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Twin Method: Defense of a Critical Assumption

Sandra Scarr[1] and Louise Carter-Saltzman[2]

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Since Galton's time, critics of the twin method have rejected the evidence of genetic differences in human behavior, because the twin method assumes that identical and fraternal pairs have equally similar environments. Twins whose genetic similarity is misperceived by themselves and others provide a critical test of the adequacy of this assumption. The relative effects of perceived and actual genetic similarity on cotwin differences in cognitive, personality, and physical development were assessed in a sample of young, adolescent twins whose genetic similarity was often misperceived. Twins' responses to questions about their own and others' judgments about their zygosity and physical similarity, and the ratings of similarity by eight judges, were used to estimate the perceived similarity of the twins. Actual zygosity was established by matching cotwins on 12 or more blood group loci. Perceived zygosity and perceived similarity by self and others were found to be insignificant biases in the twin study method.

KEY WORDS: zygosity; twins; blood groups; cognitive abilities; personality; skeletal growth; tissue growth; skin reflectance; perceived similarity of twins.

INTRODUCTION

Twin studies have provided the bulk of evidence for genetic variance in human behavior. The classic twin study method compares the similarity of monozygotic (MZ) to dizygotic (DZ) pairs. The greater similarity of MZ than DZ twins is interpreted as evidence for the influence of genetic differences on behavior.

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[1] Department of Psychology, Yale University, New Haven, Connecticut 06520.
[2] Department of Psychology, University of Washington, Seattle, Washington 98195.

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One of the basic assumptions of the twin method is that the within-family environments of MZ and DZ twins are equally variable. Kamin (1973), for example, has suggested that the greater intellectual similarity of MZ twins can be accounted for by the greater similarity of their environments.

Most investigators of twins would agree that MZ twins share more experiences during development. Monozygotic twins are more often confused for each other by parents, teachers, friends, and strangers (Cederlof *et al.*, 1961; Cohen *et al.*, 1973; Nichols and Bilbro, 1966). Because of their striking physical resemblance, MZ twins are likely to be treated more alike by significant others. Parents, in fact, report that their MZ twins were more similar behaviorally throughout development. Parents also hold more similar expectations for their MZ than DZ twins with respect to social responsibility and independence (Scarr, 1968).

Likewise, MZ twins themselves report that they are more similar in many aspects of their life style. They more often share the same friends, spend more time together, and make more similar choices in dress, foods, sports, study habits, etc. (Jones, 1955; Scarr, 1968; Smith, 1965). Thus the evidence of greater environmental similarity for MZ than DZ twins is overwhelming. But does this constitute a bias in the twin study method?

Critics of twins studies have assumed that differential treatment of MZ and DZ pairs constitutes *prima facie* evidence of bias. It does not. The direction of effect in the correlation between zygosity and environmental similarity is not at all clear. It is possible that the greater genetic similarity of MZ twins leads to more similarity in their environments. Parents and others may respond to the behavioral similarity of MZ pairs with more similar expectations for them, and identical twins themselves may select and attend to more similar aspects of their environments.

If the usually observed behavioral differences between MZ cotwins are smaller than those between DZ cotwins, then critics assume that the experiential differences between DZs are a sufficient explanation for their greater behavioral differences. If that were true, then MZs who are treated more differently by their parents than other MZs would be less similar than MZs who are treated more alike. This was the logic of the study by Loehlin and Nichols (1976), who calculated the correlations between environmental differences of MZ cotwins on those variables that differentiated MZ and DZ twins and personality and intellectual differences between MZ cotwins. They found little relationship between differences in parental treatment and experiences and test score differences. Thus the differences in treatment between MZs who were treated similarly and those who were treated differently could not account for the magnitude of the differences between MZs and DZs.

Our strategy was to examine the relationship between self-perceptions and others' perceptions of twin similarity and actual similarity on cognitive, personality, and physical variables.

