Process of entrainment in the early stage of life has been altered in the modern society.

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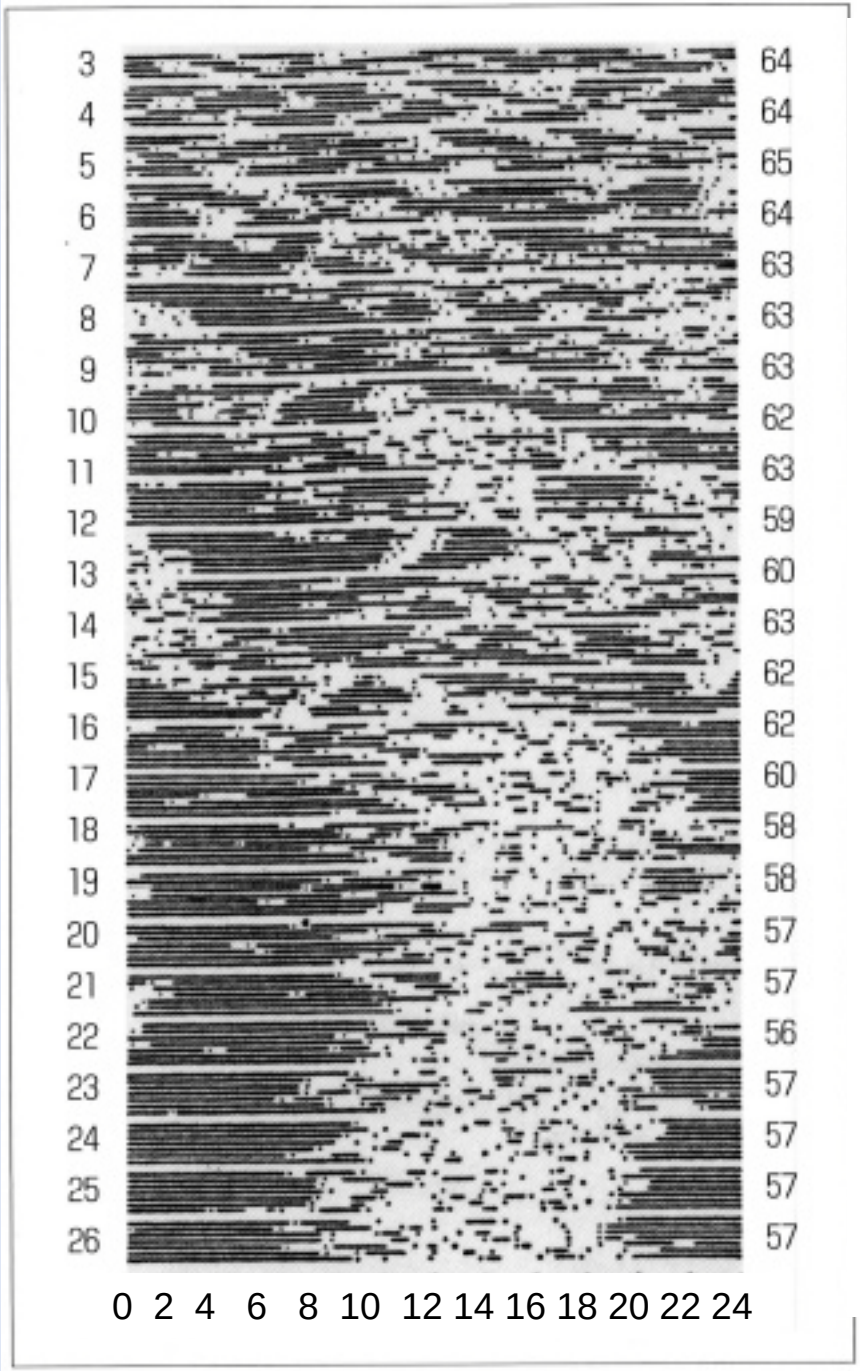

This famous sleep log tell us that infants reveal a free-running sleep-wake rhythm before the entrainment, and also that the entrainment establishes by the 12th to 14th week of life.

