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Similarity of childhood experiences and personality resemblance in monozygotic and dizygotic twins: a test of the equal environments assumption

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Abstract

The equal environments assumption suggests that the environment does not contribute more strongly to the similarity of monozygotic (MZ) compared to dizygotic (DZ) twins. It was tested in 525 MZ, 200 same-sex DZ, and 68 opposite-sex DZ twin pairs. Almost 80% of the twins were female, and their age varied widely around a mean of 32 years. Similarity of twin environments was assessed by a self-report questionnaire on childhood experiences, and personality resemblance was measured using the self-report and peer-report versions of the NEO-Five-Factor Inventory. MZ twins reported more similar experiences than DZ twins and were also more alike in personality. Across twin pairs, however, treatment similarity was unrelated to personality resemblance, except in the combined group of MZ and DZ twins. These results are consistent with the equal-environments assumption.

Keywords: Behavior genetics; Shared environment; Genetic influence; Twin studies; Equal environments assumption

Quantitative behavior-genetics accounts for higher resemblance between monozygotic (MZ) compared to dizygotic (DZ) twins in terms of genetic influence on the phenotype. According to the basic twin model, additive as well as interactive effects of genes correlate perfectly for MZ twins but 0.50 (additive gene effects) or 0.25 (effects of gene dominance) for DZ twins, whereas

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the contributions of genes, shared environment, and nonshared environment to the phenotype are assumed to be equal across zygosity groups. The most controversial of these assumptions is the so-called *equal environments* assumption that the contribution of the shared environment to twin resemblance (c^2) is equal for MZ and DZ twins (Joseph, 1998; Kendler, Gardner, & Prescott, 1998; Klump, Holly, Iacono, McGue, & Willson, 2000; Pam, Kemker, Ross, & Golden, 1996). At first glance, this assumption seems to be disconfirmed by the finding that MZ twins are treated more alike during childhood than DZ twins. For example, Loehlin and Nichols (1976) and Plomin, Willerman, and Loehlin (1976) reported that MZ pairs were not only more similar in personality and intelligence than DZ pairs, but were also dressed more alike in childhood, spent more time together, and were more frequently confused with each other.

That does not imply, however, that the MZ twins' more similar environments actually account for their higher resemblance in behavior. Rather, there are three reasonable models, illustrated in Fig. 1, that may explain these findings. According to Model A, there are no direct effects whatsoever of treatment similarity on resemblance in behavior or vice versa. Rather, the correlation between treatment similarity and similarity in behavior is entirely mediated by the higher genetic relatedness of MZ twins. According to Model B, there are direct effects, but they run from the more similar behavior of MZ twins to their more similar environments, implying that the more similar environment of MZ twins is a child effect (Lytton, 1977; Scarr & McCartney, 1983). Finally, Model C states that there are direct effects of the more similar treatment of MZ twins on their more similar behavior. Model C is at variance with the equal environments assumption, as would be a combination of Model B and Model C, assuming direct effects of treatment similarity on resemblance in behavior and vice versa.

Model A would be supported by findings that there is no relation between environmental and behavioral similarity if genetic similarity is controlled. In this report, we analyze data from the Bielefeld–Warsaw Twin Study to test this assumption. The Bielefeld–Warsaw Twin Study is a cross-cultural German–Polish self-report and peer report study on genetic and environmental influences on individual differences in personality and temperament that is described in more detail by Riemann, Angleitner, and Strelau (1997).

1. Method

1.1. Participants

Only the German data were used for the present analyses. The twin pairs were approached through announcements in newspapers and magazines, via radio and TV, and through twin clubs and twin meetings. All twin pairs volunteered for this study, and this may explain the overrepresentation of female and MZ pairs.

Moreover, each twin approached two knowledgeable informants (that did not overlap between co-twins) who knew one twin but (preferably) not the co-twin very well. Complete datasets were available for 525 MZ twin pairs (422 of them female), 200 same-sex DZ twin pairs (175 of them female), and 68 opposite-sex twin pairs. The twins' age ranged from 14 to 80 years with a mean of 31.92 (S.D. = 12,92) and a median of 29.00 years.

