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APPLICATION OF BAYESIAN NETWORKS AS A STRATEGIC TOOL TO ASSESS AND FOLLOW PATIENTS WITH HOSPITAL DISCHARGE OF LEPROSY: A CROSS-SECTIONAL OBSERVATIONAL STUDY

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ABSTRACT

Introduction: In leprosy, for the study of disabilities, functional limitation (physical deformities), activity limitation, and social participation are considered, such disabilities can be measured respectively by the simplified neurological assessment of eyes, hands, and feet (EHF) and by the scales SALSA and Social Participation. This process can be facilitated with the support of artificial intelligence (AI), specifically by Bayesian networks (BN). ***Objective:*** To present and discuss the relative results of two modules of SADHANS, SalsaS, which presents the conditions of the evolution of functional limitation, and the SpartS, which presents the evolution of the restriction to social participation in patients after discharge from leprosy. ***Methods:*** This work described a cross-sectional study to model (STROBE rules) a support system for the identification of the development of disabilities in leprosy (SADHANS), especially concerning activity limitation (SalsaS) and social participation (SpartS).Its performance was approved by the Research Ethics Committee of the Pontifical Catholic University of Paraná – PUCPR, opinion 0004697/11. ***Results and Conclusion:*** The SalsaS and SpartS modules were developed to help identify the probabilities that a patient discharged from leprosy has developed disabilities related to activity limitation and social participation. The system is essential to help health services to care for patients during treatment and after the therapeutic cure of leprosy, as it directly assists in the prevention of disabilities, presenting what should be monitored. The main contribution of the modules is in offering the probabilities that involve the development of new and the evolution of disabilities, according to the characteristics of the patient. It is a system modeled from Bayesian networks, which indicates the elements that must be monitored to avoid and/or control the evolution of disabilities. According to the research results, it appears that the disability prevention policies developed by the health system must overcome the discussion and practices aimed at physical deformities, offering answers to problems also related to social participation and limitation of activities. Finally, it is considered that the modules are ready to be applied in the health system for the care of patients after leprosy discharge.

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INTRODUCTION

Leprosy is an infectious disease caused by the bacillus *Mycobacterium leprae* (Bernardes Filho, 2022; Pitta, 2022; Tiago, 2021). The condition compromises the neural fibers, producing a decrease or loss of sensitivity, skin lubrication, and muscle strength, leading to the development of physical disabilities (Glennie, 2021; Alemu Belachew, 2019; Rodrigues, 2000; BRASIL, 2008). In the early 1980s, the World Health Organization (WHO) introduced multidrug therapy (MDT), a treatment that eliminates the bacilli, interrupts the development of leprosy, and ends the chain of transmission, thus promoting therapeutic cure (WHO, 1982).

Considering that neural damage is irreversible, disabilities can develop even after treatment. Besides, disabilities, in a generic way, are physical or emotional changes that limit daily activities or social coexistence, according to age, socioeconomic reality, and/or education (Gonçalves, 1979). In leprosy, for the study of disabilities, functional limitation (physical deformities), activity limitation, and social participationare considered, such disabilities can be measured respectively by the simplified neurological assessment of eyes, hands, and feet (EHF) and by the scales SALSA and Social Participation (Amiralian, 2000). Moreover, the simplified EHF neurological assessment is an instrument used to measure functional limitation, it measures degrees of disability based on the assessment of the eyes, hands, and feet, considering the right and left sides. Grades from 0 to 2 are measured for each member and the total EHF grade can vary from 0 to 12. The higher the grade, the more disabilities the individual has. In this sense, the SALSA Scale assesses the development of activity limitations both in areas where disabilities have already developed and in development. It is an instrument of rapid application, according to the validation: 10 minutes. The final score of the scale can vary from 0 to 80, and the higher the score, the greater the activity limitation (Van Brakel, 1999). The Social Participation Scale is used to identify the restriction on social participation of people affected by leprosy. The scale covers eight of the nine main areas of life defined in the International Classification of Functioning (ICF). The scale score ranges from 0 to 90; the higher the score, the greater the restriction to social participation (Van Brakel, 1999).