The critics seldom note that twins, their parents, and others often make wrong judgments about the twins' zygosity. In several studies (Carter-Saltzman and Scarr, 1977; Scarr, 1968; Smith, 1965) from 18% to 40% of twins and their parents believe MZs to be DZs and the reverse. Raters who are asked to assign zygosity on the basis of photographs in large samples of twins have similarly high error rates (Gottesman, 1963).

Twins who are wrong about their own zygosity afford an unusual opportunity to study the direction of effect in the correlation between zygosity and environmental similarity. If genetic similarity were the sole determinant of behavioral likeness, then DZ twins who believe themselves to be MZs will be no more alike than other DZs, and MZs who mistake themselves for DZs will be no more different than other MZs. If, however, beliefs about zygosity determine the extent to which cotwins are behaviorally similar, then DZ twins who believe they are MZs will be as similar as true MZs. Likewise, MZs who believe they are DZs will be as different as true DZs.

Even this apparent bias, should it be found, has an alternate explanation. The degree of similarity between cotwins may influence their judgments about zygosity, so that particularly similar DZs are more likely to believe themselves to be monozygotic and particularly dissimilar MZs tend to believe they are dizygotic. While both physical and psychological similarities may be the basis for beliefs about zygosity, it is very difficult to disentangle the extent to which beliefs about zygosity influence *behavioral* similarity or are based on it.

Since degree of *physical* similarity (in height, skin color, and skeletal age, for example) is highly unlikely to be affected by twins' beliefs about their own zygosity, any correlation between physical similarity and beliefs about zygosity must be caused by physical resemblance and not by beliefs.

This study tests the hypothesis that actual zygosity, not the twins' (correct or erroneous) beliefs about it, determines the degree of behavioral similarity between cotwins. In addition, physical similarity is proposed as the basis for the twins' perceptions of their own zygosity.

METHOD

Subjects

A sample of 400 pairs of same-sex, 10- to 16-year-old twins was drawn from black and white populations in the Philadelphia metropolitan area.

Each child was assessed on cognitive, personality, and anthropometric measures. Blood samples, personal interviews, and X-rays were also taken.

Interview

Each twin was individually interviewed about his perceptions of his zygosity and similarity to his cotwin. The measures of perceived similarity included the twins' answers to four questions: "Are you and your twin identical or fraternal twins?" "Do you and your twin look as alike as carbon copies?" "Are you and your twin often mistaken for each other by teachers and friends?" and "Do you and your twin dress alike? If so, how often?" Since few of the twins dressed alike often, the question was dichotomized into yes (ever) and no (never).

Photographs

Two-thirds of the twin pairs were photographed in front-full-face and lateral poses. One-third were not photographed because of limitations in the facilities. Black and white prints of the twins' photographs were mounted in albums with one pair per page. Eight graduate students judged the similarity in appearance of the twin pair on a scale from 1 = surely MZ to 6 = surely DZ. For more procedural detail, see Carter-Saltzman and Scarr (1977).

Measures

Each twin was tested, in a small group apart from the cotwin, on the following six clusters of cognitive, personality, and physical measures: (1) *cognitive abilities:* Raven Standard Progressive Matrices, Peabody Picture Vocabulary Test (Dunn, 1959); Columbia Mental Maturity Scale (Burgemeister *et al.*, 1959); and the Revised Visual Retention Test (Benton, 1963); (2) *personality:* Junior Eysenck Personality Inventory (Eysenck, 1965) and the Coopersmith Self-Esteem Inventory (Coopersmith, 1967); (3) *skeletal growth:* stature (stat), sitting height (sit ht) by standard anthropometric techniques, and skeletal age (SA), rated by the Greulich-Pyle method from hand-wrist X-rays; (4) *tissue growth:* weight (wt), upper arm circumference (UAC), and triceps skin fold thickness (TSFT) by standard anthropometric techniques; (5) *skin reflectance:* (RFH) by reflectometer with red filter on the forehead; (6) *blood group loci:* the 12 loci on which complete data were available for a large number of twin pairs are ABO, Rh, Kell, Duffy, MNSs, AK, Hp, Tf, Gm, Gc, Cp, and INV_1. Zygosity was determined by concordance or discordance at 12–23 loci by the Minneapolis War

Memorial Blood Bank. If cotwins were found to be discordant at only one locus, the laboratory tests were rerun to exclude errors in zygosity determination.

