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Original Article

Effect of Sleep Quality and Duration on Jitter, Shimmer, and Harmonics-to-Noise Ratio among Colombian University Professors

María Paula Rincón-Pinilla [a], Andrés Carrillo-González [b, c] and Lady Catherine Cantor-Cutiva [c, d, *]

[a] *Universidad Manuela Beltrán, Bogotá, Colombia.*
[b] *Fundación Universitaria del Área Andina, Departamento de Psicología, Colombia.*
[c] *Departamento de Salud de Colectivos, Universidad Nacional de Colombia, Colombia.*
[d] *Communicative Sciences and Disorders Department, Michigan State University, USA.*

ABSTRACT

Professors who sleep 6 or fewer hours are more likely to report voice symptoms. However, only three studies have been published on this topic, basing their conclusions on self-reported surveys and displaying an overall weak methodological quality, which hinders the generalization of these results. This exploratory, correlational, and longitudinal study aimed to determine the association between sleep quality and duration and three acoustic parameters linked to voice harmonicity and quality (jitter, shimmer, and Harmonics-to-Noise Ratio [HNR]) among 24 Colombian university professors. Generalized linear models with gamma distribution were used to analyze this association. Our results indicate that the professors who reported good sleep quality had significantly lower HNR values compared with those who had a low sleep quality. Additionally, increased jitter (B= 0.10) and shimmer (B= 0.10), and decreased HNR (B= -0.05) values were found when the duration of sleep increased. In contrast, participants with good self-perceived sleep quality and a shorter sleep duration presented lower voice harmonicity compared to those with bad sleep quality and shorter sleep duration, which may be associated with the physiological and emotional effects of sleep on voice production. Considering the multifactorial nature of voice production and the exploratory nature of the present study, it is important to note that a statistically significant correlation between sleep quality and duration and voice harmonicity does not necessarily imply that sleep directly causes voice disorders, but rather suggests that sleep is a variable to be considered when analyzing and treating individuals with voice issues. These findings provide insight into the complex interplay of variables that may contribute to voice disorders and highlight the importance of considering sleep as a potential contributing factor in the assessment and management of individuals with voice issues.

Keywords:
Voice; Sleep Quality; Voice Quality; Voice Disorders; Professors

Efecto de la calidad y duración del sueño sobre el Jitter, Shimmer y la Relación Armónicos-Ruido en profesores universitarios colombianos

RESUMEN

Los profesores que duermen 6 horas o menos tienen más probabilidades de reportar síntomas de voz. Sin embargo, solo se han publicado tres estudios sobre este tema, los cuales basan sus conclusiones solo en auto reportes, lo que dificulta la generalización de esta relación. Este estudio exploratorio, correlacional y longitudinal tuvo como objetivo determinar la asociación entre la calidad y la duración del sueño con tres parámetros acústicos relacionados con la armonía y la calidad de la voz (jitter, shimmer y relación armónicos-ruido (HNR) en 24 profesores universitarios colombianos. Se utilizaron modelos lineales generalizados con distribución gamma para determinar la asociación de estas variables con los parámetros acústicos de la voz. Nuestros resultados indican que los profesores con buena calidad de sueño tenían valores de HNR significativamente más bajos en comparación con aquellos con menor calidad del sueño. Específicamente, hubo un aumento del jitter (B= 0,10), shimmer (B= 0,10) y disminución del HNR (B= -0,05) al incrementar la duración del sueño. Por su parte, los profesores con una buena calidad del sueño y con una corta duración de este (medida a través de auto-reporte) tenían menos armonía vocal que aquellos con una mala calidad y una duración del sueño corta, lo que puede estar asociado con los efectos fisiológicos y emocionales del sueño en la producción vocal. Teniendo en cuenta la naturaleza multifactorial de la producción de voz y la naturaleza exploratoria del presente estudio, es importante destacar que una asociación estadísticamente significativa entre la calidad y duración del sueño con la armonía vocal no implica necesariamente que la mala calidad o corta duración del sueño causen directamente trastornos de voz. Más bien, sugiere que el sueño es una variable que debe considerarse al analizar y tratar a personas con problemas de voz. Estos resultados proporcionan información sobre la compleja interacción de factores que pueden contribuir a los trastornos de voz y resaltan la importancia de considerar el sueño como un factor potencial que contribuye en la evaluación y tratamiento de las personas con dichos trastornos.

