Predictors of low perceptual-motor skills in children at 4-5 years of age

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Abstract

Objectives: the purpose of this study was to evaluate the predictors of low perceptual-motor skills in children at preschool age.

Methods: this is a cross-sectional study nested in a birth cohort involving mother-child pairs. The children's perceptual-motor skills were assessed individually in their homes when they were 4-5 years old using the Pre-Literacy Skills and Knowledge Test (THCP®), a validated Brazilian instrument. Logistic regression analysis was used to estimate the association between cognitive perceptual-motor skills and potential maternal and child risk factors.

Results: of the 199 children included in the study, 53.8% were boys, 90.8% attended school, and 91.1% were enrolled in a public school. Among the children, 114 (57.3%), 41 (20.6%) and 44 (22.1%) had low, moderate and high perceptual-motor skills, respectively. Multivariate logistic regression analysis revealed greater odds of children at preschool age having low perceptual motor skills for boys (OR=2.10; CI95%= 1.14-3.88), children who did not attend school (OR=4.61; CI95%= 1.21-17.49), and those with a household income <5 minimum wages (MW) (OR=4.28; CI95%= 1.49-12.26).

Conclusions: our study showed that male gender, not attending school and a monthly household income <5 MW were predictors of low perceptual-motor skills in children at 4-5 years of age

Key words *Perceptual-motor skill, Cognitive development, Cognitive skill, Pre-school age, Motor skill*

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Introduction

Child cognitive development is complex, is influenced by multiple factors,[1] and comprises different cognitive skills such as attention, memory, execution/expression of information, and perceptual-motor skills.[2] Motor skills comprises motor proficiency, which consists of a set of motor skills that describe an individual's overall motor condition.[3] Perceptual-motor skills refer to the recognition and interpretation of sensory stimuli, followed by a response in the form of movement[2] and also a set of skills that involve coordination and sequencing of movements to achieve a particular goal.[4]

Motor development promotes and requires improvements in behavioral flexibility because new motor skills provide new opportunities for action but also require new solutions.[5] This area of functioning includes balance, fine and gross motor movements, speed, strength, agility, and manual dexterity.[4] In general, individuals with low perceptual-motor skills have low academic performance, writing problems, and difficulty in performing professions that require high perceptual-motor skills.[6]

Perceptual-motor skills cannot be understood as independent processes and dissociated from the environment[7] since they are associated with several factors such as personality, weight status, feeding practice, physical development,[8] cognitive, affective or motor disorders, socioeconomic characteristics, and motor stimulation in the family environment and at school.[6,9-12] School is also crucial for the child's cognitive development since the latter occurs during an important period of the child's development.[6,9] Identifying the factors that affect perceptual-motor skills at the beginning of learning not only contributes to the improvement of the child's performance in the classroom,[9] but also to his/her professional performance as an adult.

Within this context, the aim of this study was to examine the association of biological, socioeconomic and demographic characteristics of mothers and their children with the child's perceptual-motor skills four years after delivery. The results of this study will be useful to increase our understanding of children's perceptual-motor skills at preschool age.

Methods

This is a cross-sectional study nested within the Predictors of Maternal and Infant Excess Body Weight - PREDI Study, a birth cohort study conducted at the Darcy Vargas Maternity Hospital in Joinville, the largest city in the State of Santa Catarina, Brazil. The PREDI Study was designed to examine the determinants and consequences of large birth size and child/maternal excess body weight in mothers and their children over the years.

The present study used data collected from adult women and their children at baseline (2012, when the children were born) and at 2 years and 4 years of follow-up (2014 and 2016, respectively). Details of the recruitment process at baseline have been described previously.[13,14] Subsequently, all women over the age of 18 years who gave birth to a full-term singleton (between 37 and 42 weeks of gestation) were invited to participate in the study with their newborns in January-February 2012 (baseline). The baseline exclusion criteria included pre-eclampsia, presence of an infectious contagious disease (AIDS, hepatitis, syphilis, and toxoplasmosis), birth defects, and plans of giving up the newborn for adoption immediately after delivery. Of the 529 eligible pairs (mothers and infants), 58 did not meet the study criteria and 36 were not considered for other reasons, totaling 435 mother-infant pairs who participated in the baseline assessment in 2012 (Figure 1).

