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HEREDITY – ENVIRONMENT INFLUENCES, ON GROWTH AND MATURATION DURING PUBERTY

A CROSS-CULTURAL COMPARISON

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Abstract: *In a Swedish longitudinal project (SLU) a model has been developed presenting hypothetic within-pair similarity for MZ and DZ twins for different types of characteristics and environments.*

Two main results were found: The influence of hereditary and environmental factors will vary for different characteristics. – The influence of hereditarty and environmental factors will vary for the same characteristic depending upon differing environmental impact.

To further explore the importance of environmental variation a cross-cultural comparison is presented. Height and weight growth for MZ and DZ twins in Poland and India has been related to height and weight growth for Swedish twins. Within pair similarity for MZ and DZ twins in physical growth seems to be fairly similar for Sweden and Poland, while data from India partly show a different trend.

These results are discussed in relation to the model and environmental differences between countries.

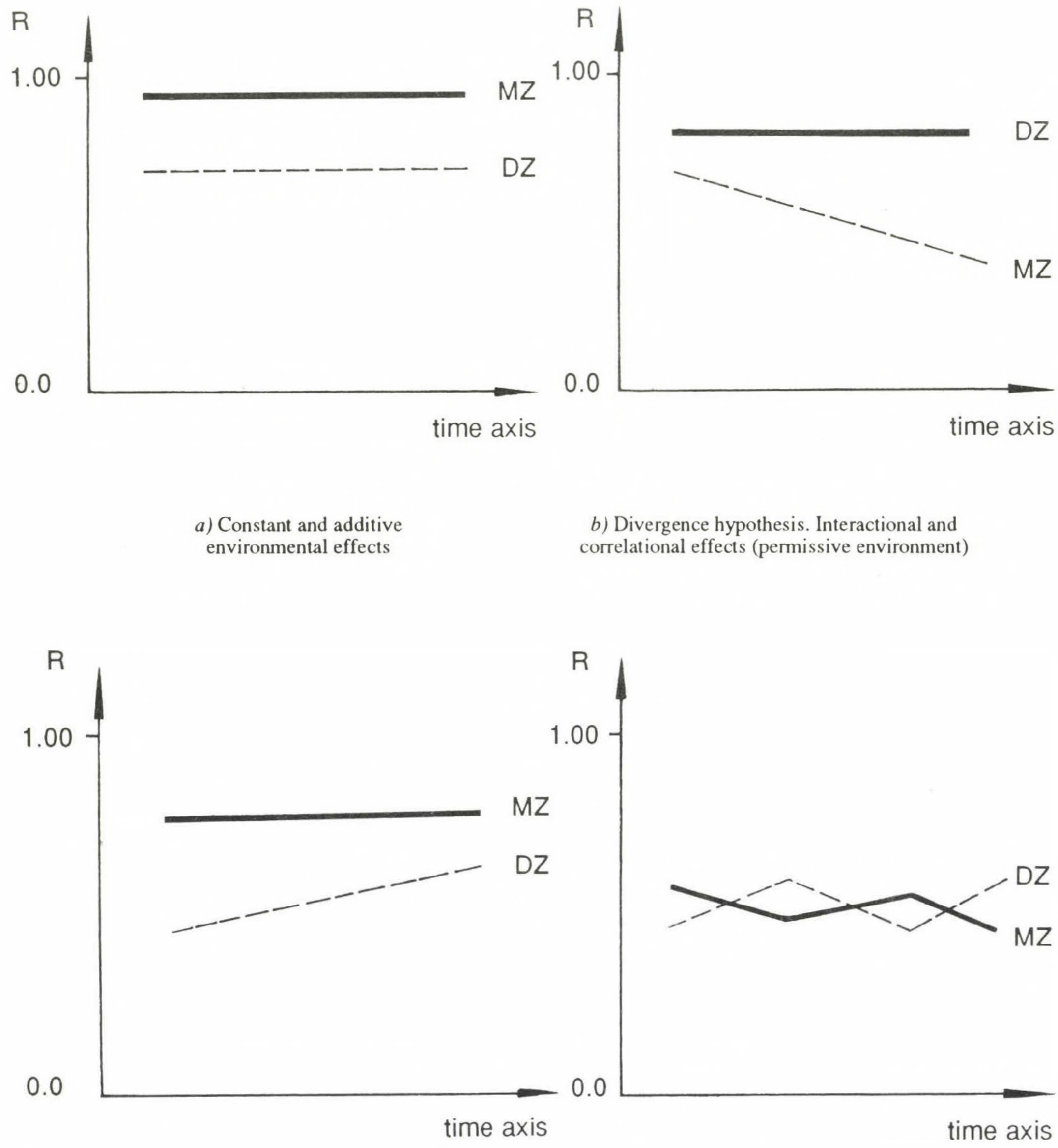
Key words: *Growth and maturation; Twins; Model of nature-nurture contribution; Swedish, Polish and Indian boys and girls.*