Also, several surveys are carried out to collect data that identify the patient's condition and, thus, monitor the development of disabilities (Van Brakel, 1999; Stremel, 2009; BaBNosa, 2009). One way to analyze these clinical data is the application of conditional probability analysis methods (Koehler, 1998). Such probabilities, according to the treatment of information, present evidence that can be used by medicine. Besides, evidence-based medicine suggests that decisions are made based on clearly stated probabilities. This implies finding, understanding, and applying the results of studies to specific cases of patients. This process can be facilitated with the support of artificial intelligence (AI) (Castagnari, 2004), specifically by Bayesian networks (BN), which correlate the data and present the conditional probabilities between them. The use of technological resources facilitates and enables different ways of analyzing the collected data, offering information that can be used in preventive practices. There are studies on disability prevention regarding new cases of leprosy, focusing on discharge and post-discharge. However, Van Brakel et al. (1999) and Rodrigues et al. (2000) state that research indicates the probabilities of a patient treatment developing some specific type of disability, its evolution in a few years, and the aspects that should be monitored, are incipient and restricted. In addition, the characteristics related to the reactional state, which can generate disabilities after a therapeutic cure, are not yet fully defined and described. Thus, the simplified EHF neurological assessment and the SALSA and Social Participation scales measure disabilities, but there are no data in them that indicate whether these are due to neural damage before therapeutic cure or whether they are related to the reactional state. Furthermore, Brazil detects, on average, 47,000 new cases every year, and about 12,700 (23%) have neural damage and some type of disability at the time of diagnosis, which may continue to develop (BRASIL, 2000). Early diagnosis and treatment are the only sure way to prevent disabilities (BaBNosa, 2008; Norsys, 2009). The present study was motivated by the need to know the process of development and evolution of disabilities after leprosy discharge so that health professionals can intervene properly with preventive techniques. The study of the variables collected by EHF, SALSA, and Participation with the help of BN (conditional probability) results in trends in the evolution of disabilities in leprosy. To understand this evolution, a system called SADHANS (Girardi, 2011) was developed, consisting of 6 modules, which analyzes the evolution of disabilities with data from patients discharged more than 20 years ago and patients recently discharged. Therefore, the present study aimed to present and discuss the relative results of two modules of SADHANS, SalsaS, which presents the conditions of the evolution of functional limitation, and the SpartS, which presents the evolution of the restriction to social participation in patients after discharge from leprosy.

METHODS

Study Design: This study followed a prospective observational cross-sectional model, following the rules of clinical research of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology), available at: https://www.strobe-statement.org/.This work described a cross-sectional study to model a support system for the identification of the development of disabilities in leprosy (SADHANS), especially concerning activity limitation (SalsaS) and social participation (SpartS).

Ethical Approval: The present research fully complied with the provisions of Resolution 196/96 of the National Health Council (20). Its performance was approved by the Research Ethics Committee of the Pontifical Catholic University of Paraná – PUCPR, opinion 0004697/11. Information that identifies patients in the databases has not been used and will not be published.

Development of Modules and System: The modules were developed in four stages:

- **Step 1 -** Selection of variables;
- **Stage 2 -** Development of SalsaS and SpartS modules;
- **Stage 3 -** Module tests;
- **Step 4 -** Study of data from recently discharged patients.

For the development of the system, two databases were used, built from research such as the application of EHF, SALSA, and Social Participation, as shown below:

- ASYLUM CITIZENS LEFT FROM THE SANITARY DERMATOLOGY HOSPITAL OF PARANÁ: WHO ARE THEY AND HOW ARE THEY? (18), in this work called remote discharge base. CEHF consists of 84 (eighty-four) patients who were cured and discharged from leprosy before 1984, residing in the Municipality of Piraquara, State of Paraná, and who were admitted to the Hospital Colônia São Roque, currently the Hospital of Sanitary Dermatology of Paraná;

- POST DISCHARGE IN LEVERAGE: VIEWS ON POLICIES, HEALTH CARE NETWORK, LIMITATION OF ACTIVITIES, AND SOCIAL PARTICIPATION OF AFFECTED PEOPLE (13), here referred to as the recent increase base. CEHF consists of 304 individuals, with cure and discharge from leprosy after 2006, living in Sobral and Fortaleza, Ceará.

