Research proposal

Is early-life digital screen exposure (0–3 years) associated with disrupted circadian entrainment, as measured by dim light melatonin onset (DLMO), and with sleep-wake regularity?

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Abstract:

Exposure to digital screens in early childhood exposes children to artificial blue light during a formative stage of circadian development. While linked to sleep disruption, its role in circadian entrainment during early childhood remains unclear. This longitudinal observational study investigates whether screen exposure is associated with circadian phase (DLMO) and behavioral sleep-wake regularity, using parental reports and actigraphy. This research may contribute to evidence-based guidance on the use of digital screens by young children.

Introduction:

Digital screen use in early childhood suggests exposure to artificial light during biologically sensitive periods of development, which may influence circadian timing processes regulated by environmental light cues. This study investigates the influence of digital screen exposure on circadian entrainment and sleep-wake regularity in young children (0–3 years). Entrainment refers to the synchronization of internal circadian phase to the external light-dark cycle, distinct from the generation of rhythms themselves. Proper circadian entrainment is considered fundamental for developing regular sleep habits and healthy overall physiological functioning (Kok et al., 2025; Miike, 2025). Circadian misalignment may lead to adverse long-term health and cognitive outcomes (Sletten et al., 2023; Wahl et al., 2019).

Literature review:

Previous research suggests that the blue light emitted by digital devices may impact sleep quality and disrupt circadian rhythms (Oh et al., 2015). Circadian rhythms are influenced by light exposure via the retina and are subsequently transmitted to the central circadian system, primarily the suprachiasmatic nucleus (SCN), which regulates circadian timing. Mis-timed light exposure can disrupt circadian entrainment by altering the alignment between internal rhythms and environmental light-dark cycles. According to Miike T. (2025), circadian rhythm generation develops early in life, while entrainment (synchronization to environmental cues) continues to refine during infancy, which makes young children especially vulnerable to environmental disruption. While circadian rhythm development has been studied, the process of entrainment remains underexplored, particularly in toddlers.

Hypothesis:

Higher levels of early digital screen exposure in early life (0-3 years) are associated with later circadian phase (DLMO) and reduced sleep-wake regularity over time.

Methodology:

Quantitative + observational + longitudinal

Approximately 80-120 infants (aged 6 to 12 months) will be enrolled through pediatric clinics and early childhood care centers and followed longitudinally at 6-month intervals until approximately 3-4 years of age. Recruitment from 6 months is appropriate. By this age, infants have passed the initial day-night differentiation that occurs around 2–3 months (Glotzbach et al., 1994), but circadian development is still ongoing (Miike, 2025). The participants must be born full-term (≥37 weeks), have no diagnosed neurological or sleep disorders, and a primary caregiver willing to report daily routines and screen exposure. Infants with chronic illnesses affecting sleep or development, as well as those using medication affecting melatonin or sleep regulation, will be excluded. Informed parental consent must be obtained prior to participation, all participants and their caregivers must remain anonymous.

Screen exposure will be estimated using parental reporting diaries, including daily total screen time (hours per day), timing of exposure (morning, afternoon, evening), and type of device (tablet, smartphone, television). Particular emphasis will be placed on evening screen exposure, due to its association with circadian phase delay (Höhn et al., 2021). Circadian phase will be assessed using dim light melatonin onset (DLMO) as the primary measure of entrainment (Murray et al., 2024; Smits & Pandi-Perumal, 2007). Sleep–wake patterns will be measured separately using actigraphy devices worn for 7 consecutive days at each assessment point. Environmental light exposure will be recorded to approximate external light exposure patterns. Confounding variables will be recorded via parental report or light sensors, if available, such as sleep environment (co-sleeping vs independent sleep), feeding schedule in infancy stage, parental sleep habits, and socio-economic status. At each 6-month interval, parents will complete standardized questionnaires and sleep diaries, along with using salivary melatonin sampling under controlled dim-light conditions. All procedures will aim to minimize disruption to normal family routines. Data will be analyzed using longitudinal mixed-effects regression models so as to account for individual differences and repeated measures (Cunnings & Finlayson, 2015). Primary analyses will assess whether early digital screen exposure is associated with differences in alignment between internal circadian phase (melatonin onset), behavioral sleep-wake patterns, and expected environmental light-dark cycle.

Conclusion:

By combining objective circadian phase markers with behavioral sleep data, this study addresses a critical gap in pediatric chronobiology: whether screen exposure disrupts entrainment specifically, beyond general sleep disturbance. Results may directly inform screen-time recommendations for children under three.

Addressing limitations:

This study partially relies on parental reports, which may introduce measurement bias. As an observational design, causal relationships cannot be definitely established, and the relatively small and selectively recruited sample may limit the generalization of findings. Additionally, collecting reliable DLMO data in young children presents logistical difficulties. To mitigate this, an at-home protocol with detailed parental training, dim-light kits, and researcher support will be used (Murray et al., 2024). Non-compliant samples will be excluded and repeated where possible.

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