Introduction

One way of studying heredity-environment influences on physical growth is to make a comparison of within-pair similarity for monozygotic (MZ) and dizygotic (DZ) twins. The twins are used as a *method* for separating genetic and environmental variation when looking at, for instance, height and weight growth during puberty. This can be done since MZ twins are genetically identical, while DZ twins have 50 percent of their genes in common, on average. The more similar the MZ twins are in comparison to the DZ twins, the greater the probability of genetic factors influencing the variation of the characteristic studied. This is a simplification, however, since the difference in within-pair similarity for MZ and DZ twins is often due also to an interactional effect. MZ twins tend to react to and be treated similarly by individuals in their environment, while DZ twins react to and are treated differently by these persons. Such dynamic interactional influences can be studied by means of longitudinal twin data.

Model of nature-nurture contribution

In a Swedish longitudinal twin project a model was developed presenting hypothetic within-pair similarity for MZ and DZ twins for different types of characteristics and for different types of environments. Intra-class correlations (R) have been used to illustrate within-pair similarity. This model is shown in *Figure 1.*



a) Constant and additive environmental effects

b) Divergence hypothesis. Interactional and correlational effects (permissive environment)

c) Convergence hypothesis (restrictive environment)

d) A variable primarily controlled by environmental factors

Fig. 1: Hypothetical intra-class correlations for MZ and DZ twins assuming similar environments, and varying nature-nurture contribution

Example a) Illustrates development of a characteristic primarily controlled by genetic factors, where environmental effects are assumed to be *constant* and *additive*. MZ twins, due to their identical inheritance, tend to be more similar than DZ twins and this difference tends to be of the same magnitude as long as the twins are exposed to the same environmental impact. No lowering of the intra-class correlations with increasing age is hypothesized.

Example b) illustrates a *divergence* hypothesis proposed by Fuller & Thompson (1961). Under permissive circumstances MZ twins react similarly to the same environmental influences, while DZ twins react differently and thus get progressively less similar. A lowering of the intra-class correlations for DZ twins but not for MZ with increasing age is hypothesized.

Example c) illustrates a *convergence* hypothesis also suggested by Fuller & Thompson (1961). Due to restrictive environmental influences negatively reinforcing genetic differences, DZ twins will get progressively more similar with increasing age. The intra-class correlations for DZ twins will thus be higher with increasing age and remain constant for MZ twins.

Example d) illustrates *unsystematic environmental effects* largely counteracting genetic differences. Since the identical inheritance of MZ twins does not predispose them for greater similarity, it will be incidental if the intra-class correlations for MZ twins will be higher than for DZ twins.

Of course this model is not static, but the results will vary with the populations studied and the cultural environment involved. What is classified in one society as a characteristic under a) might for instance be susceptible to interactional effects as in example b) in different environmental circumstances. Assuming comparable (similar degree of genetic regulation) variables, constitutional factors will be of relatively minor importance in a restrictive environment and of greater importance in a permissive environment.

This model thus presupposes that interactional effects will vary for different characteristics and for different environmental circumstances and it is therefore of special interest to apply it to the same type of data collected in different countries. In the following this model has been used to illustrate within-pair similarity in physical growth and maturity during puberty for MZ and DZ twins from three different countries with varying demographic, cultural and economic backgrounds, namely Sweden, Poland and India. It is hypothesized that height growth and physical maturity will be more genetically regulated than weight growth irrespective of cultural differences and that weight growth is more susceptible to interactional effects in all three countries (Fischbein 1979).