Palabras clave:
Voz; Calidad del Sueño; Calidad de la Voz; Trastornos de la Voz; Docentes

* *Corresponding Author: Lady Catherine Cantor-Cutiva*
Email: lccantorc@unal.edu.co

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INTRODUCTION

Teachers who sleep 6 or fewer hours are more likely to report voice symptoms (OR=1.6) (Carrillo-Gonzalez et al., 2021). However, only three studies have been published on this topic (Ferreira et al., 2010; Lee et al., 2018; Valente et al., 2015) basing their conclusions on self-reported surveys and with weak overall methodological quality, which hampers the generalization of this relationship.

In the general population, it has been reported that sleep disorders may affect health because during sleep the central nervous, metabolic, endocrine and immune systems recover (Gluschkoff et al., 2016). Therefore, sleep problems may lead to imbalanced functioning, impacting mood, cognitive, and motor performance; and negatively affecting voice production (Rocha & Behlau, 2018; Tavares Botelho, 2019).

Moreover, it has been suggested that during sleep, there is increased partial adduction of the vocal folds as a vegetative function because the person is less vigilant and hence less able to protect their airway (Bagnall et al., 2011). This increased partial adduction may be linked with a recovery process of the laryngeal system, and therefore, a reduction of the likelihood of voice disorders.

Concerning the impact of specific sleep disorders on voice production, a previous study including patients with obstructive sleep apnea (OSA) concluded that the Voice Handicap Index (VHI-10) values were significantly higher in patients with OSA compared with participants without OSA (Wei et al., 2021). On the contrary, fundamental frequency, jitter, shimmer, and noise-to-harmonic ratio (NHR) were not statistically different between patients with and without OSA. This suggests that OSA did not affect significantly voice quality because jitter and shimmer are perturbation measures that provide information about small fluctuations in the opening and closing times of the vocal folds, and higher values have been traditionally associated with pathological voices (Montero Benavides et al., 2014).

Another sleep condition is sleep deprivation. In this regard, it has been suggested that sleep deprivation may result in lower pitch variability, which may cause a "monotone" or "flattered" voice, resulting in comparatively steady harmonic patterns (Harrison & Horne, 1997; Nwe et al., 2006; Weinger & Ancoli-Israel, 2002). A follow-up study on the effect of 24 hours of sleep deprivation on vocal parameters of 47 young adult Hebrew speakers reported significantly higher Harmonic-to-noise ratio (HNR) values following sleep deprivation compared with nocturnal sleep among female participants (Icht et al., 2018). This result suggests higher harmonicity among participants with lower or zero sleep time and quality compared with good sleep duration and quality because higher HNR values represent a "better" voice compared with lower values that have been associated with "pathological" voices (Montero Benavides et al., 2014). However, the small sample size and short follow-up limit the generalization of the results.

As can be observed, most studies have analyzed the effects of sleep on voice harmonicity (HNR and NHR) and perturbation measures (jitter and shimmer) because these acoustic features have been traditionally reported in the detection of pathological voices. Nevertheless, current literature has focused on diagnosed sleep disorders (sleep deprivation and obstructive sleep apnea) without considering variations of sleep quality and duration within participants without diagnosed sleep disorders. Moreover, all the studies on the relationship between sleep and voice disorders among teachers have based their results on self-reported questionnaires, which may overestimate the real effect of sleep on voice production among occupational voice users.

With this in mind, we designed a longitudinal study of 15-day follow-up among Colombian college professors to determine the association between sleep quality and duration with three acoustic parameters that provide information about voice harmonicity and quality (jitter, shimmer, and Harmonics-to-Noise Ratio (HNR)).

METHOD

Study design and participants

This exploratory, correlational, and longitudinal study was performed with the participation of 24 college professors (12 females and 12 males; mean age 45.4 y/o - SD=12.3). The sample size was calculated considering a prevalence of voice disorders in teachers of 69% and a prevalence in the general population of 36% (Sliwinska-Kowalska et al., 2006), with an alpha of 0.05 and a power of 80%. To identify significant differences, a minimum sample size of 24 participants was determined. The inclusion and exclusion criteria are presented in Table 1.