A trained health professional collected the data at baseline and all follow-ups, which included anthropometric assessment and demographic, biological and socioeconomic information. In all follow-ups, data were collected individually in a private room of the family's home using a previously tested structured questionnaire.

Baseline, 2012

We used only the newborn's gender from the baseline period, which was obtained from the hospital records in 2012 when the cohort study was started.

First follow-up, 2013-2014

The children's weight was measured with a pediatric digital portable scale (Model BY20, Beurer®) to the nearest 10 g. Length was measured with a pediatric anthropometric ruler (Model Wood, WCS®) to the nearest 0.1 cm. The children's nutritional status was classified into two categories based on the 2006 World Health Organization (WHO) body mass index (BMI)-for-age growth standards: $\leq 85^{th}$ percentile, $>85^{th}$ and $<97^{th}$ percentile, and $\geq 97^{th}$ percentile.[15] All anthropometric measurements were performed in duplicate in the first and second assessment and the mean of the two measurements was used for analysis.

Duration of breast-feeding (in months) was self-reported by the mothers. Breast-feeding was classified according to the WHO indicators for assessing

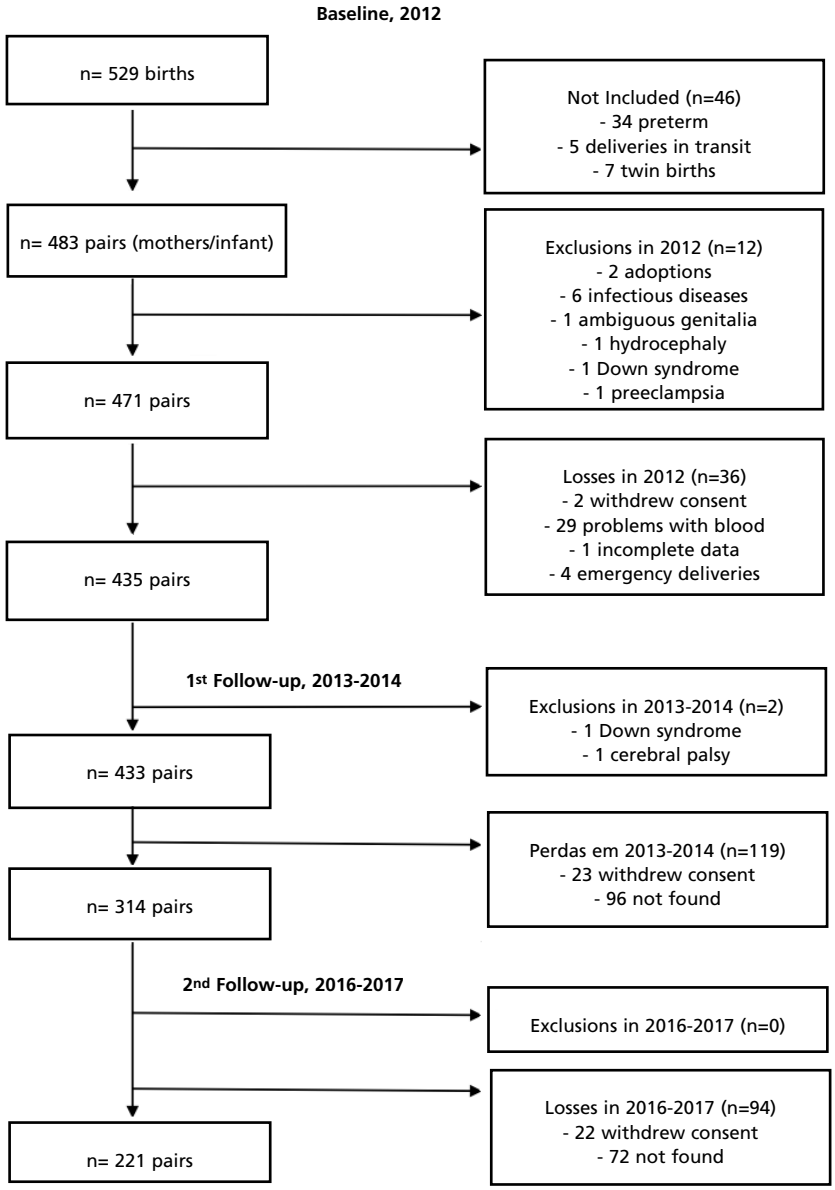
infant and young child feeding practices.[16] For the present study, all non-exclusive breast-feeding categories were combined into a single non-exclusive breast-feeding category.[16,17]

