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Daily concordance between ecological stressors and sleep in young minority children during the pre-COVID-19 outbreak period

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ABSTRACT

Objective: As the COVID-19 pandemic brings widespread changes in families, the sociology of sleep becomes noticeable. Yet, the socio-contextual determinants of a biopsychosocial phenomenon as sleep are poorly investigated. We examine changes concomitantly occurring in the child’s sleep per familial and community stressors.

Methods: During the pre-COVID-19 outbreak period, in 24 minority children (5.4 ± 1.7 years old, 54.2% girls), sleep was objectively measured 24 h for two consecutive weeks, and this was repeated three times over the study period of three months. The caregiver filled out questionnaires surveying sociodemographic, community and family aspects.

Results: Children went to bed at 22:26 and woke up at 07:04, with each a variability of about 50 min. Money and time were revealed as related key stressors to sleep. Five dimensions best fitted their association. In general, concurrent changes within the individual child indicate that mean sleep variables seem to relate to predominantly features of the stressors (explained variance of 34.7 to 56.7%), while variability of sleep tendency to associate to situational aspects of the stressors (explained variance of 30.4 to 61.8%). Associations were best explained in terms of the 24 h dimension, particularly exposing sleep variability.

Conclusion: Individual variabilities in a child’s sleep are associated with familial resources, such as caregiver’s time to self, money and basic needs. Time spent in bed, a modifiable factor by society and shaper of sleep quantity and quality, plays a key role in stressor-sleep associations. Insights from biopsychosocial perspectives may be valuable for understanding COVID-19 sleep studies, and the development of (post-) COVID-19 sleep recommendations.

1. Introduction

It has become progressively apparent that the socio-cultural niche in which the child develops exerts a major influence on their well-being [1–3]. A biopsychosocial phenomenon that has gained momentum is sleep. However, there still remains significant gaps in knowledge regarding the socio-contextual determinants of a child’s sleep [4]. Answering questions on the societal determinants of sleep has become even more pressing in present-day COVID-19 public policy decision-making [5–7].

In 1979 Bronfenbrenner [8] proposed the biocological systems (Fig. 1) perspective to conceptually understand the influence of the social context on a child’s health. His-ecosystem comprises a series of concentric levels, and their reciprocal interactions. Within the field of pediatric sleep research, this biocological framework altogether has had few applications. This is regrettable, as individual studies demonstrate the deep interconnection and impact of the components of the ecosystem on a child’s sleep, and even more since sleep problems during childhood are relatively common.

In his ecosystem, the microsystem is the closest to the child, and reflects the home, school and peers or a child’s immediate environment. Associations between several familial issues and children’s sleep have been suggested: for instance, chaos & conflict [9–11]; familial psychopathology [12–14]; and parenting [15–17]. The directionality in the dynamics of these familial issues and a child’s sleep however might be more complex, as often stated in studies: parent(s) in the direction of the child; the child towards parent(s); and the child per its own problematic daytime behavior, with none of them being mutually exclusive. They, in fact, reflect Bronfenbrenner’s second level, the mesosystem, encompassing the numerous linkages between the various microsystems. In this system, minority groups, in particular, being exposed to clustering of risk mediators and moderators may show adverse outcomes, in association with (poor) sleep [18–21]. Both the micro- and mesosystem are...
embedded within the exosystem. The exosystem is indirectly influencing the child; it involves the circles of the caregiver(s) (e.g., work environment). For instance, regardless parenting or parent-child relationships, a workplace intervention aiming at decreasing employees’ work-family conflict showed a beneficial effect on the child’s sleep [22]. Studies alike emphasize the notion of the “negotiated night” [23] or anthropological shifts in sleep [24,25] in a globalizing world. The fourth level of Bronfenbrenner’s ecosystem is the macrosystem reflecting the society in terms of culture, values & attitudes (e.g., relatives, friends), moral & political norms but also the surrounding educational system, health care system, and/or socioeconomic status. The opinion poll by the National Sleep Foundation in 2010 puts forward that African American adults have poor sleep habits and attitudes potentially leading to less optimal sleep; e.g., 75% was watching TV or 43% used a computer or the internet in the evening, both are considered indicators of poor sleep hygiene. Several publications [19,21,26–28] demonstrated that socioeconomic disparities adversely affect a child’s sleep. Farthest away from the child, is the chronosystem or the patterning of environmental events and transitions over the life course such as sociohistorical circumstances. Several sleep-related studies exist; for example, earthquake and tsunami events reduced sleep duration [29] and increased risk of sleep difficulties [30]. Alternatively, in 2012 Matriciani et al. [31] postulated that never enough sleep is a consequence of “modern life” and they quantified over a 103-years period a consistent rapid decline in the sleep duration of our youth [32].