Step 1 - Selection of Variables: For the development of the modules, the variables related to the analysis of disabilities in leprosy were selected based on remote discharge. The variables were chosen among the information from the EHF, SALSA, and Social Participation instruments. Each EHF variable assigns values from 0 to 2. The assignment of value 0 indicates the existence of the deformity, but such deformity has no functional impact, therefore variables with value 0 do not represent an impact on the final graduation. Deformities with mild functional impact are graded 1. Finally, deformities with severe functional impact are graded 2. The variables were selected to develop modules that correlate the elements of the EHF, SALSA, and Social Participation instruments.

Step 2 - Preparation of SalsaS and SpartS Modules: The Modules were developed independently to measure, in an isolated way, the probabilistic aspects linked to the development of disabilities in leprosy and the existing correlations between the development of physical disabilities, daily activities, and social participation. Each of the modules is supported by a BN structured by the induction method. The modules deal with the cause and effect relationships between the variables that identify disabilities in a given segment.

Table 1 presents the modules developed, the expected contribution of each one, and the origin of the variables used. For the structuring of the networks that make up the SpartS and SalsaS modules, 70% (59) of the cases from the remote discharge base were used and the remaining 30% (25), randomly selected, were used to test the specificity and sensitivity of the modules.

Table 1. SADHANS – Modules.

Modules	Expected Contribution	Origin of Variables
SalsaS	Identify the probabilities of developing activity limitation due to physical disabilities.	EHF SALSA
SpartS	Identify the probabilities of development restriction to social participation due to physical disabilities	EHF Social Participation

The 30% (25), selected without any bias, are nothing less than the last 25 records in the sequence of data from the remote discharge base. It was decided to develop the networks with 70% (59) of the cases from the remote discharge base and, later, carry out a study with the cases from the recent discharge base (304 individuals), to verify the probability that the individuals from the base of recent discharge have to develop the analyzed disabilities. The networks were built using the Netica shell, a specific tool to model BN (Norsys, 2009), developed by Norsys Software Corporation. The construction of the networks followed the BN construction method presented by the Norsys Software Corporation manual (Norsys, 2009). Thus, the elements (nodes) understood as conditioned were placed in the center and the arcs directed towards the conditioning elements (nodes) depart from it. It is important to point out that a character can have several conditions, which were considered in the elaboration of the modules.

Step 3 - Testing The Modules: The cases that match the selected sample were tested, one by one, in the modules to assess the sensitivity and specificity of each module. In a test to detect characteristics, with possibilities of positive and negative results, precision errors occur, being able to identify as positive a result that should be negative. The closer to 1, the greater the strength of the test. Tests with indices close to 1 correctly identify those that have a certain characteristic and those that do not. After studying the data of each individual in the modules, the true positives, false negatives, false positives, and true negatives were identified, and statistical calculations were performed to determine the sensitivity and specificity of the probabilities involving each module. To facilitate the development of the SalsaS and SpartS modules, the final scores of the SALSA and Social Participation scales were used in 5 ranges (Table 2). The division of scores on the Social Participation scale was based on the structure already validated (7). As the SALSA Scale does not have stratification of the final score, a distribution of the final score in 16-point fractions was developed, following the cut-off lines defined for the Social Participation Scale. Table 2 shows the stratification of the final score of the SALSA and Social Participation scales and the division into groups.

Table 2. Distribution of SALSA and Social Participation scale scores and division of groups

SCALE	FINAL SCORE STRATIFICATION	Group Division
SALSA	0-16 - No significant limitations 17-32 - Slight limitation 33-48 - Moderate limitation 49-64 - Great limitation 65-80 - Extreme limitation	0-32 – None to slight limitation (a) 33-80 – Moderate to extreme limitation (b)
SOCIAL participation	0-12 - No significant restrictions 13-22 - Slight restriction 23-32 - Moderate restriction 33-52 - Great restriction 53-90 - Extreme restriction	0-22 – None to slight restriction (a) 23-90 – Moderate to extreme restriction (b)

To identify the sensitivity and specificity of the SalsaS and SpartS modules, a probability of ≥ 50% was determined as the response range of the systems. A cutoff of ≥ 50% was considered because there were only two possible responses, none being mild or moderate to extreme. Thus, it was sufficient for the module to assign a probability greater than 50% to one of the items, which was assumed as the final answer. Table 3 shows the standards adopted for the statistical calculations of the modules.