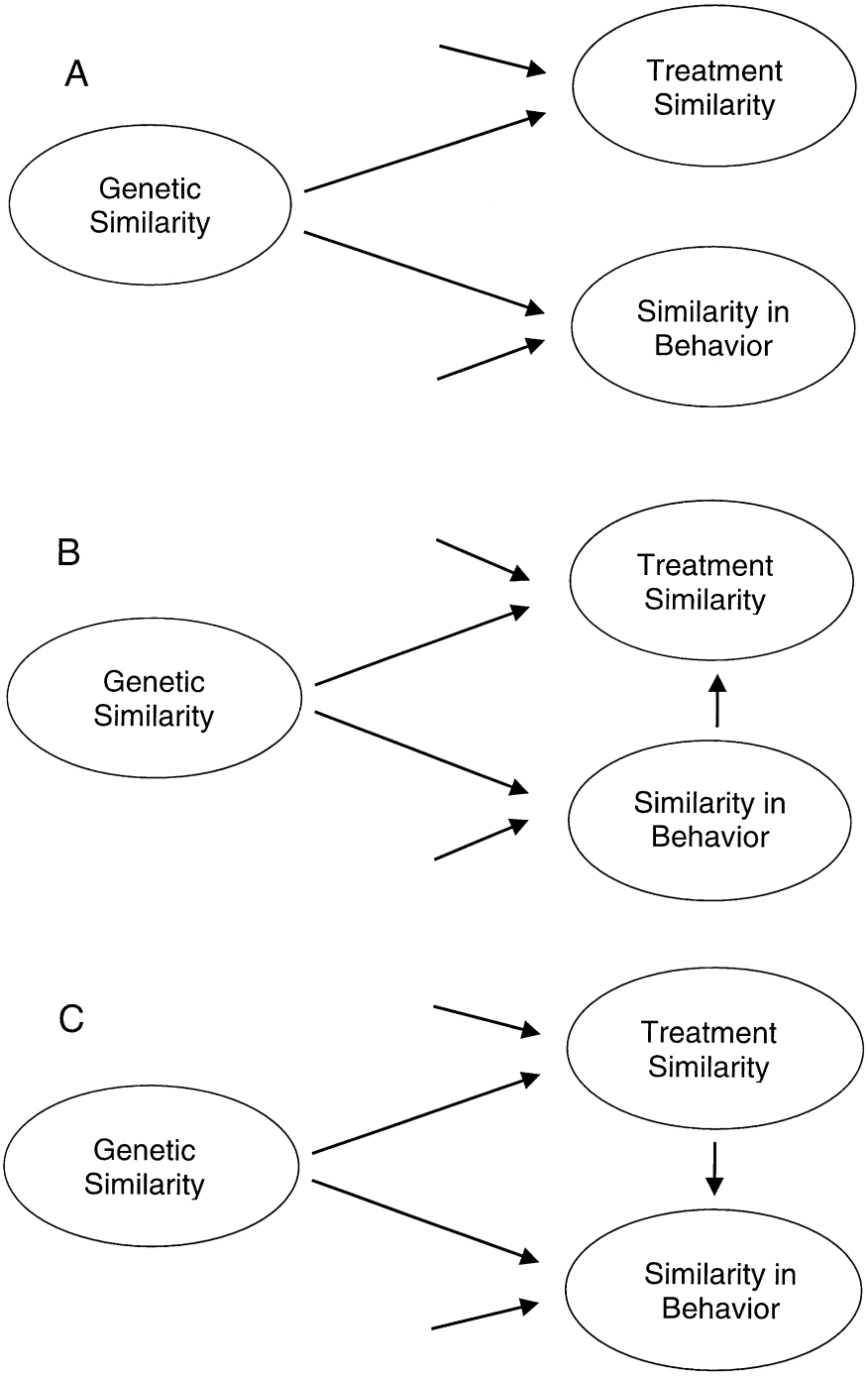

Fig. 1. Illustration of three models to account for the higher environmental and personality resemblance in MZ than in DZ twin pairs. The unmarked arrows refer to additional factors that contribute to differences between twin pairs in the similarity of their treatment and behavior.

1.2. Measures

The twins were administered, among others, a German version (Borkenau & Ostendorf, 1993) of Costa and McCrae's (1992) NEO-Five Factor Inventory (NEO-FFI). The NEO-FFI is a 60-item instrument to measure the dimensions of the five-factor model of personality, i.e. Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness. The reliabilities (Cronbach's alpha) of its scales vary from 0.71 to 0.85 (Borkenau & Ostendorf, 1993). Moreover, the peer report version of the NEO-FFI, in which the same items are worded in the third person singular, was used for obtaining peer reports. Finally, the twins were administered a self-report instrument on their childhood experiences. Ten of its items (being listed in Table 1) referred to the similarity of their treatment in childhood. The responses to these items were given on 5-point rating scales with the endpoints 0 and 4, and were keyed such that higher scores indicated a more similar treatment.