Altogether recent publications on the current COVID-19 pandemic are gradually voicing a comparable impact on a child’s sleep [5,6,33]. Pre-Covid-19 studies investigated stressors and sleep of school-aged and adolescent populations [26,34], as a predictor [35,36], mediator [37]/moderator [26,38] or associative factor [39]. In preschoolers, particularly bedtime interactions were the focus of attention [40,41]. Yet societal demands or financial strains may influence parents’ responsivity and caretaking and in view of this, the relevance of an ecosystemic impact should not be ignored. Repeated measurement designs may be the best option to capture fluctuations in stressors and a child’s sleep, which may vary on a daily basis within the child’s niche. To appraise the lessons that can be learned from Bronfenbrenner’s perspective in a pandemic state of affairs, we aim to discuss the concurrent changes in a child’s sleep with pre-COVID ecological stressors.

2. Materials and methods

2.1. Procedure

This study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of The University of Chicago (IRB 10-677-B, extended 17.01.2012). Informed consent was obtained from all subjects involved in the study with data collection running from 2011 to mid-2012, excluding holiday breaks.

Participants are children aged 3 to 9 years old and their caregivers living on the south side of Chicago. The sample is self-defined as African Americans. This study applied a cross-sectional sequence design with the child’s sleep as the core measurement, and concomitantly assessed stressors in the child’s ecosystem (per caregivers’ report). Simple random sampling within the participating community centers was applied. When several children within the family were eligible for the study, the Kish procedure [42] for subject selection was used. Children with medical illness (e.g., diabetes), developmental disabilities, psychiatric disorders or taking medications on a regular basis were excluded. Data was collected before the COVID-19 pandemic.
2.2. Measurements

2.2.1. Sleep assessment

The child’s sleep was objectively measured with the Actiwatch-2 (Phillips-Respironics, Inc. 2009, version 5) worn on the non-dominant wrist for 24 h. Sleep data recorded during 14-days, allows two weekend nights (Friday and Saturday) assessments. This sleep recording was repeated three times over a study period of three months. The full recording period therefore allows calculation of mean and variability (i.e., a measure of dispersion relative to the mean) of the standard sleep parameters: Bedtime (BT), Time In Bed (TIB), Ristetime (RT), Total Sleep Time (TST), Sleep Onset Latency (SONL), Wake After Sleep Onset (WASO), Sleep Offset Latency (SOFL), Restlessness Index (RESTLESS). Mid-point of sleep (MSF) was calculated, and is an indicator chronotype or biorhythm, and indicative for the tendency of morningness-eveningness. (see also [43–45])

We also examined the child’s sleep environment (e.g., bed- and/or room-sharing) with a five-point Likert format questionnaire (7 items) filled out by the caregiver [46].

2.2.2. Sociodemographic questionnaire

From the American Census Survey 10 socio-demographic questions were used, allowing comparison to larger samples or external generalizability of our sample. To enhance our understanding of the child’s ecosystem, 38 items from the American Community Survey developed to survey Chicago neighborhoods were used. The questionnaire was filled out by the caregiver. For instance, some of the socio-demographic items included were: number of adults/sibling living in the house, the current living arrangement, employment, education, annual household income, reasons why people would move out the neighborhood. The questionnaire included a mixture of open and closed format responses (for more information please refer to the United States Census Bureau website).

2.2.3. Family resource scale (FRS)

FRS [47,48] assesses the adequacy of concrete resources in households with young children. The scale is a 31-item 5-point Likert rating (i.e., 1: not at all adequate, to 5: almost always adequate; also, does not apply, was available) assessing Basic Needs, Money, Time for Self, and Time for Family. Lower scores indicate lower family resources. The reliability of these four subscales ranges from 0.72 to 0.84. It takes about 10 min to complete, and was filled out at the start and the end of the study by the caregiver.

