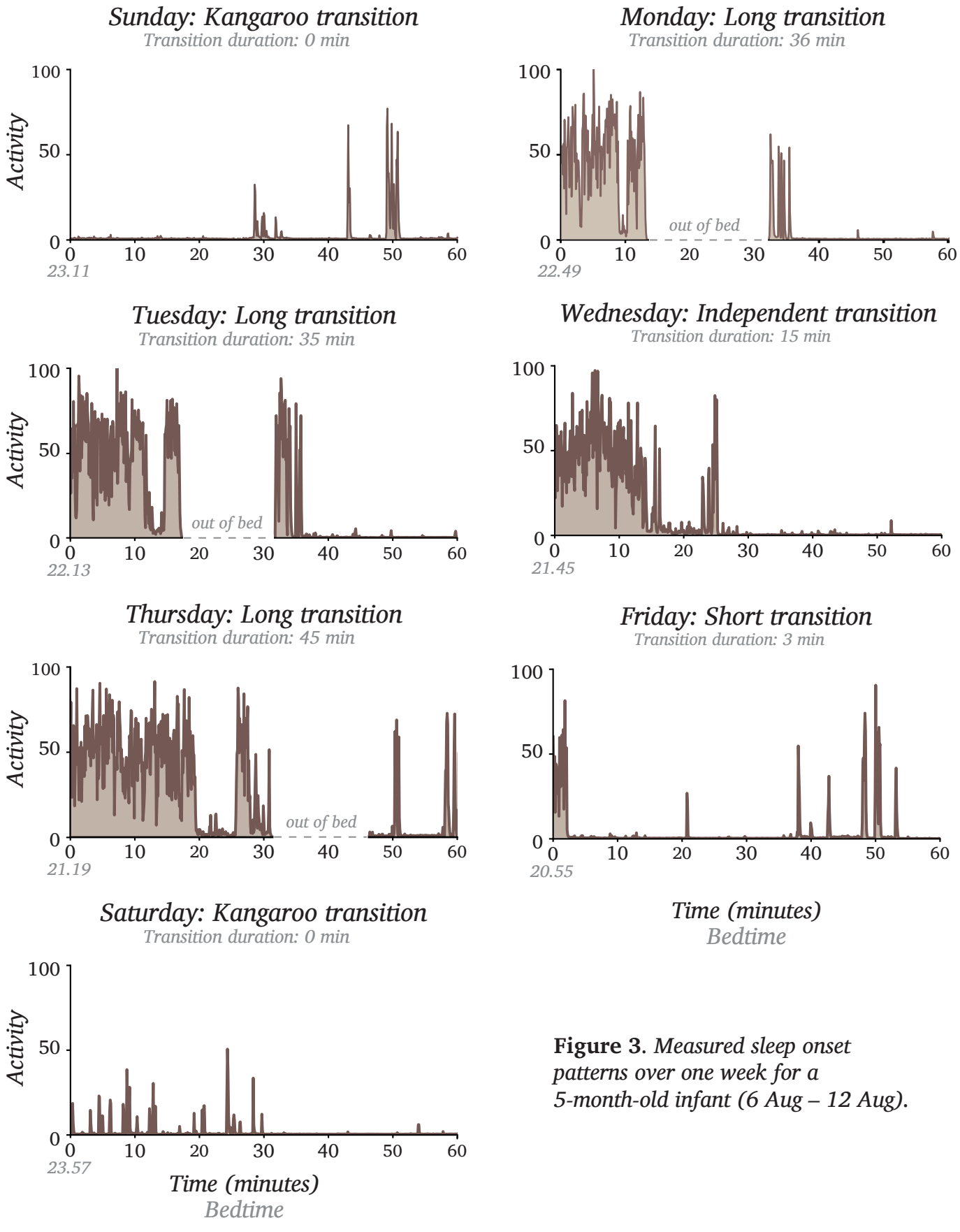


Figure 3. *Measured sleep onset patterns over one week for a 5-month-old infant (6 Aug – 12 Aug).*

Kangaroo transition: An infant falls asleep prior to bedtime and is then moved to their bed without waking.