Second follow-up, 2016-2017

In the 2nd follow-up, the child's perceptual-motor skills were collected individually using the Teste de Habilidades e Conhecimento Pré-Alfabetização (Pre-Literacy Skills and Knowledge Test, THCP® in the Portuguese acronym), a validated Brazilian instrument.[18] In addition to perceptual-motor skills, the test evaluates the most important cognitive and motor skills of pre-literacy development in children aged 4 to 7 years, including memory, language skills, quantitative thinking, and focused attention.[18] For the present study, only the children's perceptual-motor skills were considered in the data analysis. These skills include the ability 1) to perform fine and precise finger movements in response to a visual stimulus; 2) to discriminate stimuli that are perceived visually, and 3) to perceive positions in space. The test was applied by a psychologist in a private room of the participant's home, usually in the

Figure 1

Flow chart of participants through the recruitment process, Joinville, Brazil.



presence of the mother. Prior to application of the test, the mother was informed of how the test would be conducted and the importance of discretion during its execution. After the material was shown to the child, once the child became receptive, the researcher started the test. The average time of test application was 25 min. The answer to each question was converted into a score according to the child's age. The cognitive perceptual-motor score was calculated considering age and the number of correct answers obtained by the child throughout the test. The maximum score to be achieved was 30 points.

The children's perceptual-motor performance was classified into three categories according to age and the total score obtained: low (0-11), moderate (12-15), and high (≥16) for children aged 4 years; low (0-16), moderate (17-19), and high (≥20) for children aged ≥5 years. For the purpose of the present study, moderate and high scores were combined into a single category.

The data were analyzed using the IBM SPSS Statistics 22.0 software package. The χ^2 test was used to compare the frequency of categorical variables according to the child's cognitive perceptual-motor skills (low and moderate/high). Maternal age (<30, 30–40, and ≥40 years old) and monthly household income (<3, 3–5, and ≥5 minimum wages - MW) were classified according to the criteria of the Brazilian Institute of Geography and Statistics.[19] Maternal education (<9 years for women who completed primary school; 9–12 years for those who completed high school; ≥12 years for those who started/finished undergraduate courses) was classified according to the 1996 Education Law (*Lei das Diretrizes e Bases da Educação Nacional*).[20]

The Mann-Whitney U test was used to compare the median and interquartile range (IQR) of variables with non-normal distribution (perceptual-motor score, child's BMI-for-age, duration of breast-feeding, mother's age, mother's education, and monthly household income).

Logistic regression was used to estimate the association between the categories of the outcome "cognitive perceptual-motor skills (lower and moderate/high)" and the independent variables (gender, duration of breast-feeding, feeding practice, child's BMI, attending school, type of school, child stimulus, mother's age, marital status, mother's education, and monthly household income). Odds ratios (OR) and 95% confidence intervals (CI) were also calculated. In unadjusted analysis (Model 1), the crude effects of each risk factor were estimated. We used a hierarchical three-level approach (distal, intermediate, and proximal) to fit the adjusted models considering only variables with $p \leq 0.20$ in the unadjusted analysis (Model 1). The distal variables were introduced first (mother's age, mother's education, and monthly household income), followed by the intermediate (gender) and proximal (attending school and type of school) variables (Model 2). In the second adjusted model (Model 3), "type of school" was not included in the analysis since students who did not attended school were not classified regarding the type of school. The MW in 2014 was US$ 306.00.

In this study, the presence of child stimulus was defined when the mother reported practicing any activity that contributed to the child's learning, such as reading different types of books, storytelling, use of educational games, activities involving music, and other related activities. The variance inflation factor test with commonly applied cut-off values revealed little collinearity among the independent variables. A $p<0.05$ was considered statistically significant in all analyses.

All procedures developed in the study were in accordance with the ethical standards involving human participants. The Research Ethics Committee of the University of Joinville Region approved this study (Protocol Nº. 107/2011).