2. Results

We first checked the agreement between co-twins on how alike they had been treated in childhood. The agreement between co-twins (r_1) ranged from 0.34 to 0.81 with a mean of 0.56 and justified to average their responses. These averaged responses were used in all subsequent analyses. Their reliabilities (r_2) ranged from 0.51 to 0.90 with a mean of 0.73. The agreement was higher for specific questions, such as "Were you dressed alike?" ($r_2 = 0.90$), than for more general questions like "Have you been presented as a twin pair?" ($r_2 = 0.51$). The correlations between the ten items varied from 0.01 to 0.71 with a mean of 0.27 and a median of 0.25.

A next set of analyses focused on whether MZ twins had been treated more alike than DZ twins in childhood, and whether same-sex DZ twins had been treated more alike than opposite-sex DZ twins. We first ran a MANOVA on all 10 items. The multivariate F was highly significant, Wilk's Lambda $(20,1192) = 34.23$, $P < 0.001$, as were most of the 10 univariate F-ratios. We therefore ran planned Helmert contrasts between MZ pairs and DZ pairs and between same-sex DZ pairs and opposite-sex DZ pairs. The means, univariate F-ratios, and significance levels for the planned contrasts are reported in Table 1.

The MZ pairs reported a more similar treatment than the DZ pairs, and the same-sex DZ pairs reported a more similar treatment than the opposite-sex DZ pairs. This pattern held for each of the 10 variables, 90% of these differences being statistically significant. Note, however, that according to the grand means reported in the bottom row, the differences between same-sex and opposite-sex DZ twins were larger than the differences between MZ and same-sex DZ twins.

Resemblance in personality was assessed via intrapair differences between co-twins' self-reports or peer reports on the NEO-FFI. These intrapair differences were then submitted to the same kind of MANOVA as the environmental similarity measures. The multivariate F-ratio was again highly significant, Wilk's Lambda $(20,1554) = 5.11$, $P < 0.001$. The means, univariate F-ratios, and Helmert contrasts are reported in Table 2.

As expected, the intrapair differences in personality traits were larger for DZ than for MZ twins, the difference being statistically significant for nine of the 10 comparisons. Moreover, the differences in personality resemblance were larger between MZ and same-sex DZ twins than

Table 1
Self-reported similarity of treatment in childhood among MZ pairs, same-sex DZ pairs, and opposite-sex DZ pairs[a]

Item	Means			*F*-ratio (d.f. = 2,604)	Helmert contrasts	
	MZ	DZ-SS	DZ-OS		MZ-DZ	DZ-SS-DZ-OS
Have you been dressed alike?	3.10	2.54	0.99	91,11***	$P<0.001$	$P<0.001$
Was your hair style the same?	3.62	2.58	0.49	313,78***	$P<0.001$	$P<0.001$
Have the same leisure activities been arranged for you?	2.54	2.34	1.55	23,74***	$P<0.001$	$P<0.001$
Did you receive the same toys as presents?	3.06	2.63	1.26	105,04***	$P<0.001$	$P<0.001$
Were larger purchases done only once for both twins?	2.52	2.45	1.68	11,74***	$P<0.001$	$P<0.001$
Have you been presented as a twin pair?	2.63	2.41	2.38	2,21	$P<0.05$	n. s.
Was it emphasized that you attended the same kindergarten group?	2.90	2.73	2.33	4,71**	$P<0.01$	$P<0.05$
Was it emphasized that you attended the same class in school?	3.14	2.77	2.37	12,14***	$P<0.001$	$P<0.05$
Were you frequently referred to as "The Twins"?	2.12	1.86	1.47	4,75**	$P<0.01$	n.s.
Have you generally been treated alike during childhood?	3.28	2.62	2.34	49,18***	$P<0.001$	$P<0.05$
Mean for the 10 items	2.89	2.49	1.69			

[a] MZ, monozygotic; DZ, dizygotic; DZ-SS, dizygotic same-sex; DZ-OS, dizygotic opposite-sex.
** $P<0.01$.
*** $P<0.001$.

between same-sex and opposite-sex DZ twins. Indeed, the intrapair differences for the same-sex DZ twins were even larger (although not significantly) than those for opposite-sex DZ twins in three of the 10 comparisons. Thus, sex was more important than zygosity for treatment similarity, whereas zygosity was more important than sex for personality resemblance.