Data collection procedures

After approval of the Institutional IRB (approval reference 014-19), participants were invited to take part in this research via email. Professors who accepted to participate had a first meeting with the second author and were informed about the objective of the research, risks, and the duration of the study. Then, all participants gave written informed consent to participate in the study and fill out an online survey and record two voice samples (sustained vowel /a/ and /i/) on the first and the last day of a 15-day follow-up.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
To be an active college professor at the beginning of data collection. To own a smartphone and a laptop or desktop computer.	To present a disorder medically diagnosed related to sleep, stress, or voice function

For this research, an online survey, distributed via Google Forms, was designed to assess the work-relatedness of voice disorders, stress levels, and sleep duration and quality among college professors. This survey was filled in on the first and the last day of the 15-day follow-up. The survey was designed based on previously standardized instruments applied to investigate voice disorders among teachers (Angelillo et al., 2009; Cantor Cutiva et al., 2013; Cantor Cutiva & Burdorf, 2014; Chen et al., 2010), stress, and sleep quality. The final version of the survey included 46 questions on demographics (age, gender, marital status, level of education), working conditions (duration of occupational voice use, number of students per class, number of classes per day and per week), lifestyle habits (smoking, alcohol consumption, water consumption), and health-related conditions (respiratory diseases, gastrointestinal diseases, allergies, stress levels, sleep duration, and quality). Although the survey included questions regarding working conditions, lifestyle habits, and health-related conditions, because other results have been published with different analyses of this data (Carrillo-González, 2020), this manuscript is focused on the analysis of the relationship between sleep duration and quality with voice acoustic parameters.

Sleep quality was evaluated with a single item: "How would you evaluate your previous night's sleep?" (Sonnentag & Binnewies, 2013) using a Likert scale from 1 to 5, where 1 indicated the worst quality and 5 designated the best quality of the previous night's sleep. It is important to mention that teachers were not instructed as to what sleep quality was because we were interested in preserving the subjectivity of the response within the range proposed in the response scale. Since participants were Spanish speakers, the sleep question was translated and adapted to Spanish: ¿Cómo evaluaría el sueño de su noche anterior? (Carrillo-González, 2020).

To evaluate sleep duration, participants were asked to use the mobile app Sleep as Android and provide information about their sleep hours. Sleep as Android is a highly reviewed and frequently downloaded sleep-tracking app available on the Google Play store (Ong & Gillespie, 2016). Participants were instructed to activate the app just before falling asleep and to indicate when they woke up the following morning. The sleep duration recorded by the Sleep as Android app was then entered into a Google form for data collection. The question used was: According to the Sleep as Android application, how many hours did you sleep the previous night? (Use the format #hours: #minutes).

To determine voice functioning, in this manuscript we used three voice acoustic parameters extracted from two voice samples (vowel /a/ and /i/) at the beginning and the end of the follow-up (day 1 and day 15). All recordings were performed at the same time of the day to avoid voice changes related to the daytime. Voice recordings were performed in the Health and Safety at Work Lab at the college campus. Professors were located inside a soundproof booth, requested to take a deep breath, and produce a sustained vowel /a/ at a conversational pitch and loudness for as long as possible (without finishing the production with residual air). This procedure was repeated three times. After, they were requested to repeat the same procedure with the vowel /i/. The voice recordings were performed using a unidirectional microphone AUDIOART ART-139, which frequency response range is between 50Hz - 15KHz, a sensitivity of -53 ± 3dB, and an impedance (at 1KHz) of 600Ω ± 30%. All recordings were performed at a sampling frequency (fs) equal to 44,100 Hz. During the recordings, the participants were requested to sit with the microphone in front of their mouth keeping a fixed mouth-microphone distance of five centimeters.

Data processing and acoustic analysis

Voice acoustic analysis was performed using the software Praat (version 6.1.04) (Boersma & Weenink, 2012; Harrison & Horne, 1997). The middle part of all the vowel productions was analyzed for jitter, shimmer, and Harmonics-to-Noise ratio (HNR). The first and last part of the production was not considered during the analysis to avoid onset and offset effects, expecting perturbations to be more steady (Vasilakis & Stylianou, 2009).