Results

Of the 199 children included in the study, 114 (57.3%), 41 (20.6%) and 44 (22.1%) had low, moderate and high perceptual-motor skills, respectively. Table 1 shows the categorical variables of the children and mothers from 2012 to 2016 according to perceptual-motor skills at 4-5 years of age. The proportion of children with significantly lower perceptual-motor skills was higher among boys (63.6%), children not attending school (83.3%) and those studying at public schools (56.4%) compared to girls, children attending school and those studying at private schools, respectively. Regarding maternal characteristics, the proportion of children with low perceptual-motor skills was significantly higher among mothers who studied less than 12 years (70.3%) and whose monthly household income was <5 MW (60.2%) compared to those studying 12 or more years and earning 5 or more MW.

The determinants of low perceptual-motor skills are described in Table 2. Unadjusted analysis (Model 1) showed that boys and children not attending school had significantly greater odds of lower perceptual-motor skills at 4-5 years of age than girls (OR = 1.74, CI95%= 0.99-3.07) and those attending school (OR = 4.23, CI95%= 1.18-15.11). Regarding

Table 1

Characteristics (categorical variables) of the study participants according to the child's perceptual-motor skills at 4-5 years of age. PREDI Study, 2014-17.

Variables	Perceptual-motor skills (n = 199)						*p*
	Low		Moderate/High		Total		
	n	%	n	%	n	%	
Children							
Gender							0.054
Female	46	50.0	46	50.0	92	46.2	
Male	68	63.6	39	36.4	107	53.8	
Duration of breast-feeding (months)							0.417
≥ 6	40	60.6	26	39.4	66	33.5	
≥ 4 and < 6	41	59.4	28	40.6	69	35.0	
< 4	31	50.0	31	50.0	62	31.5	
Feeding practice							0.687
Exclusive breast-feeding	41	60.3	27	39.7	68	34.5	
Non-exclusive breast-feeding	63	54.3	53	45.7	116	58.9	
Artificial feeding	8	61.5	5	38.5	13	6.6	
Child's BMI (percentile)							0.592
≤ 85th	78	56.9	59	43.1	137	69.5	
> 85th and < 97th	22	52.4	20	47.6	42	21.3	
≥ 97th	12	66.7	6	33.3	18	9.2	
Attending school							0.023
Yes	97	54.2	82	45.8	179	90.8	
No	15	83.3	3	16.7	18	9.2	
Type of school							0.054
Private	5	31.3	11	68.8	16	8.9	
Public	92	56.4	71	43.6	163	91.1	
Child stimulus							0.722
Yes	90	56.3	70	43.8	160	81.2	
No	22	59.5	15	40.5	37	18.8	
Mothers							
Mother's age (years)							0.231
≥ 40	10	43.5	13	56.5	23	11.7	
30 - 40	43	54.4	36	37.9	95	48.2	
< 30	59	62.1	36	37.9	79	40.1	
Marital status							0.350
Marriage/consensual union	75	45.2	91	54.8	166	85.6	
Other	10	35.7	18	64.3	28	14.4	
Working							0.301
No	50	47.2	56	52.8	106	54.6	
Yes	35	39.8	53	60.2	88	45.4	
Mother's education (years)							<0.001
≥ 12	31	37.3	52	62.7	83	42.8	
9 - 12	46	70.8	19	29.2	65	33.5	
< 9	32	69.6	14	30.4	46	23.7	
Monthly household income (MW)							0.007
≥ 5	6	26.1	17	73.9	23	11.9	
3 - 5	32	57.1	24	42.9	56	28.9	
< 3	71	61.7	44	38.3	115	59.2	

BMI = Body mass index; MW = Minimum wage.

maternal characteristics, the odds of children having low perceptual-motor skills at 4-5 years of age were higher for mothers who studied less than 9 years and those earning <5 MW when compared to those who studied ≥9 years and those earning ≥5 MW (OR = 2.11, CI95%= 1.04-4.27; OR = 4.29, CI95%= 1.61-11.43, for mother's education and monthly household income, respectively). After adjustment considering only variables with $p<0.20$ from the unadjusted analysis (Model 1), male gender and monthly household income <5 MW were associated with higher odds of having low perceptual-motor skills at 4-5 years of age compared to female gender and monthly household income ≥5 MW (Model 2: OR = 2.11, CI95%= 1.12-3.97; OR = 5.10, CI95%= 1.58-16.45, respectively).