2.2.4. Urban stress scale (USS)

USS evaluates urban community-level stressors [49,50]. Based on a 5-point Likert rating (i.e., 1: no stress at all, to 5: extremely stressful—more than 1 can handle) of 21 items the level of stress associated with various aspects of life is measured: i.e., perceived stressors of economic stability, social & community context, and neighborhood & physical environment. Higher scores mean higher perceived stress. The reported Cronbach’s alpha coefficient was 0.84, and the split-half reliability was 0.77. It was filled out at the start and the end of the study by the caregiver.

2.3. Statistical analysis

Descriptive statistics were performed with Statistica TIBCO Software Inc (TIBCO, 2017) version 13. This is a within-effect design where participants are their own controls. The power of this sample (n = 24) for two assessment points to detect an effect size (ES) of 0.15 = 30%; ES of 0.25 = 65%; ES of 0.35 = 91% and ES of 0.45 = 98%.

To pursue our associative analyses, we calculated the individual change scores for the stress and sleep variables. They express the change within the individual over the study period. This statistical approach expresses true change (i.e., when beyond one standard deviation) occurring in the individual. In addition, change scores allow calculation of the number of children for which a significant clinical (“true”) increase/decrease of variables is noted (here expressed in percentages).

The association between changes in familial and community stressors and sleep of the child denotes their concurrence. To analyze this concurrent relationship between ecological stressors and sleep Multi-dimensional Scaling (MDS; NewMDSX) [51] was applied on the individual change scores. MDS (MRSCAL, i.e. MetRic SCALing algorithm) rearranges data in a space with a minimal number of dimensions to express the associations. More technically, MDS searches for the least number of dimensions such that the interpoint distances of variables scattered along dimensions closely correspond to the original (dis)similarities in data points, which are in fact associations between pairs of variables in space. For non-statisticians, although the mathematical formula is different, the conceptual approach of MDS is comparable to what factor analysis or principal component analysis does.

In MDS, the interpoint distances or scalars allow for (1) measuring an association, (2) portraying complex associations across multiple variables in a simpler way and (3) inferring latent dimensions. In lay terms, the larger the scalar value the larger the dissimilarities (the further in space). In short, dimensions can be replaced by concepts expressing the core associations between variables. Hereby, extremes, the clustering of variables and the zero-points along the dimension are used for interpretation. The fit of the configuration is expressed by the badness-of-fit measure, known as the coefficient of alienation K and a goodness-of-fit measure MU. The lower K is the better the fit, with the best fit being equal to zero. The higher MU is the better the fit, with the best fit being equal to 1. In other words, interpretation is analogous to factor analysis, where extremes determine the main latent concept of the dimension and a percentage of explained variance is given (PEV).

3. Results

3.1. The sample

The sample involves 24 children with mean age 5.4 ± 1.7 years old including 54.2% girls. Table 1 shows the characteristics of the sample and their ecosystem.

3.2. The ecosystem

3.2.1. Chronosystem

In the current 21st century, their chronosystem can be described as 50% single mom families with few having a master or higher-level education. They lived about 4–5 years in this neighborhood; i.e., minimum of 2 years to maximum 35 years. The main reasons for living on the south side were: comparable to previous neighborhood; having groups that deal with local issues; park, playground or open space within walking distance; family health service in the vicinity; after school programs such as academic and/or recreational activities. Overall 66.7% liked and 25% disliked the neighborhood (8.3% refused answering). The (dis)liking was related to good public transport, access to shopping, restaurants and other nightlife opportunities versus the (high) cost of living, (high) crime rate and (few) job opportunities. Reasons for leaving this ‘chronosystem’ are better schools for kids, being away from drugs and crime context.

3.2.2. Macrosystem

Their macrosystem is an (self-defined) African American community. 66.7% of the caregivers were employed. During the study period, the majority of caregivers kept their job. Approximately 60% have low social economic status (SES) of which 75% are renting their home. This macrosystem is further characterized as 33.3% people selling or using drugs, 29.2% teenagers/adults hanging out and causing trouble and for 29.2% police is not patrolling the neighborhood. Hence, these findings portray a semi close-knit neighborhood where people mostly go their own way: e.g., some people are willing to help others, likely some...
Table 1
Sample characteristics and ecosystem per sociodemographic and sleep questionnaire items.