Twin Differences

Twin pairs were classified as MZ or DZ by blood-group zygosity. All scores on the psychological and physical measures (with the exception of blood groups) were standardized to a mean of 0 and a standard deviation of 1 within each 1-year age group (with at least 100 children in each age band). This procedure eliminated age differences and permitted comparisons of cotwins' differences across measures. Absolute differences between cotwins were calculated on the standard scores for each physical and psychological measure.

RESULTS

Perceived Zygosity

Three hundred and forty-two of the 400 pairs of twins had nearly complete data on blood groups, self-perceived zygosity, and physical and psychological measures. The relationship between actual zygosity and self-perceived zygosity is shown in Table I.

Only 60% of both MZ and DZ groups were correct about their own zygosity. Forty percent of the twins either were wrong or disagreed about their zygosity.

To test the effects of true (blood-grouping) zygosity and the twins' perceptions of their own zygosity, absolute differences in test scores, physical measures, and blood groups were calculated. Table II gives the average absolute differences in scores for the MZ and DZ twins who classified themselves as MZ or DZ or who disagreed about their zygosity.

There were two patterns of relationship between zygosity and absolute difference scores: (1) those where true zygosity, but not self-perceived

Table I. Blood Group and Self-Perceived Zygosity of 10- to 16-Year-Old Twins

	Claimed zygosity			
Blood group zygosity	Agree MZ	Disagree	Agree DZ	
MZ	104	49	21	174
DZ	20	47	101	168
Total	124	96	122	342

zygosity, was related to cotwin differences and (2) those where both true and perceived zygosity were correlated with cotwin differences.

On intellectual measures cotwins were found to resemble each other according to their true, not self-perceived, zygosity. Identical twins had smaller absolute differences on the four cognitive tests, regardless of their beliefs about their monozygosity, as shown in Table II. The trend toward smaller absolute differences among cotwins who believed they were MZs results from a highly inconsistent pattern of results across tests and was not statistically significant (see Table VIII for a similar result). Differences in skin color reflectance were also related to actual and not perceived zygosity. Evidently, twins' beliefs about zygosity are not influenced by the relatively subtle cotwin differences in pigmentation or cognitive skills.

For personality measures MZ twins were significantly more similar than DZs, and DZ twins who believed they were monozygotic were more similar than those who disagreed and those who correctly believed they were fraternal pairs. Both true and perceived zygosity were related to cotwin similarity on personality measures.

Two sets of physical measurements show that both actual and perceived zygosity were related to the degree of physical similarity in a pair of twins. Although identical twins were more similar than fraternals on all measures of skeletal and tissue growth, DZ pairs who were particularly similar in physical growth were more likely to believe that they were identical.

Blood group similarities at 12 loci showed that those DZ twins who believed they were MZs were actually more similar genetically than other DZ pairs. On the average DZ cotwins differed at 2.75 blood group loci ($SD = 1.46$). Those DZs who agreed they were DZs differed at more than three loci, whereas those who incorrectly agreed they were MZs differed at only one and one-half loci, on the average. DZ pairs who disagreed about their zygosity had an intermediate number of blood group differences. Beliefs about zygosity were highly related to the genetic similarity of the DZ twins.

Perceived Similarity

A single measure of self-perceived zygosity may not be the most accurate representation of what the critics mean by biasing perception of the two kinds of twins. Also, in a sample of young twins, self-perceptions may not be an adequate guide to how similar they appear to others. Therefore, we included the several interview questions asked of the twins (Look alike?, Mistaken for each other?, Dress alike?) with the direct question about their zygosity. In addition, eight graduate students in psychology

Table II. Average Absolute Differences in Cognitive, Personality, and Physical Measures by True and Perceived Zygosity