Model 3 was adjusted considering only variables with $p<0.20$ from the unadjusted analysis, except for "type of school". Male gender and not attending school continued to be independent predictors of low perceptual-motor skills (OR = 2.10, CI95%= 1.14-3.88; OR = 4.61, CI95%= 1.21-17.49, respectively). Regarding maternal characteristics, monthly household income <5 MW continued to be strongly associated with low perceptual-motor skills in children at preschool age (OR = 4.28, CI95%= 1.49- 12.26).

Discussion

The present study showed that gender, not attending school and monthly household income were associated with increased odds of children having low perceptual-motor skills at 4-5 years of age. Additionally, we observed a positive association between mother's education and child's perceptual-motor skills, but without statistical significance after adjusting for important confounders.

Some authors studied how children and adults perceive their movement skills (object control and locomotor) and how their perceptual skills are linked to the environment and concluded that children of both sexes were generally accurate in perceiving their movement competence.[21,22] There seems to be a gender difference in favor of girls for almost all motor skill tasks of preschoolers.[23] Girls tend to develop more fine motor skills that request better concentration such as painting, drawing, modeling objects, and playing dolls, while boys tend to perform more gross motor activities such as sports, climbing trees, and running.[3] Girls develop the areas of the brain responsible for motor development one year earlier than boys.[24] In other words, greater control of performing repetitive and standardized movements tends to occur earlier in preschool girls compared to boys of the same age group.[24]

Environmental and cultural factors may be one of the causes for the difference in motor skill strengths between boys and girls.[23] However, this difference in perceptual-motor development between boys and girls tends to disappear in adolescence.[24] These effects are in agreement with our findings showing better perceptual-motor skills in girls.

The stimulation of cognitive functions at preschool age is extremely important and the effective participation of parents and relatives is necessary to continue promoting activities that stimulate the child's cognitive development. Children show better cognitive development when their mothers have more years of education and higher IQ test scores compared to mothers with lower education level,[25,26] even when they are born preterm.[27,28] In the present study, children born to mothers with a higher education level exhibited better perceptual-motor skills in unadjusted analysis, but not in the adjusted model. Mothers with higher education level are likely to stimulate their children and to become more engaged in their children's school activities.

The socioeconomic status is also an important condition that influences the child's cognitive development. Children whose parents had higher education showed better body coordination,[23] which agrees with our results. We demonstrated that the proportion of children with low perceptual-motor skills was significantly higher among mothers who reported a monthly household income <5 MW compared to those who earned five or more MW. In general, low-income families cannot afford materials that help stimulate their children's cognitive development, such as books, educational games, toys, drawings, and paintings, nor do they have adequate space to play with their children. Most parents of low-income families work all day, leaving the child with relatives such as siblings, grandparents, or uncles/aunts who are also engaged in other household activities. It is also important to emphasize that low-income families generally do not have the culture of investing in their children's learning because they did not receive such encouragement as a child. Both reading and writing are associated with the development of perceptual-motor skills.[10,24]

Another important finding of the present study was the association between not attending school and increased odds of having low perceptual-motor skills, which is probably due to the lack of stimuli. Children who attend school participate in various activities that stimulate different cognitive skills, including perceptual-motor skills. Some authors have highlighted the role of the school in the

Table 2

Determinants of low cognitive perceptual-motor skills in Brazilian children at 4-5 years of age. PREDI Study, 2014-17.