| Chronosystem Marital status | Ecosystem Anywhere in the neighborhood | Microsystem Home environment | Sleep environment: Own bedroom |
|-----------------------------|---------------------------------------|-------------------------------|-------------------------------|
| never married & living alone | 50% | 25% | biological mother | 87.50% | Not applicable/never | 50% |
| never married and living with someone separated | 20.80% | 16.70% | biological father | 20.80% | Occasionally (<1/week) | 29.20% |
| divorced | 8.30% | 41.70% | adoptive/foster parent(s) | 4.20% | Not applicable/never | 8.30% |
| married | 16.70% | 30.40% | sibling(s) | 29.20% | Sleep environment: Own bed |

Educational level

| never married & living alone | high school graduate | partial college (at least 1 year) or specialized training | standard college or university graduate | graduate professional training/degree (graduate degree, master’s degree, doctorate) | un answered |
|-----------------------------|----------------------|----------------------------------------------------------|--------------------------------------|-----------------------------------------------------------|---------------|
| Educational level | Fight with weapon | grandparent(s) | 33.30% | Occasionally (<1/week) | 8.40% |
| high school graduate | Do not know | other relative(s) | 41.70% | Occasionally (<1/week) | 83.30% |
| partial college (at least 1 year) or specialized training | never | other non-relative(s) | 12.50% | Occasionally (<1/week) | 45.90% |
| standard college or university graduate | rarely | Family and relatives in the neighborhood | 47.90% | Occasionally (<1/week) | 4.20% |
| graduate professional training/degree (graduate degree, master’s degree, doctorate) | sometimes | no relatives in neighborhood | 47.90% | Occasionally (<1/week) | 4.20% |

Macrosystem

| not married & living alone | not married & living with someone separated | divorced | married |
|---------------------------|-------------------------------------------|-----------|---------|
| Macroystem | Gang fight | 1–2 relatives living in neighborhood | 16.70% | 50% |
| Employment | do not know | 1–2 friend(s) living in neighborhood | 12.50% | Has computer |
| currently employed | never | 3–5 friends living in neighborhood | 22.90% | Not applicable/never | 66.70% |
| got a new job | rarely | >10 friends living outside neighborhood | 37.50% | Occasionally (<1/week) | 4.20% |

Social Economic status

| not married & living alone | not married & living with someone separated | divorced | married |
|---------------------------|-------------------------------------------|-----------|---------|
| Social Economic status | kept their job lost their job | Social Economic status | lower class middle class upper class |
|---------------------------|-------------------------------------------|-----------|---------|
| lower class | Siblings in the house | 58.30% | 37.50% | 4.20% |
| middle class | No sibling | 31.60% | Has intrusive light | 87.50% |
| upper class | 1 sibling | 52.60% | Not applicable/never | 12.50% |
| Housing | 2 siblings | 10.50% | Occasionally (<1/week) | 41.70% |
| rent own | 3 or more siblings | 5.30% | Not applicable/never | 8.30% |
| unanswered | 4.20% | Occasionally (<1/week) | 79.20% | 20.80% |

*Based on Chicago’s median household income of $46,877 and Chicago’s Below Poverty Level of 20.9% per United States Census Bureau 2010.
neighborhood watch by adults on youngsters, neighbors would break up fights.

3.2.3. Ecosystem

Their ecosystem has been reported to show various degrees of criminal activities. The main issues reported are property damage and areas where criminal activities are custom. Overall, in about 9.4% of the cases weapons and gang fights are "sometimes" to "often" occurring.

3.2.4. Mesosystem

Their mesosystem suggests steady community stressors (USS mean: 3.8 ± 0.9; above 2.5 on a scale of 1–5) and moderate family resources regarding money and personal time of the caregiver (half above 2.5 on a scale of 1–5): i.e., BN: 4.4 ± 0.7, TF: 4.2 ± 0.8; TS: 3.1 ± 0.9; M: 2.9 ± 1.1. Money and personal time are at the top of the pyramid (Fig. 2), which demonstrates over a period of 3-months the least/most stable stressors and family poverty of the sample.