Kleitman N, Engelman T. Sleep characteristics of infants. J Appl Physiol 1953;6:269-282.

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Original article

Emerging and entraining patterns of the sleep–wake rhythm in preterm and term infants

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Abstract

It has been repeatedly reported that the sleep–wake rhythm in infants entrains around 3–4 months of age after a transient free-run rhythm. To clarify the emerging and entraining patterns of the sleep–wake rhythm, the sleep and wakefulness of 84 infants (44 preterm and 40 term infants) were longitudinally recorded at home for more than 16 weeks by the day-by-day plot method. Our results showed that the entrained sleep–wake rhythm emerged after transient manifestation of either ultradian or irregular sleep–wake patterns for 3–4 weeks in 75% of the infants. Only 7% of the infants showed a free-running sleep–wake rhythm before the entrainment. These facts suggest that most infants would be entrained to an ordinary daily schedule of mothers without expression of overt free-running rhythm of the biological clock. The mean age of the entrainment was 44.8 postconceptional weeks. There were no significant differences in either frequency of each pattern or the mean age of the entrainment, between preterm and term infants. In conclusion, the entrained sleep–wake rhythm emerges around 1 corrected month, after ultradian patterns in the majority of infants.

Keywords: Sleep–wake rhythm; Circadian rhythm; Entrainment; Infants; Development

In conclusion, the present study demonstrates that the entrained rhythm emerges around one corrected month, after either the ultradian or irregular sleep-wake pattern, in the majority of infants.
It was noted that only a small number of infants showed a free-running sleep wake-rhythm before the entrained rhythm emerged.