Table 3. Cutting assignments - SalsaS and SpartS

Final score Salsa scale and social participation Parsleys / sparts	Cut-line	Real Final score Salsa scale and social participation	Attribution
a) none take it	≥ 50%	a) none take it	True Positive
a) none take it	≥ 50%	b) moderate to extreme	False Positive
b) moderate to extreme	≥ 50%	b) moderate to extreme	True Negative
b) moderate to extreme	≥ 50%	a) none take it	False Negative

After defining the probabilistic cutoff and studying each of the cases of remote discharge, the results were applied to the sensitivity and specificity formulas, and the validity of the modules was obtained.

Step 4 - Study of Data from Recently Discharged Patients: The data that form the basis of the recent increase was analyzed in the developed modules. The analysis indicated the probabilities involving the evolution and development of disabilities in patients with recent discharge. The study also presents what should be monitored to reduce the chances of developing disabilities.

RESULTS

SalsaS Module: SalsaS present the relationships between acquired physical deformities and the limitation of patients' activities. Figure 1 shows the structuring of the SalsaS module.

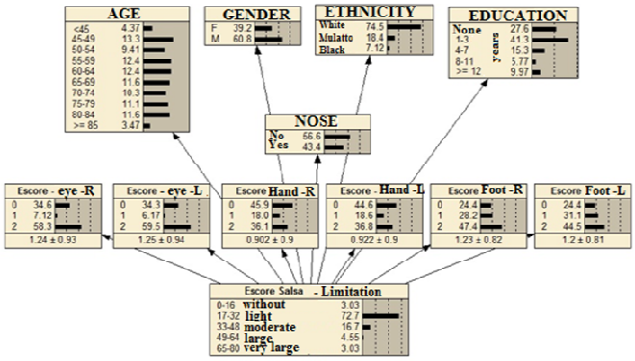

Figure 1. SalsaS Module

SalsaS showed a high capacity to identify individuals who have a low functional limitation, with sensitivity 1. However, the system does not have much strength to identify those who tend to develop high functional limitations, since its specificity was 0.47. The remote discharge baseline test showed that women tend to develop less activity limitation, in any age group and with the same EHF rating as men.With the results obtained, the simple average was calculated, according to the age groups, and it was found that women with an EHF 2 degree have, on average, a 72.1% of chance of developing a SALSA score at a moderate and severe activity level. . Men with an EHF 2 grade have, on average, an 82.8% chance of having a SALSA score at moderate levels and severe activity limitation. In the study of the remote discharge base, presented in Table 4, it is clear that there is no good correlation between the EHF and SALSA grades because even with the increase in the EHF grade, individuals with EHF 12 tend to have a SALSA score between none of them. limitation and slight limitation.

Table 4. SalsaS – Correlation between EHF and SALSA – remote high base

EHF	SALSA
0	80.7% (None - Slight Limitation)
1	87.8% (None - Slight Limitation)
2	84.5% (None - Slight Limitation)
3	83.8% (None - Slight Limitation)
4	81.5% (None - Slight Limitation)
5	68.2% (None - Slight Limitation)
6	83.8% (None - Slight Limitation)
7	76.2% (None - Slight Limitation)
8	79.2% (None - Slight Limitation)
9	61.8% (None - Slight Limitation)
10	67.2% (None - Slight Limitation)
11	65.1% (None - Slight Limitation)
12	57.9% (None - Slight Limitation)

The recent SalsaS database study, on the other hand, revealed a correlation between SALSA and the simplified EHF neurological assessment, so the higher the EHF grade, the lower the possibility for the individual to develop no or slight activity limitation. The total EHF rating of individuals with a recent discharge base ranges from 0 to 9, there are no individuals with an EHF rating greater than 9. The SALSA score, on the same base, varies from 17 to 65. The relationships between EHF ratings and the SALSA score can be seen in **Table 5.**