Next, we tested Model A in Fig. 1. At first glance, it might seem appropriate to run partial correlations between treatment similarity and intrapair differences in personality, controlling for zygosity. Note, however, that the DZ twins are a heterogeneous group: not only is it composed of same-sex and opposite-sex pairs, but even within these two groups the pairs vary in the proportion of shared genes. Thus zygosity is a less-than-perfect measure of genetic relatedness.

Therefore, we ran separate analyses for (1) all twins, (2) MZ twins, (3) same-sex DZ twins, and (4) opposite-sex DZ twins. We paid special attention to the findings for MZ twins because this was the largest group, and because MZ co-twins do not vary in genetic relatedness.

More specifically, we ran moderated regression analyses for these four groups, predicting the trait level of Co-twin 2 from the trait level of Co-twin 1, using treatment similarity as a second predictor and the product of Twin 1′s trait Level and how alike the twins had been treated in childhood (entered after the two predictors) as a moderator term. Thus the regression model was:

$$T_{2j} = b_1\ T_{1j} + b_2\ A_j + b_3\ T_{1j}xA_j + e_{2j}, \tag{1}$$

T_{2j} being the trait level of co-twin 2 of twin pair j, T_{1j} being the trait level of co-twin 1 of twin pair j, A_j being the averaged report on how alike twin pair j has been treated in childhood, $T_{1j} \times A_j$

Table 2
Intrapair differences in personality for MZ pairs, same-sex DZ pairs, and opposite-sex DZ pairs[a]

Personality trait	Mean of intrapair differences			F-ratio (d.f. = 2,786)	Helmert Contrasts	
	MZ ($n = 525$)	DZ-SS ($n = 200$)	DZ-OS ($n = 68$)		MZ-DZ	DZ-SS-DZ-OS
Self-reports						
Neuroticism	6.28	7.98	9.54	13,21***	$P < 0.001$	n.s.
Extraversion	5.08	6.52	7.58	14,14***	$P < 0.001$	n.s.
Openness to experience	4.43	4.94	4.80	1,49	n.s.	n.s.
Agreeableness	4.75	5.53	5.38	3,00	$P < 0.05$	n.s.
Conscientiousness	5.00	6.13	8.05	14,61***	$P < 0.001$	$P < 0.01$
Mean for self-reports	5.11	6.22	7.07			
Averaged peer reports						
Neuroticism	5.71	7.23	7.83	10,24***	$P < 0.001$	n.s.
Extraversion	5.01	5.71	6.54	5,14**	$P < 0.01$	n.s.
Openness to experience	3.72	4.49	4.22	5,16**	$P < 0.05$	n.s.
Agreeableness	5.01	5.30	6.72	5,27**	$P < 0.01$	$P < 0.05$
Conscientiousness	4.85	5.43	6.38	5,23**	$P < 0.01$	n.s.
Mean for peer reports	4.86	5.63	6.29			

[a] MZ, monozygotic; DZ, dizygotic; DZ-SS, dizygotic same-sex; DZ-OS, dizygotic opposite-sex.
** $P < 0.01$.
*** $P < 0.001$.

being the moderator term, and b_1, b_2, and b_3 as regression coefficients. The crucial information in this model is coefficient b_3 that gets positive if higher treatment similarity co-occurs with a steeper regression slope of Twin 2's trait level on Twin 1's trait level, indicating a higher resemblance among co-twins. Model A, but not Model B and C predict a zero regression weight of the moderator term if genetic relatedness is kept constant. Due to sampling error, regression weights of exactly zero are highly unlikely, but Model A implies that positive and negative coefficients b_3 should occur with equal probabilities if the moderated regression analyses are run within the group of MZ twins.