Material and Methods

In *Sweden* 323 twin pairs were followed as part of a larger project from 10 years of age to 16 years of age for the females and 18 years of age for the males. Of the twin pairs there were 94 MZ pairs, 133 like-sexed DZ pairs and 97 unlike-sexed pairs. For classifying the like-sexed twin pairs a morphological diagnosis according to a special schedule was applied. Erroneously judged cases can be estimated as not more than 10 percent with this type of similarit diagnosis (Husén 1959, Cederlöf et al. 1961). The reliability of this method can therefore be considered sufficiently accurate for group comparisons, if the groups are not too small. A thorough serological analysis has been carried out at the Karolinska Institute in Stockholm, for 71 pairs of the 133 like-sexed twin pairs. Out of these, only 3 pairs or 4 percent, had been erroneously diagnosed as MZ instead of DZ, and have thus been reclassified. The project was called the SLU-study. Height and weight growth was measured by the school nurses every half year and adjusted to the childrens' chronological age. The methods used in the SLU-project for estimating the age at which different criteria of physical maturity were reached are age at peak height velocity (PHV) and peak weight velocity (PWV) according to a modified "mid-year-velocity" method. Individual height and weight measurements were adjusted to specific chronological ages. The yearly increments were then calculated for each 6 months. The midpoint of the 12 months interval during which the maximum yearly increment occured was taken as age at PHV or PWV (Fischbein 1977a). In addition to this, ratings were made of the development of secondary sex characteristics in both the male and female twins. Menarche for the girls was also registered (Ljung et al. 1977).

In *Poland* the Wroclaw Longitudinal Twin Study consisted of 296 pairs (149 MZ and 147 DZ). Of these 195 pairs were examined in 1972. The second part of the material is including 101 pairs examined in the years 1959–1961. Zygosity diagnosis for the twins is based on three independent tests: (1) The polysymptomatic diagnosis of similarities, including different morphological traits; (2) The discriminant function, based on a complex similarity of 64 dermatoglyphic traits; (3) The analysis of blood groups concordance with calculation of monozygosity probability by means of the method of Maynard–Smith & Penrose (1955), on the basis of pD values elaborated for the Polish population. The analysis of results obtained by means of the three mentioned methods has shown that only in 5 cases per 220 twin pairs or 2.3 per cent, diagnostic difficulties, caused by various reasons, appeared (Orczykowska–Swiatkowska 1988). Anthropometric measurements as well as physiological and psychological information were collected annually by the same staff, using the same instruments. A full description of the project is given by Bergman & Orczykowska–Swiatkowska (1976).

In *India* 48 pairs of MZ and DZ like-sexed pairs were measured as part of a larger project. Height and weight measurements as well as observations of secondary sex characteristics were recorded at three-monthly intervals from 10 to 18 years of age. To estimate ages at peak height and peak weight velocities (PHV and PWV), the velocity curves of the measurements were plotted separately for each individual and the age at which the maximum velocity was reached on the graph was recorded as the age at peak velocity. The number of twins varies at different ages, since not all twin pairs were available for observations at each stage repeatedly. The subjects belonged to upper-middle class Khattris of Chandigarh city and were well fed by Indian standards. Only physically normal twins who had never suffered from any major ailment and were unmarried were included in the study. Zygosity was established on the basis of ABO, MN, Rh blood groups, ABH secretion and PTC-testing ability as well as various morphological characters (Sharma 1983).

Results

Height

For a study of concordance for MZ pairs in comparison to DZ during puberty, within-pair correlations (intra-class correlations) for height by age have been estimated. This has been done for data from the three different countries and is presented in *Table 1* and further illustrated in *Figure 2.*

Table 1. **Intra-class correlations (R) for height in male and female MZ and DZ twins from 10 to 18 years of age. Data from Sweden (Fischbein 1977b), Poland (Bergman 1988, 1989), and India (Sharma 1983)**