Shimada et al., 1999

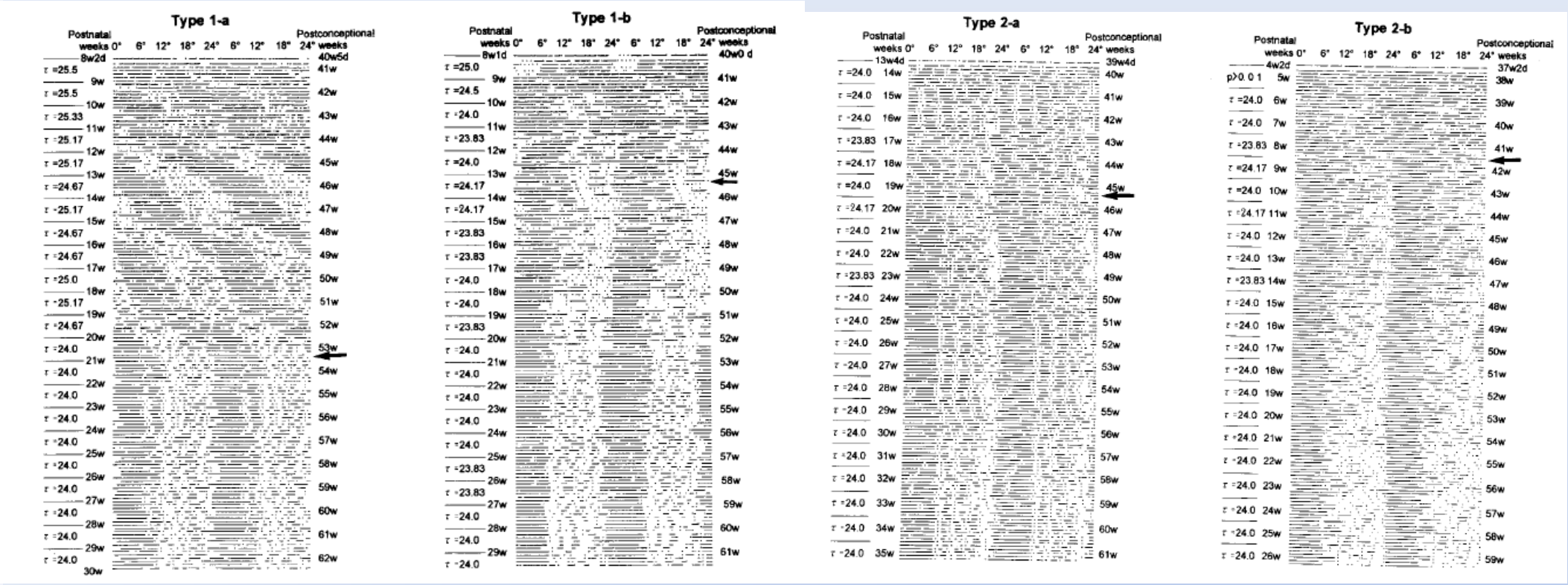


Fig. 2. Double-plotted daily patterns of sleep–wakefulness and feeding in infants. Solid bars are sleep periods, measured every 30 min, breaks between the bars are wakefulness and dots are feeding. Postnatal weeks are numbered on the left, postconceptional weeks on the right. Time of day in 6-h intervals is shown at the top. Tau on the left indicates a cycle of sleep–wake rhythm calculated by the chi-square periodogram. Arrows indicate the time of entrainment of the sleep–wake rhythm, determined by the criteria presented in the text.

Emerging and entraining patterns of sleep–wake rhythm

Entraining type	Preterm infants	Term infants	Total
Type 1a: free run (+) → 24 h	3 (6.8%)	3 (7.5)	6 (7.1)
Type 1b: free run (±) → 24 h	7 (15.9)	5 (12.5)	12 (14.3)
Type 2a: ultradian rhythm → 24 h	27 (61.4)	25 (62.5)	52 (61.9)
Type 2b: irregular rhythm → 24 h	6 (13.6)	5 (12.5)	11 (13.1)
Free run (+) → not entrained	1 (2.3)	0 (0.0)	1 (1.2)
Already entrained when the record started	0 (0.0)	2 (5.0)	2 (2.4)
Total	44 (100.0)	40 (100.0)	84 (100.0)

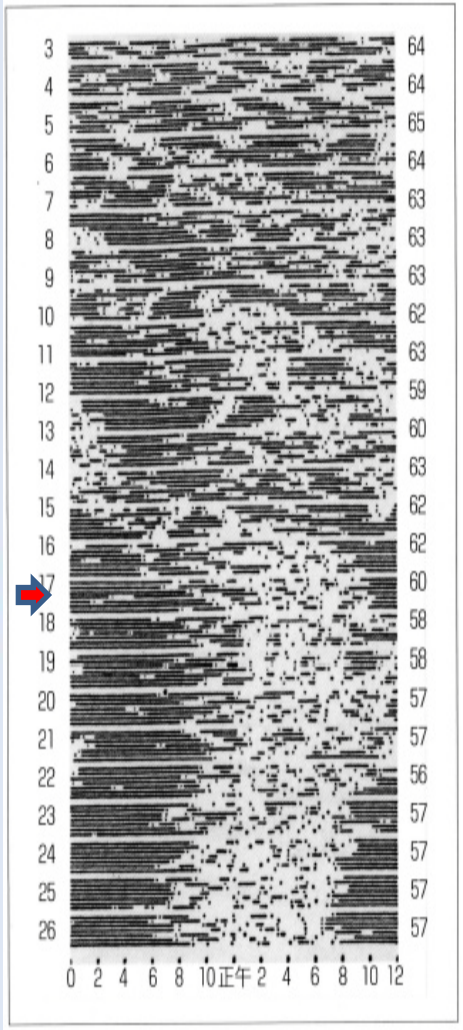
Shimada et al., 1999

Hypotheses

- The rate of infants who reveal a free-running sleep-wake rhythm before the entrainment has decreased, recently.
- Recently, the age of emergence of the entrained rhythm has become earlier.