We ran 10 (similarity of treatment variables)×4 (all twin pairs, MZ pairs, same-sex DZ pairs, opposite-sex DZ pairs)×5 (dimensions of the five-factor model)×2 (self-ratings and peer ratings)×2 (raw scores and residualized scores, controlling for linear effects of age and sex) = 800 moderated regression analyses and counted the percentages of positive regression weights for the moderator term. Table 3 reports these percentages broken down for the 10 treatment variables and the four groups of twins. Thus, each entry in the body of Table 3 is based on 20 regression analyses, and the figures in the bottom row are based on 200 analyses. Chi-square significance tests were then applied to test the null hypothesis that the probabilities of positive and negative regression weights were both $P = 0.50$.

Table 3 shows a clear pattern: as predicted by all three models, the weights of the moderator term were predominantly positive in the zygosity-heterogeneous group of all twins. If the analyses were limited to either the MZ or DZ groups, however, positive regression weights were as frequent as negative regression weights. Admittedly, the proportion of positive regression weights for the treatment variable "Common leisure activities" was higher among MZ twins than expected by chance, as was the proportion of positive regression weights for the treatment variable "Same toys" among the opposite-sex DZ twins. But these findings did not replicate in the other

Table 3
Percentage of positive regression weights for the moderator term[a]

Item	Percentage of positive Regression weights			
	All Twins	MZ	DZ-SS	DZ-OS
Dressed alike	90***	30	30	40
Same hair style	100***	60	50	45
Common leisure activities	90***	80**	45	45
Same toys	95***	50	55	80**
Only one purchase for both twins	45	35	35	60
Presented as a twin pair	50	40	50	45
Same kindergarten group	70	50	45	60
Same class in school	90***	65	60	25*
Frequently referred to as "The Twins"	75*	50	70	55
Generally treated alike	95**	60	45	45
Aggregated across the 10 treatment items	80***	52	48.5	50

[a] MZ, monozygotic twins; DZ-SS, dizygotic same-sex twins; DZ-OS, dizygotic opposite-sex twins.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$, according to a χ^2-test of equal probability.

zygosity-homogeneous samples, and for the treatment variable "Same class in school", there were even less positive regression weights among opposite-sex DZ twins than expected by chance. Hence, these were probably chance findings, and it is justified to conclude that treatment similarity was associated with resemblance in personality in zygosity-heterogeneous groups only. Exactly this is predicted by Model A.

In additional analyses, we checked if it made a difference: (1) whether raw scores or residualized scores controlling for age and sex, (2) whether self-ratings or peer ratings, and (3) which personality dimensions were studied. For these analyses, we combined the regression weights of the 800 moderator terms in different ways. For example, to compare raw scores with residualized scores, we studied the distribution of positive and negative regression weights separately for raw scores and residualized scores, and separately for the different groups of twins, but across the 10 treatment variables, the five personality dimensions, and self and peer ratings. Once more, significantly more positive than negative moderator terms were observed for the zygosity-heterogeneous group of all twins only. So the finding of lack of systematic relations, in zygosity-homogeneous groups, between treatment similarity and personality resemblance appears to be reliable.

3. Discussion

The assumption that the shared environment has the same influence on MZ and DZ twins is crucial for the internal validity of the behavior-genetic twin design. Therefore, this assumption has been repeatedly tested before. A problem with such tests, however, is that a null hypothesis is to be confirmed, and that a relation between treatment similarity and resemblance in behavior may not be obtained because important environmental variables were not included in the study. This makes it desirable to study the same problem with different environmental variables, different samples of twins, different measures of traits, and different data-analytic approaches. This was the purpose of the present study, and it provides further support for the tenability of the equal-environments assumption.

The main differences of the present study from previous tests of the equal environments assumption are that it included peer ratings in addition to self-ratings, and that the equal environments assumption was tested by moderated multiple regression, whereas similarity of treatment was correlated with co-twins' intrapair differences in previous studies (Loehlin & Nichols, 1976; Plomin, Willerman, & Loehlin, 1976).

A major advantage of our use of peer reports was that treatment similarity and trait levels were reported by different judges, reducing the possible influence of implicit theories of personality.

And the use of moderated multiple regression instead of difference scores is desirable because difference scores tend to be unreliable if the two subtracted variables are positively correlated with each other. Co-twins' trait levels, particularly those of MZ twins, are positively correlated, implying that correlations of intrapair differences between twins, particularly MZ twins, with any other variable tend to be low. Whereas low reliabilities operate against the hypothesis in most studies, they tend to operate in favor of the equal environments assumption. Fortunately, tests of the equal environments assumption via moderated multiple regression overcome this problem.

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