Three voice acoustic parameters were selected for analysis: Jitter, Shimmer, and Harmonics-to-Noise Ratio. Jitter is defined as the parameter of frequency variation from cycle to cycle and the fundamental frequency perturbation (Orlikoff, 1989; Orlikoff & Baken, 1990). Higher values of jitter might be evidenced in dysphonic voices (Narasimhan & Rashmi, 2022). Shimmer measures the short-term amplitude variation of the soundwave (Orlikoff, 1990). Harmonics-to-Noise ratio quantifies the relative amount of additive noise in the voice signal (Ferrand, 2002) and characterizes the relationship between two components: the periodic component of the acoustic wave of a sustained vowel (vocal fold regular sign) and the additional noise coming from the vocal folds (Felippe et al., 2006). HNR has been found a useful parameter for predicting vocal quality (Icht et al., 2018). These three parameters were selected because it has been reported that they are good indicators for discriminating normal voices from pathological voices (Brockmann-Bauser et al., 2014; Lathadevi & Pundalikappa Guggarigoudar, 2018).

Statistical Analysis

First, the normality of the distribution of the dependent variables was assessed by applying the Shapiro-Wilk test. Second, because data were not normally distributed, differences in jitter, shimmer, and HNR among participants were assessed by Kruskal-Wallis's test. Third, Generalized Linear Models (GLM) with gamma distribution were used to investigate associations between jitter, shimmer, and HNR with sleep quality and sleep duration. The magnitude of the association was expressed by the beta (B) and its standard error (SE). All statistical analyses were performed using SPSS (IBM Corp, 2021).

RESULTS

Sleep quality and duration among college professors

As shown in Table 2, male professors had higher quality and longer sleep duration (3.8 for quality, and 6:37 for sleep duration) compared with their female pairs (3.5 for quality, and 6:04 for sleep duration). However, this difference was not statistically significant.

Table 2. Sleep quality and quantity among college professors per gender.

Gender	Sleep Quality	Sleep Duration
Female	3.5	6:04
Male	3.8	6:37

Relationship between sleep quality and duration with jitter, shimmer, and HNR

Among the participating teachers, the mean sleep quality score was 3.66 (SD= 0.83) with a maximum score of 5. Table 3 shows mean values and standard deviations (SD) of jitter, shimmer, and HNR per sleep quality scores. Jitter and shimmer were not statistically different across the sleep quality scores. For HNR, teachers with a sleep quality score equal to 4 had significantly lower HNR values (mean= 21.86, SD= 5.10) compared with the worst sleep quality (score=1).

Table 3. Mean values of jitter, shimmer, and HNR per sleep quality scores.

	Sleep Quality			
Voice acoustic parameters	2	3	4	5 (best quality)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Jitter (%)	0.39 (0.15)	0.40 (0.20)	0.39 (0.22)	0.34 (0.12)
Shimmer (dB)	0.21 (0.14)	0.21 (0.10)	0.27 (0.17)	0.21 (0.06)
HNR (dB)	24.77 (3.48)	24.10 (5.10)	21.86 (5.10) *	23.17 (2.47)

* p-value ≤ 0.05

Table 4 shows the results of the multivariate analysis of sleep quality with jitter, shimmer, and HNR. Jitter (%) was significantly lower at the end of the follow-up (B= -0.16) compared with the first measure, and during the production of the vowel /i/ (B= -0.36) contrasted with the vowel /a/. Shimmer (dB) decreased significantly during the production of the vowel /i/ (B= -0.32) compared with the vowel /a/; whereas HNR (dB) increased during the production of the vowel /i/ (B= 0.16). No significant associations were found between sleep quality with jitter, shimmer, or HNR when the model was controlled by the day of the measure and type of vowel.

As shown in Table 5, sleep duration was statistically significantly associated with jitter, shimmer, and HNR. Professors with longer sleep duration had increased jitter (B= 0.10), shimmer (B= 0.10), and decreased HNR (B= -0.05). All the multivariate models were controlled for measure (first vs last), and type of vowel (/a/ vs /i/).

Table 4. Relationship between jitter (%), shimmer (dB), and HNR (dB) with sleep quality.