3.2.5. Microsystem

The home environment comprises primarily biological relatives such as biological (grand)parent(s) and mostly one sibling, with few other family or relatives living in the neighborhood. Regarding their sleep environment, half of the children do not have their own bedroom and the majority have their own bed (often daily). In almost 50/50 of the participants, a TV was (not) present in their sleep environment. Whilst in the majority of participants, there was not a computer nor intrusive light or noise, and the bedroom was not considered as humid. This sleep environment was consistent during the 3-month study period for 35.4% (computer) to 47.9% (humidity) of the participants.

3.2.6. Child

These children’s total sleep time is not optimal in comparison to the sleep recommendations [52,53]. Children went to bed at 22:26 and woke up at 07:04, with each a variability of about 50 min. Fig. 3 shows mean and variability of the sleep parameters, with the table below expressing in percentages the number of participants for which the individual change increased, decreased or was unaltered during the study period. This demonstrates that mainly WASO (128.9 min.), TST (390.7 min.) and MSF (2:01 AM) were stable within the individual.

3.3. The concurrent associations between individual changes in stressors and sleep

In what follows, the individual change scores that were calculated over the study period for stressors and sleep will be modeled in space. The tabulated numbers are scalars, or where the "point" is situated in the most optimal space solution, representing the underlying associations. Therefore, the final space solution expresses the proximity among the (individual changes in) stressors and a child's sleep along latent dimensions that can be labeled.

3.3.1. Mean of sleep parameters

Five dimensions modeled associations between the individual changes in stressors and mean sleep variables (K = 0.07, MU=0.997). Table 2 shows the scalars (i.e., the point in the dimensional space) and explained variances, with Dimension 1 explaining most. Overall, RT and TST contribute most to the ‘fit’ of the final solution.

Based on the extremes, and scalars, Dimension 1, might be conceptualized in terms of “source-related” associations between stressors and sleep. That is, individual changes in biopsychosocial centered variables per more WASO, RESTLESS (positive scalars) versus reduced TST and TF (negative scalars). Dimension 2, might represent “type-related” associations with more RESTLESS, long SONL versus fewer family resources per BN and TF. Individual changes in stressors and sleep that make up the Dimension 3, are increased TIB, TST versus reduced TS, shorter SONL, or “time-related” associations. Dimension 4 is considered to represent “direction-related” stressors-sleep associations; namely, being determined by the self (or inward) SONL, TIB versus determined by others (or outside) RT, SOFL. Dimension 5, or “alterability”, may represent whether associations can vary due to circumstances; later RT, more M versus reduced SOFL, USS. Noteworthy, (increased) average TIB did not change position in each of the 5-dimensions.

3.3.2. Variability of sleep parameters

Five dimensions also best fitted the associations between individual changes in stressors and variability of sleep, or its dispersion around the mean (Table 3). Here, variability of TIB and the USS contributed most to the model fitting.

Dimension 1, with less TS, and less M being daytime aspects versus increased variability of TST and RESTLESS being nocturnal aspects, may represent the concept of associated changes labeled as “24 h related”. This dimension furthermore explains the highest amount of variance
of all dimensions, and is the only dimension with clear clustering of day/night aspects. That is, all daytime stressors are on one side of the dimension with central-axis points being variability of BT, SOFL, SONL and RT. Dimension 2, is conceptualized as “circumstance-related” associations, given that on one extreme reduced variability in SONL and fewer BN versus on the other extreme increased variability in SOFL and more TS are located. Thus, balancing between personal needs versus familial ones as they are close on this dimension to the time to fall asleep or get up. Dimension 3 labelled as “environment-related” associated changes, such that reduced variability of SOFL and MSF being a more person-oriented (e.g., biologically such as a lark) trigger versus increased variability of TST and more US being prompted by the environment or community aspects. With reduced variability of BT and WASO versus increased variability of TST and TF, Dimension 4 is labeled “context-related”, possibly reflecting the sleep arrangements. Lastly, Di-

Table 2
Association between stressors and mean sleep.