Age (year)	Sweden				Poland				India			
	MZ		DZ		MZ		DZ		MZ		DZ	
	M	F	M	F	M	F	M	F	M	F	M	F
10	.95	.97	.72	.52	.94	.93	.71	.43	.90	.92	.68	.70
11	.96	.96	.68	.68	.95	.92	.72	.46	.92	.93	.58	.65
12	.96	.94	.69	.66	.95	.93	.68	.50	.89	.90	.46	.56
13	.97	.93	.66	.64	.96	.93	.65	.56	.92	.90	.44	.52
14	.96	.94	.65	.67	.96	.94	.66	.54	.90	.88	.50	.54
15	.95	.91	.63	.73	.96	.94	.72	.49	.87	.87	.52	.51
16	.95	.93	.68	.54	.96	.94	.75	.45	.88	.91	.56	.51
17	.91	–	.74	–	.95	.94	.77	.50	.89	–	.62	–
18	.94	–	.74	–	.96	.91	.80	.40	.88	–	.58	–

For both male (M) and female (F) twins the intraclass correlation coefficients tend to be very high (around .90) in all three countries. In India the correlations seem to be somewhat lower than in Sweden and Poland and sometimes drop below .90. They are, however, stable over time and there is no sign of a decreasing within-pair similarity by age.

The DZ correlations tend to be lower but we can also see a sex difference in Sweden and Poland, which is not evident in India. In the first-mentioned countries the male correlations are fairly high (around .70) during puberty, while the female correlations tend to be somewhat lower (around .50–.60). This trend seems to be the same in both Sweden and Poland even if the female correlations tend to be a little lower in Poland. In India, on the other hand, the intra-class correlations seem to be of the same magnitude (around .50–.60) irrespective of sex. We can also see from *Figure 2* that, generally, the MZ correlations are very stable over time in all these countries even if they tend to be a little lower for the Indian twins. The DZ correlations, on the other hand, fluctuate much more in all three countries, which is at least partly a reflection of the variation in the onset of growth spurt in the DZ twins.

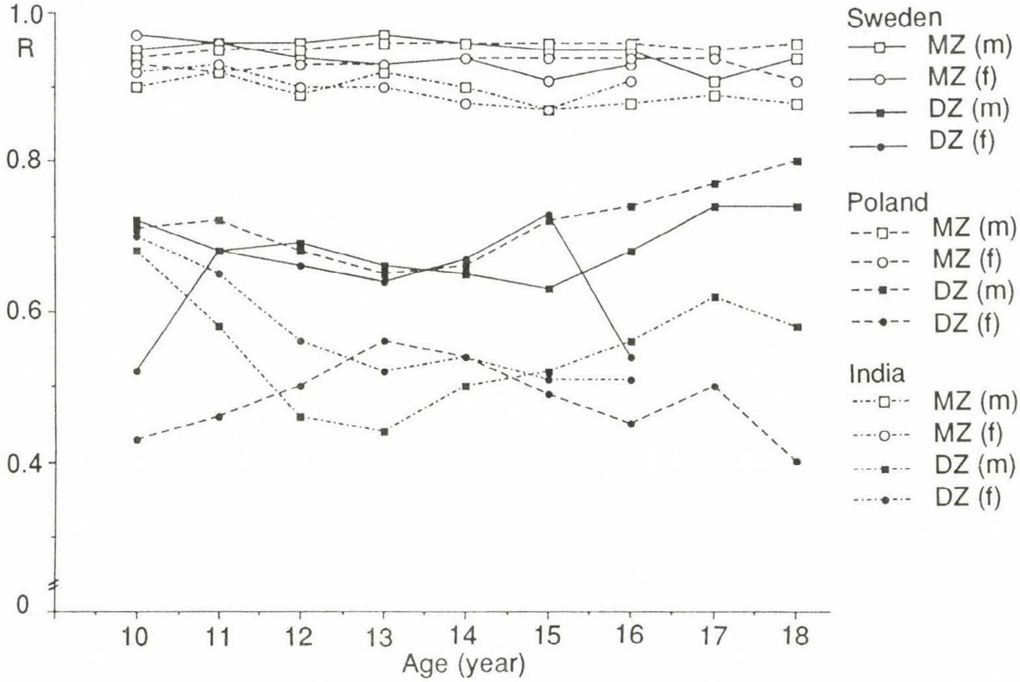


Fig. 2: Intra-class correlations for height from 10 to 18 years of age for male and female MZ and DZ twins