Parameter	Jitter (%)			Shimmer (dB)			HNR (dB)		
	Beta	SE	p-value	Beta	SE	p-value	Beta	SE	p-value
Intercept	-0.74	0.12	0.00	-1.40	0.13	0.00	3.15	0.09	0.00
First Measure (day 1)	Reference Category			Reference Category			Reference Category		
Last Measure (day 15)	-0.16	0.06	0.01*	-0.07	0.07	0.32	-0.03	0.05	0.55
Vowel /a/	Reference Category			Reference Category			Reference Category		
Vowel /i/	-0.36	0.06	0.00*	-0.32	0.07	0.00*	0.16	0.05	0.00*
Sleep Quality Score = 2	Reference Category			Reference Category			Reference Category		
Sleep Quality Score = 3	0.03	0.12	0.79	0.01	0.13	0.94	-0.04	0.09	0.69
Sleep Quality Score = 4	0.04	0.12	0.74	0.24	0.13	0.06	-0.13	0.09	0.15
Sleep Quality Score = 5	-0.07	0.14	0.59	0.01	0.15	0.95	-0.07	0.10	0.51

*p-value ≤ 0.05

Table 5. Relationship between jitter (%), shimmer (dB), and HNR (dB) with sleep duration.

Parameter	Jitter (%)			Shimmer (dB)			HNR (dB)		
	Beta	SE	p-value	Beta	SE	p-value	Beta	SE	p-value
Intercept	-1.38	0.20	0.00	-1.95	0.23	0.00	3.40	0.15	0.00
First Measure (day 1)	Reference Category			Reference Category			Reference Category		
Last Measure (day 15)	-0.17	0.06	0.01*	-0.06	0.07	0.43	-0.03	0.05	0.49
Vowel /a/	Reference Category			Reference Category			Reference Category		
Vowel /i/	-0.38	0.06	0.00*	-0.33	0.07	0.00*	0.16	0.05	0.00*
Sleep duration	0.10	0.03	0.00*	0.10	0.03	0.00*	-0.05	0.02	0.02*

*p-value ≤ 0.05

DISCUSSION

This study aimed to determine the association between sleep quality and duration with three acoustic parameters that provide information about voice harmonicity and quality (jitter, shimmer, and Harmonics-to-Noise Ratio (HNR)) among Colombian college professors. Three main results were found. First, teachers with good sleep quality (score=4) had significantly lower HNR values compared with the worst sleep quality (score=1). Second, sleep quality was not statistically associated with any of the acoustic parameters. However, Jitter (%) was significantly lower at the end of the follow-up (B= -0.16) compared with the first measure, and during the production of the vowel /i/ (B= -0.36) contrasted with the vowel /a/. Shimmer (dB) decreased significantly during the production of the vowel /i/ (B= -0.32) compared with the vowel /a/; whereas HNR (dB) increased during the production of the vowel /i/ (B= 0.16). Third, there is an increased jitter (B= 0.10), shimmer (B= 0.10), and decreased HNR (B= -0.05) when the sleep duration increases.

Concerning the first result, although the best quality score (=5) was not statistically different compared to worst sleep quality (=1), good sleep quality (=4) was statistically lower compared to worst quality. Traditionally, low HNR values are associated with pathological voices (Narasimhan & Rashmi, 2022; Uloza et al., 2015), including hoarseness, roughness, and breathiness (de Krom, 1995), resulting in a higher noise level in the spectrum (Mohseni & Sandoughdar, 2016). HNR values are usually higher in normal voices than in pathological voices, since normal voices are more sonorant than pathological ones (Asiaee et al., 2022). Also, this measure may provide better clinically relevant information than jitter and shimmer, but only under control voice sound pressure levels effects (Brockmann-Bauser et al., 2018). Therefore, our results suggest that teachers with good sleep quality (self-perceived) may have significantly worst voice harmonicity. A possible explanation for this result is that a high level of energy achieved through better sleep quality may cause lower vocal effort self-monitoring, which may reduce voice quality. Previous studies (Norlander et al., 2005; Torsvall & Åkerstedt, 1980) have suggested that a high level of energy, optimism, and sleep quality are positively intercorrelated. However, a lower HNR usually is related to more pathological voices (Montero Benavides et al., 2014; Müller et al., 2020). Thus, it seems likely that after having a good night´s sleep, professors wake up feeling more energized, making them lower their vocal effort self-monitoring and underestimating their voice use throughout the day. This behavior sustained over a long period could certainly decrease the harmonicity of the voice (Shama et al., 2006).