Table 5. SalsaS – Correlation between EHF and SALSA – recent high base

EHF	SALSA
0	92.4% (None and Slight Limitation)
1	92.1% (None and Slight Limitation)
2	88.3% (None and Slight Limitation)
3	90.9% (None and Slight Limitation)
4	78.7% (None and Slight Limitation)
5	76.8% (None and Slight Limitation)
6	77.8% (None and Slight Limitation)
7	76.8% (None and Slight Limitation)
8	69.5% (None and Slight Limitation)
9	57.4% (None and Slight Limitation)

If the correlation between the EHF rating and the SALSA score per segment is considered, it is noted that the most significant impact is on the EHF eye rating. Any individual, in any age group, will have the possibility of increasing the SALSA score as a result of ocular deformities, especially corneal anesthesia. Thus, EHF 1 grade due to corneal anesthesia has more impact on the SALSA score than any deformity in another segment. An individual, based on the simple average between age groups, with Korean anesthesia in either eye, has, on average, a 68.38% chance of developing moderate to severe activity limitation.

SpartS module: The SpartS, shown in Figure 2, shows the possible relationships between physical deformities and the social participation of individuals after leprosy discharge Figure 2. SpartS module. The study of data from the remote discharge database showed that there is no direct relationship between physical deformity, as measured by the EHF rating, and social participation. Network analysis shows that 88.9% of individuals are between 0-12 (no restrictions) or 13-22 (slight restriction on social participation). The system has high sensitivity (1) and low specificity (0.14). The analysis showed that the impact on social participation is not directly linked to the development of physical disabilities.

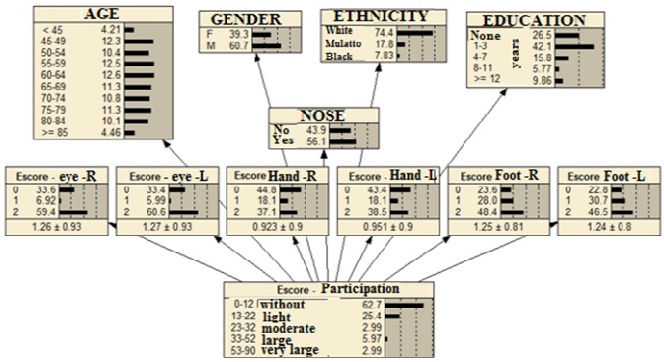

Figure 2. SpartS module

Because there is no direct relationship between the results of the EHF graduation and the results of the Social Participation scale scores. Even with a total EHF rating of 12, individuals have low restrictions on social participation. However, in the study of a demographic variable related to color (white / mulatto / black), the most significant trends in social participation are presented. Such variables direct the network to a score, higher or lower, according to individual characteristics related to color. Considering that the Social Participation scale measures subjective criteria, individuals by age group and with the same characteristics were considered for the study, only differentiating the criterion color, white and black. The study shows, after a simple average of the results by age groups, that white patients have, on average, a 65.16% chance of, even with total EHF graduation of 12, developing a social participation score of 0-12 (no restrictions). On the other hand, black patients, with the same conditions as whites, have, on average, a 58.67% chance of developing severe restrictions on social participation (35-52). The analysis of the recent discharge base shows patterns linked to nasal deformities. For young patients, under 44 years of age, with low limitation to social participation (0-12 no restrictions) who have a total EHF score of 0 and nasal deformities, the system tends to increase the restriction to social participation. In other age groups, the system tends to maintain the social limitation score.

DISCUSSION

When analyzing the probabilities involving the development of activity limitation, the system identified that women, with the same disabilities as men and in the same age groups, have a greater tendency to adapt to daily activities, regardless of functional limitations. In the literature, especially studies published by the World Health Organization, it is known that women with disabilities suffer more discrimination than men, especially concerning insertion in the world of work and social relationships (21,22). However, the study shows that women have an easier time adapting to limitations, therefore having an easier time working. Here arises the need for a more in-depth study, considering gender issues, which involves adaptations to the daily activities of patients with disabilities. Martins and Caponi (23) deal with the adaptations of women affected by leprosy but do not perform a comparison with men. Barbosa (16) argues that there is a correlation between the EHF rating and the SALSA Scale, so that the higher the EHF rating, the higher the SALSA score. However, the study of the bases in SalsaS shows that there is a relationship when it comes to recent highs. The recent discharge base study confirms BaBNosa's statement (16), however, the remote base study does not show a correlation between the EHF grade and the SALSA score, because, even with a high value for the EHF grade, individuals maintain a low score PARSLEY. This indicates that after years of living with disabilities, individuals tend to adapt, learning to live with deformities. In the study of the bases, the variables related to the eye were identified as elements with the greatest impact on activity limitation. Individuals with ocular deformity, especially with corneal anesthesia, are more likely to develop activity limitations than other individuals (24). This data becomes interesting if the issues involving SALSA are analyzed. Of the twenty questions on the scale, only the first is directly related to