Variable	Model 1 (n = 199)		Model 2 (n = 176)		Model 3 (n = 193)	
	OR (CI95%)	*p*	OR (CI95%)	*p*	OR (CI95%)	*p*
Children						
Gender						
Female	Reference		Reference		Reference	
Male	1.74 (0.99 - 3.07)	0.054	2.11 (1.12 - 3.97)	0.021	2.10 (1.14 - 3.88)	0.018
Duration of breast-feeding (months)						
≥ 6	Reference					
< 6	0.79 (0.43 - 1.45)	0.451				
Feeding practice						
Exclusive breast-feeding	Reference					
Non-exclusive breast-feeding	0.81 (0.44 - 1.46)	0.479				
Child's body mass index (percentile)						
≤ 85th	Reference					
> 85th	0.99 (0.54 - 1.83)	0.972				
Attending school						
Yes	Reference				Reference	
No	4.23 (1.18 - 15.11)	0.027			4.61 (1.21 - 17.49)	0.025
Type of school						
Private	Reference		Reference			
Public	2.85 (0.95 - 8.58)	0.062	1.97 (0.60 - 6.48)	0.266		
Child stimulus						
Yes	Reference					
No	1.14 (0.55 - 2.36)	0.723				
Mothers						
Mother's age (years)						
≥ 30	Reference		Reference		Reference	
< 30	1.52 (0.86 - 2.67)	0.152	0.72 (0.38 - 1.38)	0.331	0.67 (0.36 - 1.22)	0.186
Marital status						
Marriage/consensual union	Reference					
Other	1.48 (0.65 - 3.41)	0.352				
Working						
No	Reference		Reference			
Yes	0.74 (0.42 - 1.31)	0.302	1.07 (0.57 - 2.00)	0.930		
Mother's education (years)						
≥ 9	Reference		Reference		Reference	
< 9	2.11 (1.04 - 4.27)	0.038	1.34 (0.61 - 2.96)	0.461	1.72 (0.80 - 3.66)	0.163
Monthly household income (MW)						
≥ 5	Reference		Reference		Reference	
< 5	4.29 (1.61 - 11.43)	0.004	5.10 (1.58 - 16.45)	0.006	4.28 (1.49 - 12.26)	0.007

MW = Minimum wage; Model 1 corresponds to unadjusted analysis; Model 2 corresponds to adjusted analysis including variables with $p \leq 0.20$ in Model 1; Model 3 corresponds to adjusted analysis including variables with $p \leq 0.20$ in Model 1, except for "type of school".

improvement of children's cognitive development.[27,28] Children who do not attend school or are not stimulated by their parents at home are more likely to have low perceptual-motor skills. School educational activities at the beginning of literacy are critical for children to improve different cognitive skills and will certainly influence their school performance over the years.

Most studies evaluating the relationship between breast-feeding and cognitive functions in children and adolescents have used general assessment tests to evaluate cognitive development, such as the IQ test. In general, these tests are strongly influenced by biological factors such as physical state, mood, and motivation,[2,29] and are conducted when the child has already started elementary school.[10,30] We used a specific test validated exclusively for Brazilian children to evaluate the child's perceptual-motor skills, which may reduce the influence of factors associated with tests developed in other populations.

The strengths of the current study should be mentioned. The data obtained in this study are primary data, a fact providing opportunities for future research in this field. Furthermore, this is a longitudinal study in which the mother-child pair was evaluated at the same time by the same team, ensuring the quality of the information. The adjustment for several important confounding factors is also an important strength of the study. Finally, the test used to evaluate the child's perceptual-motor skills was developed in Brazil and adaptation to our population was therefore not necessary.

This study also has some limitations. First, the lack of studies and the different study designs made it difficult to compare the data. Second, since data collection took place in the family homes, children may have been influenced by the presence of the parents or distractions in the home environment. Third, some children were not motivated to respond to the instrument until the end of the study, a fact that may have influenced the test results and led to lower final scores. Motivation is important for any psychology test as it maintains interest and improves the response performance. Fourth, although the Mann-Whitney U test showed no significant difference in maternal education years, birthweight or child's BMI-for-age between mothers/children enrolled at baseline and those who were not enrolled in the follow-ups, possible bias resulting from losses to follow-up cannot be disregarded. Finally, the relatively high prevalence of children with low perceptual-motor skills (57.3%) who were from families with low income (monthly household income <5 MW in 83.5%) in our study suggests them to be a high-risk group.

In conclusion, our study showed that gender, not attending school and monthly household income are important factors that have an impact on perceptual-motor skills at the beginning of literacy. From an educational and public health perspective, we believe that strategies aimed at enhancing the child's perceptual-motor skills may help improve cognitive performance in adolescence and adulthood.

Author's contribution

Santos EMM contributed to data collection, analyses, drafted and revised the manuscript. Constantino B contributed to data collection, analyses, drafted and revised the manuscript. Rocha MM drafted and revised the manuscript. Mastroeni MF conceptualized and designed the study, contributed to the statistical analysis, coordinated and supervised data collection, drafted and revised the manuscript. All authors read and approved the final manuscript.

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