| Dimension 1PEV: 56.72% | Dimension 2PEV: 47.46% | Dimension 3PEV: 45.57% | Dimension 4PEV: 35.32% | Dimension 5PEV: 34.73% |
|------------------------|------------------------|------------------------|------------------------|------------------------|
| Scalar                | Variable               | Scalar                | Variable               | Scalar                | Variable               |
| –0.8907               | TST                    | –0.7164               | BN                     | –0.6096               | TS                     |
| –0.6377               | TF                     | –0.5649               | TS                     | –0.5932               | SONL                  |
| –0.6092               | MSF                    | –0.6286               | M                      | –0.4871               | BT                     |
| –0.3497               | USS                    | –0.5842               | TS                     | –0.358                | RESTLESS              |
| –0.3348               | BT                     | –0.2621               | SOFL                   | –0.2738               | USS                   |
| –0.2828               | SOFL                   | –0.994                | TS                     | –0.1818               | BN                     |
| –0.1696               | RT                     | 0.093                 | RT                     | –0.1261               | M                      |
| –0.0319               | TS                     | 0.1488                | WASO                   | 0.1137                | TF                     |
| 0.2221                | M                      | 0.1934                | BT                     | 0.1378                | MSF                   |
| 0.266                 | SOFL                   | 0.2861                | TIB                    | 0.1986                | SOFL                  |
| 0.3079                | TIB                    | 0.4212                | MSF                    | 0.2085                | WASO                  |
| 0.5605                | BN                     | 0.527                 | US                        | 0.3462               | RT                     |
| 0.7068                | RESTLESS               | 0.5477                | SONL                   | 0.5483                | TST                   |
| 1.2461                | WASO                   | 0.7119                | RESTLESS               | 1.0767               | TIB                   |

Table 3
Association between stressors and variability of sleep.

| Dimension 1PEV: 61.83% | Dimension 2PEV: 47.59% | Dimension 3PEV: 42.79% | Dimension 4PEV: 34.06% | Dimension 5PEV: 30.36% |
|------------------------|------------------------|------------------------|------------------------|------------------------|
| Scalar                | Variable               | Scalar                | Variable               | Scalar                | Variable               |
| –1.0879               | TS                     | –0.6569               | SONL                   | –0.783                | SOFL                  |
| –0.8914               | M                      | –0.6314               | BN                     | –0.4296               | MSF                   |
| –0.7916               | BN                     | –0.4702               | RT                     | –0.3458               | M                      |
| –0.3828               | TF                     | –0.4299               | TIB                    | –0.1844               | RESTLESS              |
| –0.1621               | USS                    | –0.3162               | MSF                    | –0.0816               | TIB                   |
| –0.1441               | BT                     | –0.2904               | TS                     | –0.0187               | RT                     |
| –0.0974               | SOFL                   | –0.0901               | M                      | –0.0967               | BT                     |
| –0.904                | SONL                   | 0.0034                | BT                     | 0.0007                | SONL                  |
| 0.2129                | RT                     | 0.0894                | TS                     | 0.0463                | BN                     |
| 0.5314                | WASO                   | 0.221                 | WASO                   | 0.0546                | TF                     |
| 0.5256                | TIB                    | 0.5373                | US                        | 0.0555               | WASO                  |
| 0.6344                | MSF                    | 0.5708                | RESTLESS               | 0.1127               | TS                     |
| 0.8018                | TST                    | 0.708                 | TF                     | 0.535                | TST                   |
| 0.9353                | RESTLESS               | 0.7549                | SOFL                   | 1.1351               | US                        |

BN: Basic Needs; BT: Bedtime; M: Money; MSF: Mid-point of sleep; PEV: percentage explained variance; RESTLESS: Restlessness Index; RT: Risetime; SOFL: Sleep Offset Latency; SONL: Sleep Onset Latency; TF: Time for Family; TIB: Time in Bed; TS: Time for self; TST: Total Sleep Time; USS: Urban Stress Score; WASO: Wake After Sleep Onset.

Conceptualization of associations between stressors and sleep: Dimension 1: source-related; Dimension 2: type-related; Dimension 3: time-related; Dimension 4: direction-related and Dimension 5: alterable-related.

Appendix A
dimension 5 consists of reduced variability of RT and RESTLESS versus increased variability of WASO and MSF, or “agitation”.

In general, concurrent changes within the individual child indicate that mean sleep variables seem to relate to predominantly features of the stressors, while variability of sleep tends to associate to situational aspects of the stressors occurring within the ecosystems of the child. In supplement, we provide the dimensional space for week and weekend days separately. Co-occurrences here seem to suggest that average weekly sleep quality to associate with perceived support or resources, whereas associations with sleep variability propose the efforts across the ecosystem. For weekend days, time necessity stressors seem to co-occur, particularly associating with average sleep quantity. At what level this time management stressor is situated appears to relate especially with weekend sleep variability of the child.