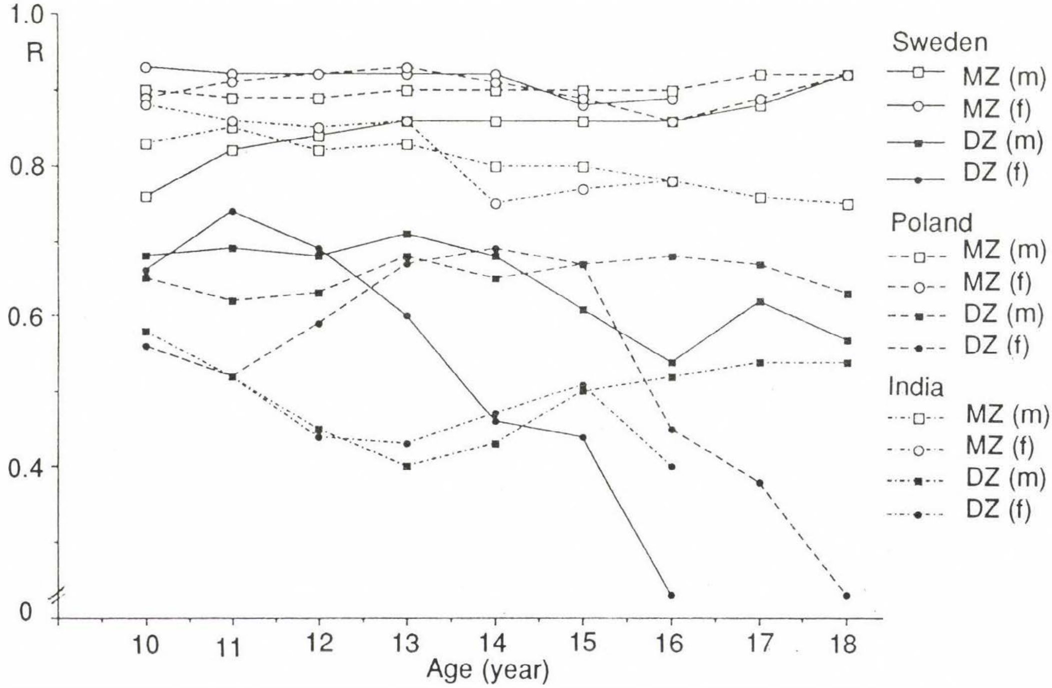


Fig. 3: Intra-class correlations for weight from 10 to 18 years of age for male and female MZ and DZ twins

Table 2. **Intra-class correlations (R) for weight in male and female MZ and DZ twins from 10 to 18 years of age. Data from Sweden (Fischbein 1977b), Poland (Bergman 1988, 1989), and India (Sharma 1983)**

Age (year)	Sweden				Poland				India			
	MZ		DZ		MZ		DZ		MZ		DZ	
	M	F	M	F	M	F	M	F	M	F	M	F
10	.76	.93	.68	.66	.90	.89	.65	.56	.83	.88	.58	.56
11	.82	.92	.69	.74	.89	.91	.62	.52	.85	.86	.52	.52
12	.84	.92	.68	.69	.89	.92	.63	.59	.82	.85	.45	.44
13	.86	.92	.71	.60	.90	.93	.68	.67	.83	.86	.40	.43
14	.86	.92	.68	.46	.90	.91	.65	.69	.80	.75	.43	.47
15	.86	.88	.61	.44	.90	.89	.67	.67	.80	.77	.50	.51
16	.86	.89	.54	.23	.90	.86	.68	.45	.78	.78	.52	.40
17	.88	–	.62	–	.92	.89	.67	.38	.76	–	.54	–
18	.92	–	.57	–	.92	.92	.63	.23	.75	–	.54	–

Weight

In *Table 2* and *Figure 3* intra-class correlations for weight during puberty in the three countries are presented.

Also for weight the MZ correlations are very high during puberty for both male (M) and female (F) twins in all the three countries (around .80–.90). The DZ twins show a remarkable sex difference in both Sweden and Poland. Male DZ twins are fairly similar in weight during the whole growth period, while female DZ twins tend to become less similar. At 16 and 18 years of age respectively, the dizygotic twin girls show a correlation of .23, which is much lower than would be expected if only genetic influences were operating.