- *Technical features*: From the onset of the session, the sensor captures only minimal disturbances. Infant movements are almost undetectable or very low intensity.
- *Practical perspectives*: The caregiver experiences an emotional bond while holding the infant until sleep takes over. The infant feels safe and comfortable in the caregiver's arms, then keeps sleeping peacefully when moved to their crib.

Short transition: An infant settles to sleep within 5 minutes of being placed in their bed.

- *Technical features*: Sensor data indicate a rapid decrease in movement intensity after the infant is placed in bed, suggesting a swift transition from wakefulness to sleep. Subsequently, the movement signal stabilizes.
- *Practical perspectives*: Caregivers may feel relief and satisfaction when the infant quickly falls asleep in their own bed, confirming the readiness for sleep and facilitating a smooth transition. This swift transition promotes a sense of ease and relaxation for both the caregiver and infant.

Independent transition: An infant settles down and falls asleep on their own within 20 minutes of being placed in their bed.

- *Technical features*: The sensor data indicate a gradual decrease in movement intensity over approximately 20 minutes, characterized by a diminishing pattern of activity.
- *Practical perspectives:* Caregivers feel proud and happy when they see the infant falling asleep on their own, demonstrating that the infant is learning to regulate their sleep and readiness for sleep. This perception of the infant sleeping on their own fosters a sense of accomplishment and reinforces the infant's growing independence.

Long transition: An infant might face difficulties in falling asleep and require prolonged soothing. They may leave their bed, taking more than 20 minutes from the initial attempt to finally settle down for rest.

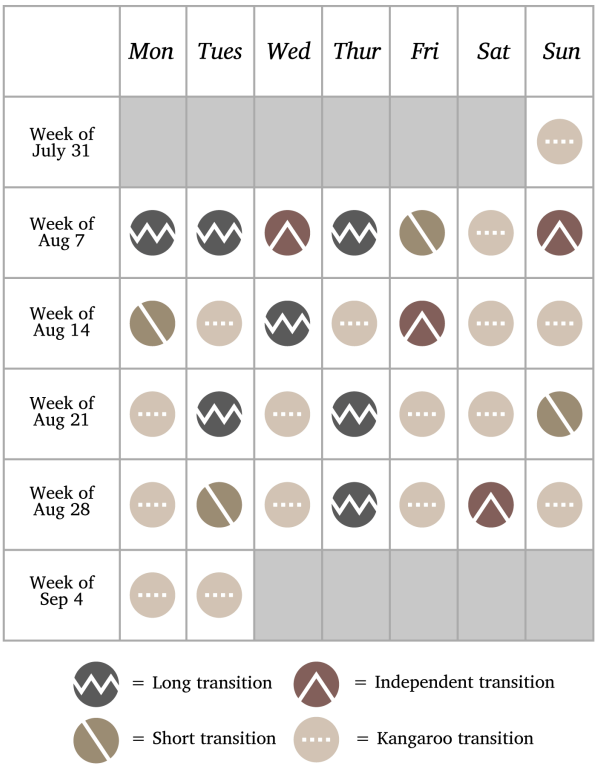
- *Technical features*: The sensor detects prolonged and irregular movements for more than 20 minutes. Additionally, it captures at least one instance of the infant leaving and then re-entering the bed.
- *Practical perspectives*: Caregivers might face difficulties in calming the

infant for rest, which may result in prolonged efforts to soothe them. From the infant's viewpoint, evenings might seem confusing and distressing. They rely on caregivers for comfort and safety, seeking reassurance and closeness. Discomfort may manifest as crying or restlessness. Common soothing practices include breastfeeding, singing lullabies, rocking, swaying, and cuddling, which all contribute to a sense of comfort. Nonetheless, caregivers might feel frustration or helplessness if these methods do not work immediately. Eventually, the infant settles down and falls asleep, either in the caregiver's arms before being moved to the bed, or directly in their bed.

One month of sleep onset patterns

Table 3 outlines the predominant way of falling asleep in the fifth month. In this case study, the Kangaroo transition was the most frequently observed sleep onset pattern, occurring 16 times in the fifth month. The second most common category was sessions marked by Long transitions, occurring 7 times. Short and Independent transitions were also noted, with each happening 4 times. In the first week of the observed month, Long transitions were most frequent, numbering three, and this period also saw the highest variation in timing (standard deviation of bedtime start was 1.01).