4. Discussion

This study is the first to demonstrate in early childhood the daily concordance of changes in sleep with ecological stressors over a period of three months. Namely, familial resources such as time for self of the caregiver, money and basic needs seem to associate with individual variabilities in a child’s sleep. A key player is a child’s time in bed, which is known to concomitantly influence other sleep parameters, shaping their sleep quantity and quality. Overall, within children’s ecosystem concurrent changes in their average sleep appear to relate to features of familial and community stressors. Whereas sleep variability tends to concur with the situational aspects of the stressors occurring within the child’s ecosystems. Particularly, given the COVID-19 pandemic, decisions made on societal level may impact the resilience of families, which will possibly influence the 24 h sleep-stressor associations. Such trickling effect per Bronfenbrenner’s systems perspective may suggest varyingly presented changes in sleep quantity and quality of a child. Sleep studies and recommendations during and after the pandemic should therefore be sensitive and specific concerning the societal context.

Recent reviews indicate that children with minority backgrounds have poor sleep and hence sleep disparities are concluded [54,55]. Herein the role of the societal context, beyond the conglomeration of “SES” or the race/ethnicity variable, is ignored. Namely, studies reviewed apply them as a defining variable yet families are resourceful in dealing with adversity and foremost ‘being black is not a risk factor’. It is the societal pathways along the levels of the ecosystem that deserve our attention [56].

According to the 2010 U.S. Census, approximately 50.3% of Black people attain a high school or graduate degree or less. 55.2% have a one-parent arrangement and 74% are at or above 100% poverty. Our minority sample is comparable to these Black family sociodemographics, and to a large-scale study sample surveying sleep in the south side of Chicago 28. That is, most grow up in an environment characterized by lower SES and a single mom that attained a (partial) college degree. Beside a societal “stereotyped” chronosystem and macrosystem, also the exosystem demonstrates archetypal fear-neighborhood perceptions, and has been characterized in our sample as a semi close-knit community. In the sleep literature, the interrelation of these ecosystems is potentially masking the actual directionality of the sleep associations reported. That is, marital conflicts have been related to decreased sleep quantity & quality 9, and increased sleepiness 34 as well as to influencing child sleep arrangements [57]. Household chaos yet has been equally linked to socioeconomic risk, negative life events, less favorable parenting and less emotional availability at bedtime [58]. Thus bi- or multidirectionality can be put forward in studies, as they each show, on the one hand, the risk factors such as parental drinking [59], child’s sleep problems [60] and, on the other hand, the protective factors such as emotional security in family interactions [61], time spent to sleep while in bed [62], physical activity [63]. Similarly, moderator and mediator effects have been a topic of great interest [54,55]. That is, apart from race/ethnicity26, principally SES and sleep problems [27,64,65] have been examined. However, and as an example, co-sleeping or changing sleep arrangements should not be ignored in a 21st century society, as found in this study and previously 28. Our statistical approach shows indeed that multiple layers need to be considered. That is, whilst past studies show parts of the puzzle, Bronfenbrenner’s ecological perspective highlights their concentric relationship. Subsequently, the impact of disparities experienced by minorities may caution us about the post-Covid-19 chronosystem.

Contrary to others, we analyzed changes concomitantly occurring in the child’s sleep per familial and community stressors. First, our findings corroborate an insufficient sleep duration 31,54,55, in which a modifiable factor is TIB. This can be obtained by shifting BT, RT and creating sleep-promoting arrangements (e.g., no TV in room used for sleeping). This study further demonstrates that changes should be understood within a 24 h dimension. Namely, given a one-parent family, with potentially limited social and economic resources, it might be a daily challenge to safeguard ‘optimal sleep’ due to levels beyond the microsystem. For instance, some caregivers could not keep their job over a period of 3-months. During the COVID-19 lockdown, a recent study showed that particularly women are the most vulnerable individuals [66]. It has further been suggested that the duration and quality of mothers’ sleep is associated to children’s sleep [67]. The ecosystem strain felt by the caregiver, as expressed in this study, may affect caregiver-child interactions. Indeed, our study showed recurring familial bottlenecks (or the lack of such resources) are TS, TF and BN as source-, type- and time-related stressors linking to a child’s sleep quantity (i.e., TST, TIB) as well as sleep quality (i.e., SONL, WASO, RESTLESS) (see Table 3 Dimension 1–3 with extremes of mean sleep). This finding corroborates with studies showing that adolescent’s sleep under varying levels of family stress show altered sleep duration, sleep variability, and time spent awake during the night 16,65. Quality of parenting, chiefly per infant sleep studies, is well-acknowledged [68,69] but again cannot be disconnected from a real-world context15. Hence sleep-interactions might be determined by stressor-sleep associations originating in the child (e.g., SONL, SOFL), the caregiver (e.g., M) or the surroundings (e.g. USS), which might be inferred from the direction-related and alterability dimensions. Our findings, in fact, suggest a multidimensional relationship between familial and community stressors, and a child’s sleep. More studies are still needed focusing on resilience and coping strategies along the levels of the ecosystem. Alternatively, COVID-19 sleep surveys, in particular those measuring sleep schedules during lockdown, may spotlight our 21st society Achilles heel.