In India this sex difference seems to be less conspicuous for both height and weight growth. MZ correlations for weight seem to drop, however, for both boys and girls after puberty, which might be an indication of a larger influence from environmental factors.

Onset of puberty

To study onset of puberty in boys and girls the ages of peak height or peak weight velocity (PHV and PWV) can be compared. For girls age at menarche can also be used as a measure of physical maturity. *Table 3* presents intra-class correlations for age at PHV and PWV for male and female MZ och DZ twins as well as age at menarche for female MZ and DZ twins in Sweden, Poland and India.

The MZ correlations are higher than the DZ correlations for all measures of physical maturity in all the three countries. The highest correlations are found for MZ twins for age at menarche (around .95). The intra-class correlations for measures of physical maturity general tend to be of the same magnitude for both MZ and DZ twins in Sweden, Poland and India which might be due to the fact that these samples are living in fairly good environmental circumstances.

Table 3. **Intra-class correlations (R) for age at PHV and PWV for male and female MZ and DZ twins as well as for age at menarche for female MZ and DZ twins. Data from Sweden (Fischbein 1977a,b), Poland (Bergman 1988, 1989), and India (Sharma 1983)**

Measures of physical maturity	**Sweden**				**Poland**				**India**			
	MZ		**DZ**		**MZ**		**DZ**		**MZ**		**DZ**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Age at PHV	.85	.78	.42	.39	.93	.87	.57	.59	.98	.95	.36	.58
Age at PWV	.68	.83	.38	.50	.87	.81	.42	.59	.75	.85	.30	.42
Age at menarche	–	.93	–	.62	–	.95	–	.61	–	.97	–	.50

Summarizing the results concerning intra-pair similarity in physical growth data during puberty for MZ and DZ twins in Sweden, Poland and India, the main conclusion is that differences between countries are not very large and conspicuous. The sex differences with lower female DZ correlations found after puberty for both height and weight growth in Sweden and Poland does not seem to be present in the Indian sample. In all these countries, MZ correlations seem to be fairly high and stable over time. There can be seen, however, a trend for decreasing MZ correlations in the Indian sample particularly for weight growth, which is not evident in the other two countries.

Discussion

Within-pair similarity in physical growth for MZ and DZ twins during puberty has been compared for three different countries, Sweden, Poland and India. This is done with reference to a model illustrating nature-nurture interaction in longitudinal twin data. It is hypothesized that height growth and physical maturity will be more genetically regulated than weight growth irrespective of cultural differences. Weight growth, on the other hand, will be more susceptible to interactional effects, which might influence within-pair similarity for MZ and DZ twins differently in the three countries, depending upon cultural variations.

The twin samples were all longitudinal and living in fairly good environmental conditions. The results indicate that *height growth* generally follows a trend compatible with example *a)* in the model. Within-pair correlations for MZ twins are consistently high during the whole pubertal period. Data from the Indian twins show somewhat lower correlations but no increasing or decreasing trend. DZ correlations fluctuate much more, due to variations in age at PHV for the twins in a pair. There is, however, no consistent increasing or decreasing trend for DZ correlations in height growth during this period. Within-pair similarity in physical maturity also seems to be high for the MZ twins and moderate for the DZ twins. These data thus indicate a primarily genetic regulation of height growth and physical maturity in the three countries.

Weight growth, on the other hand, shows the same trend in Sweden and Poland with high intra-pair correlation coefficients for MZ twins and decreasing DZ correlations, particularly for the female twins. This trend is in accordance with example *b)* in the m del and seems to imply larger interactional effects for girls than for boys in weight growth during puberty. This sex difference is, however, not evident in the Indian sample. The MZ Indian twins also show somewhat decreasing within-pair similarity during the pubertal period, which indicates a converging trend compatible with example *c)* instead of a diverging trend as in example *b).* A possible explanation of these results might be that nature-nurture interactional effects on weight growth in the Indian society are mainly of a restrictive character for both boys and girls, while a permissive situation is Sweden and Poland gives more room for individual regulation. This might be especially evident for the girls due to weight being a more sensitive characteristic, where beauty ideals and dieting is more linked to body image and weight growth for girls than for boys.

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