On the other hand, another aspect that influences a decrease in the harmonicity of the voice is the column of air used for voice production, which cannot be subjectively measurable by teachers. Reflecting this association between harmonicity and airflow, previous research has reported that teachers who register low values of the HNR reported having a better quality of sleep (Teixeira & Gonçalves, 2014). Therefore, another explanation is related to the effect of sleep quality on air control for speech. Future research is advised to explore this aspect.

In conclusion, a high level of energy achieved through better sleep quality may make speakers get different conditions of vibratory characteristics of the vocal folds, as well as decrease vocal effort self-monitoring, which may be associated with decreased harmonicity.

Regarding the second result, none of the voice acoustic parameters were statistically associated with sleep quality when the model was controlled by the day of the measure and type of vowel. However, in the multivariate model, jitter and shimmer were statistically lower when calculated in the vowel /i/ compared with the vowel /a/; whereas HNR (dB) increased during the production of the vowel /i/ (B= 0.16). One possible explanation is that the high tongue position when producing high vowels (/i/ and /u/) contributes to an increased rate of glottal pulses; in contrast, when the tongue moves inferiorly in the mouth while producing the /a/, the hyoid bone does posteriorly; as a result, laryngeal tension decreases (Akif Kiliç et al., 2004; Lin et al., 2000). Our results agree with previous research that reported a lower shimmer in the production of the vowel /i/ compared to the vowel /a/ (Gelfer, 1995; Milenkovic, 1987). However, other studies found no differences between the type of vowel (Brockmann et al., 2011; Orlikoff, 1995). Although several studies have explored the relationship between vowel articulation (or type of vowel) and voice, the opposite results show that further analysis considering intermediate variables that influence this association is needed (Brockmann et al., 2011).

Concerning the third result, we found an increased jitter (B= 0.10), shimmer (B= 0.10), and decreased HNR (B= -0.05) when the sleep duration increased. One explanation is the changes in the distribution of fluids in the mucous membranes of the head and neck structures during nocturnal sleep, where the vocal folds slightly swell while sleeping, affecting vocal fold vibratory characteristics (Icht et al., 2018).

Sivasankar & Leydon (2010) mentioned that long periods of sleep may cause vocal folds' surface dehydration, causing higher viscosity and vibrating with more subglottal pressure, which may cause lower values of HNR. Moreover, Cho et al. (2017) reported an inverse relationship between voice production and both short and long sleep duration. Since long sleep duration may mediate metabolic, endocrine, inflammatory, or immune outcomes linked to the risk of respiratory syndromes (Nieto et al., 2012; Parish, 2009), the impact of long sleep duration on voice may be associated with inflammatory and immunologically mediated responses that can affect the respiratory system with subsequent vocal alterations (Hamdan et al., 2020). Therefore, it is likely that the response of the larynx may induce voice disorders after a long sleep duration (Cho et al., 2017).

This study has some limitations. First, sleep quality was determined by self-reports, which implies high subjectivity of the response. However, considering that sleep quality is a perception, self-report was a valid approximation to measure this aspect. Second, sleep quantity was determined using the mobile App, but this value may be biased because teachers could activate the app but not fall asleep immediately. However, due to budget restrictions more objective measures (such as polysomnography) were not available. Third, this study reported the association between quantity and quality of sleep with measures of voice perturbation; however, being voice a multifactorial aspect, these changes may be associated with other factors not measured in this research.

In conclusion, contrary to what was expected, teachers with good self-perceived sleep quality and shorter sleep duration had lower voice harmonicity compared to their colleagues with bad sleep quality and shorter sleep duration, which may be associated with the physiological and emotional effects of sleep on voice production. However, considering the multifactorial nature of voice production and the exploratory nature of the present study, a statistically significant association between sleep quality and duration with voice harmonicity does not necessarily mean that sleep induces voice disorders. It only means that sleep is a variable that we, as clinicians and researchers, may want to consider when analyzing/treating individuals with voice issues. Moreover, our results highlight the importance of designing more holistic interventions for specific populations, for instance, occupational voice users.

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