Second, in this study concurring sleep-stressor associations were best explained in terms of the 24 h dimension, particularly exposing sleep variability. Altogether, these dimensions depicting sleep variability are suggestive of the importance of situational aspects, likely prevailing at the mesosystem. In this sample, given the FRS and UUS scores (and pyramidal) the ecological stressors might be situated at the everyday level of personal time and economic strain. These two aspects are in the current pandemic likely undergoing modifications in many families (U.S. Census Bureau, Household Pulse Survey, and others [70]). Whilst family cohesion is known to be a cornerstone of a child’s health, and sleep 9,16, the pandemic brings widespread changes in family financial situations [71], school rhythms [72], well-being [73] and uncertainty about the future. Each of them have been in part separatedly linked to poor sleep of the child, and are yet to be determined within current and future sleep studies. It should be additionally noted that sleep and the biological stress system activity are interlinked [74], placing caregiver and child at increased health risks.

Several limitations and strengths about our study warrant discussion. Strengths of the study are the objective sleep assessment beyond 7-days including surveying the sleep environment. Being a repeated measurement over a prolonged period with multiple assessments, the small sample is however able to detect moderate to large effect sizes with more than 90% power. Similarly, the stressor questionnaires used, are frequently applied in minority samples. Furthermore, the family dynamics
are understood from a bioecological perspective (e.g., MSF). As a limitation, the sample was recruited through simple random sampling within the participating community centers, and was due to budget constraints limited to a small group of participants randomly participating in a longitudinal study. Despite comparability to the U.S. Census Black families, the sample remains small, potentially limiting the expression of certain sleep-stressor tendencies. No causality or directionality can be inferred in part due to the cross-sectional approach but primarily because the aim was to examine the daily concordance. This was possible due to the repeated measurements and the use of change scores over a period of three months. In addition, we did not query about child-caregiver interactions, however, we previously demonstrated that individual changes in sleep onset and offset might be important clinical markers of a chronic ‘social dysregulation’. Lastly, crime rate in Chicago is higher than the U.S. average.

5. Conclusions
In conclusion, the feature of the stressor and its context may adversely influence a child’s sleep quantity and quality. Elements in the child’s ecosystem may exert an influence beyond the customarily investigated child microsystem. Thus, the ecosystem of the child, or community and familial stressors, should be considered when developing sleep promotion guidelines and parenting interventions, particularly post-COVID.

Supplementary materials

Table S1: Association between stressors and mean sleep for week;
Table S2: Association between stressors and variability of sleep for week;
Table S3: Association between stressors and mean sleep for weekend;
Table S4: Association between stressors and variability of sleep for weekend.

Declaration of Competing Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement
Calista U. Alaribe: Writing – original draft, Writing – review & editing. Odoochi U. Nwabara: Writing – original draft, Writing – review & editing. Karen Spryut: Conceptualization, Supervision, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition.

Acknowledgments
Herewith we would like to acknowledge the funding organization to make this project possible and the community members that have supported this study. We are grateful for the participation of families and children. Special thanks goes to Calista and Odoochi for their unweaving enthusiasm.

Funding
This study was financially supported by the Consortium to Lower Obesity in Chicago Children (CLOC) subcontract Chicago Community Trust Grant No. C2010-01060 with the corresponding author as Principal Investigator.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sleep.2021.100007.

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