the eyes "can you see?" (7) the others are related to other segments. With this information, it is noted that corneal anesthesia not only leads to the evolution of ocular disabilities but has a strong impact on the limitation of activities.

In the study developed at SpartS, it was concluded that there is no direct relationship between physical deformities and social participation. These results, in a way, disagree with the statements of Maciel (Macie, 2004), as there were no signs of great restriction to the social participation of patients as a result of disabilities. But it can be corroborated by Dias and Pedrazzani (26) and Minuzzo (27), as they claim that the difficulties in social participation are linked to the stigma that the disease historically carries. Perhaps, in SpartS it is not possible to identify the direct relationship between disability and social participation, as there is a tendency for social adaptation over time (12). In this way, the impact of restricting social participation would be stronger at the time of diagnosis, with adaptation naturally emerging over time (Minuzzo, 2008). Two factors have a relevant impact on social participation, color, and nasal deficiencies. As for color, even with the advance of affirmative policies, the differences between blacks and whites are somehow maintained.

Blacks in Brazil still feel excluded in terms of social participation (Guimarães, 2004). However, for an accurate analysis of this study, it is important to consider that the remote base is based on information from patients whose vast majority are white, living in the state of Paraná, southern Brazil, a factor that may have determined a bias towards the system. According to a study published in 2009, the white population, of European origin, predominates in southern Brazil, 81.50% of the total, the remainder is divided between African descendants (9.3%) and Amerindians (9.2%) (Poiares, 2009). Considering that the Social Participation scale was not developed exclusively for leprosy patients, the skin color factor can be a determinant in the relationship with social participation, regardless of leprosy. So, it is not possible to infer whether the restriction on the social participation of blacks, in this case, is due to leprosy or other issues related to social reality. Regarding nasal deformities, the system shows that their presence in patients under 45 years of age determines a relevant impact on social participation. In a specific study on facial deformities resulting from leprosy, we read about nasal deformities: "such alteration manifested itself in the psycho-emotional scope as shame, mixed with sadness, which culminated in failed attempts to hide the facial deformity" (BaBNosa, 2007; Glynn, 2001). Even dealing with the various facial deformities, the study places nasal deformities as the most relevant in terms of psychosocial limitations (BaBNosa, 2007; Glynn, 2001). In a way, considering issues related to appearance, it was expected that patients with nasal deformities would have greater restrictions on social participation.

CONCLUSION

The SalsaS and SpartS modules were developed to help identify the probabilities that a patient discharged from leprosy has developed disabilities related to activity limitation and social participation. The system is essential to help health services to care for patients during treatment and after the therapeutic cure of leprosy, as it directly assists in the prevention of disabilities, presenting what should be monitored. The main contribution of the modules is in offering the probabilities that involve the development of new and the evolution of disabilities, according to the characteristics of the patient. It is a system modeled from Bayesian networks, which indicates the elements that must be monitored to avoid and/or control the evolution of disabilities. According to the research results, it appears that the disability prevention policies developed by the health system must overcome the discussion and practices aimed at physical deformities, offering answers to problems also related to social participation and limitation of activities. Finally, it is considered that the modules are ready to be applied in the health system for the care of patients after leprosy discharge.

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ETHICS APPROVAL

This research fully complies with the provisions of Resolution 196/96 of the National Health Council. Its performance was approved by the Research Ethics Committee of the Pontifical Catholic University of Paraná – PUCPR, opinion 0004697/11. Information that identifies patients in the databases has not been used and will not be published.

***Informed Consent*:** The patients signed the informed consent form.

Data Sharing Statement: No additional data are available.

Conflict Of Interest: The authors declare no conflict of interest.

Similarity Check: It was applied by Ithenticate[@].

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