I–a I–b

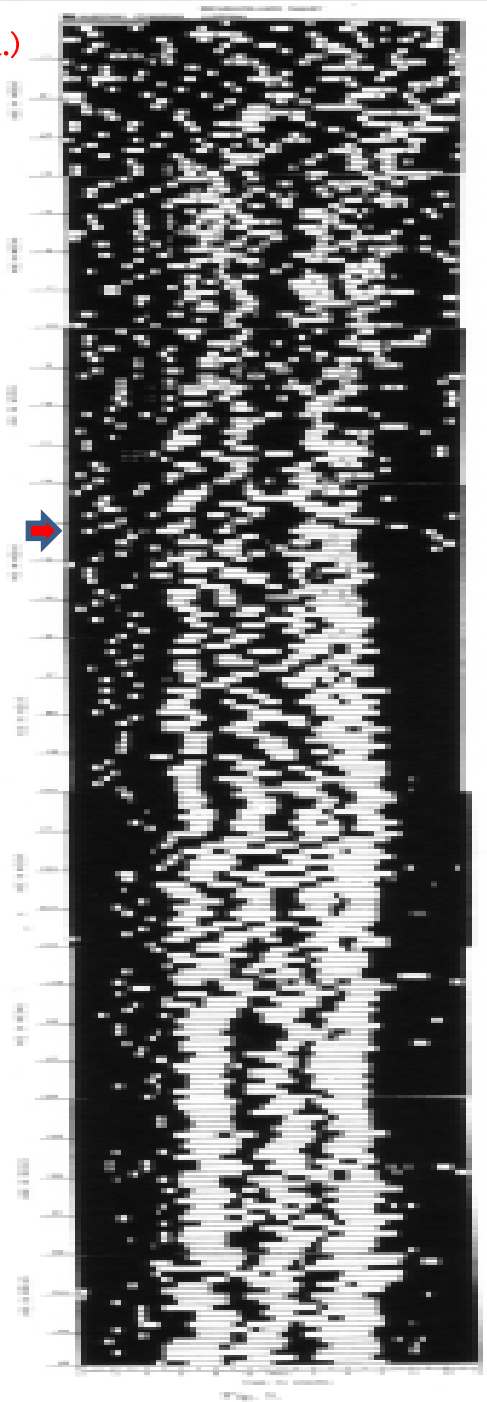
(according to the classification by Shimada et al.)