Table 3. *Measured sleep onset patterns over 1 month for a 5-month-old infant*



Discussion

This whitepaper examined the bedtime timings, regularity and sleep onset patterns of an infant over an 11-month period using a motion sensor placed under the crib mattress. As a primary outcome, the whitepaper revealed variations in the timing and regularity of bedtimes, both monthly and weekly, particularly at five months of age.

Additionally, four distinct measured sleep onset patterns were identified: Kangaroo transition, Short transition, Independent transition, and Long transition.

A key difference between adult and infant sleep is the constant evolution of an infant's sleep rhythm and structure, as they are still developing (Nauha and Kinnunen 2023). Unlike adults, who generally sleep in bed, infants frequently fall asleep in various locations. The Kangaroo transition was the most common way of falling asleep for the infant in this study. Furthermore, the study highlighted that bedtime routines for infants can fluctuate daily and weekly. Notably, family schedules, like those during holidays, can affect sleep timing, with the entire family's later bedtimes during vacations potentially delaying the infant's bedtime as well. This study was conducted in Finland, where light conditions vary significantly throughout the year. This factor, too, may potentially impact the child's sleep. A regular light-dark rhythm during the infant's first year, alongside other regular routines in life support the infant's sleep quality. (Kärki et al. 2019, 2020)

Unobtrusive observation of sleep onset patterns can reveal the infant's typical sleep onset style and how these styles evolve with age. Additionally, early signs of poor evening routines may be identified. However, this approach necessitates categorizing sleep onset patterns from best to worst. From a parent's perspective, Independent and Quick transitions are often preferred for their ease and pleasantness. Nonetheless, during Long transitions, the parent's presence to offer comfort and support to the infant is essential. In addition, the Finnish cohort study on infant sleep suggests that if an 8-month-old generally takes more than 40 minutes to fall asleep, it may indicate sleep problems (Paavonen et al. 2020).

Measuring an infant's bedtimes allows observation of which daytime activities facilitate smooth transition to sleep. The idea that good sleep is made while awake is well supported, with scientific evidence highlighting its validity. Light exposure is one example of how events during wakefulness are relevant to sleep. Research indicates that light exposure affects sleep patterns, with daytime exposure to daylight reducing daytime sleep and increasing wakefulness, while nighttime light disrupts quiet sleep and overall sleep duration, leading to more nighttime awakenings (Yoshida, Ikeda, and Adachi 2023). Scheduling wake times during daylight hours, when ample light is available, is beneficial for the development of the circadian rhythm. (Rivkees 2003).

Future research would benefit from using larger and more diverse samples, conducting longitudinal studies to observe changes in sleep routines over time, and performing comparative analyses across various age groups. Additionally, examining sleep quality throughout the night and the entire day in subsequent studies could provide a more thorough understanding of the impact of infants' bedtime routines on their overall sleep patterns and quality (Mindell et al. 2010). The sleep environment plays a crucial role in facilitating the transition to sleep for infants (Camerota, Propper, and Teti 2019). Creating a calm, dark, and comfortable sleep environment can signal to the infant that it is time to sleep. Minimizing noise and distractions can also help promote a smoother transition from wakefulness to sleep. Environmental measurement data could provide further insights into the infant's sleep onset patterns.

When interpreting this study's results, considering potential measurement errors is crucial. There might be instances where the motion sensor failed to trigger, or parts of or entire sessions were missed due to internet connectivity issues. This could result in a misinterpretation of the sleep onset pattern or timing. Given the monthly variation in bedtime starts, individual nights can have a significant impact. For example, at the age of 7 months, the infant's sleep onset pattern started at 5.00 AM which could account for a later average bedtime start throughout the entire seventh month. Presumably, the infant had already fallen asleep elsewhere prior to this session.

In conclusion, analyzing sleep onset patterns has the potential to provide supplementary insights into an infant's sleep habits. This approach enables both researchers and caregivers to deepen their understanding of the various factors that affect an infant's sleep patterns and pre-bedtime behaviors.

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