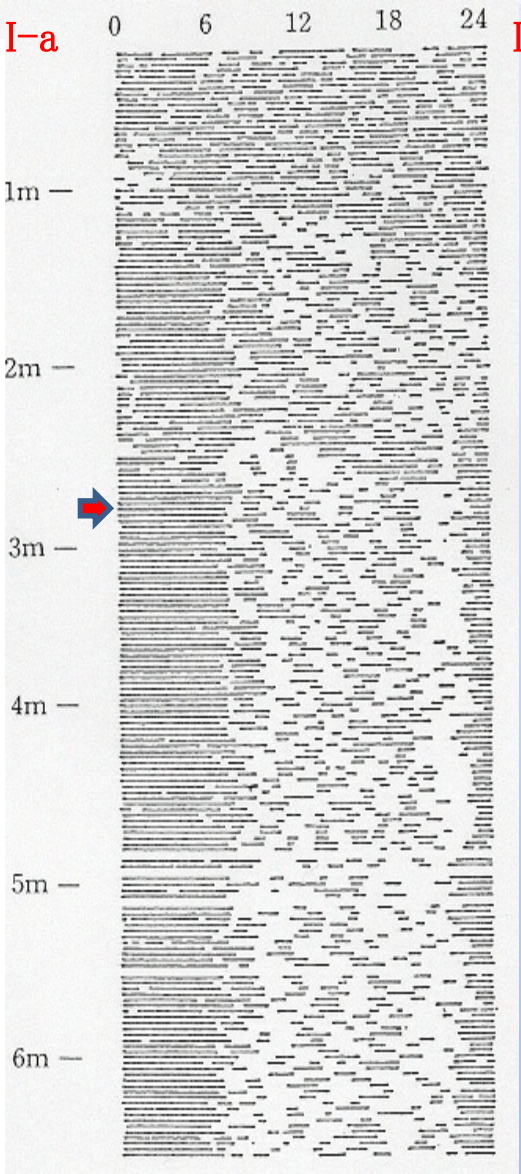
↑

Kleitman N, Engelman T. 1953、

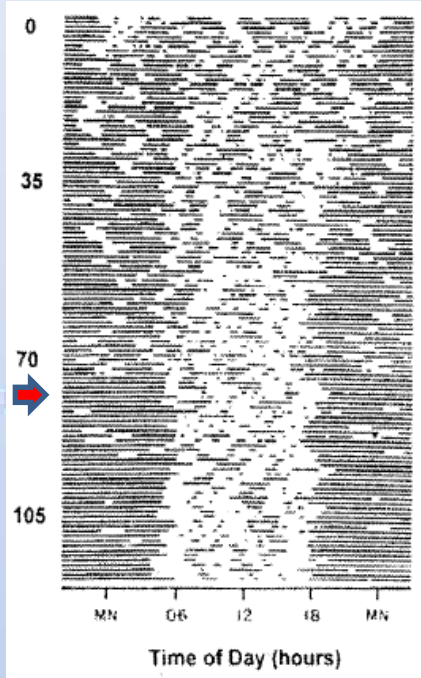
Made from Parmelee AH Jr, 1961
by Kohyama J →



I–a I–b



Segawa M: Sleep mechanism and its development. Pediatric Review 1984;20:828-853 (in Japanese)



Rivkees SA: Developing circadian rhythmicity in infants. Pediatrics, 2003;112:373-381.

➡ Estimated point of the entrain-ment by JK.

The rate of infants who reveal a free-running sleep-wake rhythm before the entrainment is hypothesized to decrease, recently.

Kleitman showed a famous plotted figure of free-running sleep-wake rhythm in one infant, together with the vague result of free-running `in most of 19 infants'.

The current analysis revealed that an infant reported by Parmelee in 1961 did not exhibit a typical free-running sleep-wake rhythm before the entrainment.

A single case report made by Segawa in 1984 showed a typical free-running sleep-wake rhythm before the entrainment.

A recent case report did not reveal a typical free-running rhythm before the entrainment.

According to Shimada et al, only 7% infants showed a free-running sleep-wake rhythm before the entrainment .

If this assumption is true, taking reports by Kleitman et al. and Segawa into consideration, we had a very rare (7% x 7% = 0.49%) experience.

Although not every infants showed a typical free-running sleep wake-rhythm before the entrained rhythm emerged, the current hypothesis could not be denied. More survey on the development of sleep log during early infancy is needed to confirm the hypothesis.

Recently, the time of emergence of the entrained rhythm is hypothesized to become earlier.

Several previous studies found that the diurnal sleep-wake rhythm emerged around 3-4 months of age.

Shimada et al. reported that the mean age of the entrainment was 44.8 postconceptional weeks.

The current analysis revealed that that the time of emergence of the entrained rhythm has recently become earlier.

Although the neuronal mechanisms producing the early emergence of entrainment remain to be solved, several observations to have presumable effects on the development of sleep-wake rhythm during early stage of life are shown in the other sheet (※).

Although the reasons have remained to be solved,
the current hypothesis could not be denied.

※

- **Studies have shown that the earlier mothers fell into nocturnal sleep during late pregnancy, the longer the babies slept during the night at one month of age. (Hayase, M., Shimada, M., Imui, T., Nitta, N. (2008). Correlation between diurnal rhythm in the late pregnancy to postpartum mothers and sleep-wake rhythm in infants. (in Japanese). *J Child Health*, 67,746-53).**
- **Constant light condition disrupts the synchronization of neurons in the SCN in both mature and developing mouse.（Ohta, H., Yamazaki, S. & McMahon, D.G. (2005) Constant light desynchronizes mammalian clock neurons. *Nat. Neurosci*., 8, 267-269. Ohta, H., Mitchell, A.C. & McMahon, D.G. (2006) Constant light disrupts the developing mouse biological clock. *Pediatr. Res*., 60, 304-308.）**