		Perceived zygosity						Significance levels					
		Agree MZ		Disagree		Agree DZ							
Measures	True zygosity	N	$\lvert\bar{d}\rvert$	N	$\lvert\bar{d}\rvert$	N	$\lvert\bar{d}\rvert$	F_T	$p<$	F_p[a]	$p<$	$F_{T\times p}$[a]	$p<$
Cognitive	MZ	89	0.66	41	0.71	20	0.77	3.21	0.01	0.62	0.65	0.97	0.43
(4 tests)	DZ	16	0.78	33	0.83	84	0.81						
Personality	MZ	98	0.81	47	0.85	21	0.85	2.77	0.03	2.35	0.05	0.66	0.62
(2 tests)	DZ	17	0.77	47	1.07	101	0.93						
Skeletal growth	MZ	97	0.32	45	0.42	18	0.41	29.29	0.00	5.38	0.00	2.45	0.06
	DZ	19	0.39	47	0.81	98	0.72						
Tissue growth	MZ	104	0.43	49	0.48	21	0.56	23.23	0.00	5.48	0.00	2.79	0.04
	DZ	18	0.44	47	0.96	101	0.87						
Skin reflectance	MZ	93	0.30	46	0.31	19	0.19	12.07	0.00	0.72	0.40	0.81	0.37
	DZ	20	0.43	44	0.40	95	0.43						
Blood groups	MZ	80	0.00	39	0.00	14	0.00	531.84	0.00	16.64	0.00	17.86	0.00
	DZ	13	1.54	34	2.41	76	3.14						

[a] Contrasts based on agree MZ vs. agree DZ only. Analyses by SPSS ANOVA, option 9 (regression approach).

(two each, black and white, male and female) rated full-face and lateral photographs of the twins on a 6-point scale of zygosity from 1 = surely MZ to 6 = surely DZ. The eight sets of ratings were averaged for the present purposes, because there were no significant differences among the raters by race or sex (Carter-Saltzman and Scarr, 1977).

As Table III shows, the various measures of perceived and actual zygosity are moderately to highly correlated with each other. Only dressing alike is poorly related to the other measures. The number of blood group differences is, of course, highly correlated with true zygosity since MZ twins, by definition, have no differences, and about half of the pairs are identical.

Even the rating of perceived similarity by self and others may not capture the "real" similarity in the appearance of the cotwins. Therefore, we used the actual physical measurements of the twins' height, weight, arm circumference, fattiness, and the like to establish the overall physical differences between cotwins.

The measures of perceived similarity were applied to predict the differences in cotwins' cognitive scores, because this is the area of greatest dispute for the critics of the twin study method. It did not seem necessary to analyze more extensively the physical growth differences, because the twin's own perception of zygosity had already been shown to be predicted by the physical differences. The findings for the personality measures were not sufficiently robust, for either actual or perceived zygosity, to withstand the large reduction in sample size necessitated by the inclusion of the ratings of the photographs. Thus only the cognitive measures were subjected to the more extensive regression analysis.

Differences in cognitive scores were regressed on the perceived and physical differences of MZ and DZ pairs separately. For DZs only, the number of blood group differences (out of 12) between cotwins was also entered into the equation. The latter measure takes into account the varying

Table III. Correlations Among Measures of True and Perceived Differences (N = 226–361)

	1	2	3	4	5	6	7
1 True zygosity (1 = MZ, 2 = DZ)	X						
2 Number of blood group differences	0.801	X					
3 Look alike? (1 = yes, 2 = no)	0.426	0.429	X				
4 Mistaken? (1 = yes, 2 = no)	0.510	0.548	0.388	X			
5 Dress alike? (1 = ever, 2 = never)	0.023	0.040	0.286	0.202	X		
6 Twin perceived zygosity (1 = MZ, 2 = don't know, 3 = DZ)	0.566	0.621	0.546	0.542	0.194	X	
7 Eight raters' zygosity (1 = surely MZ, 6 = surely DZ	0.659	0.642	0.514	0.451	0.151	0.554	X

Table IV. Regressions of Twin Differences in Cognitive Test Scores on Measures of Perceived and Physical Differences (MZ pairs only, $N = 104$)

	Test							
Differences	Raven		PPVT		Columbia		Benton	
Perceived								
Eight raters	0.27[c]	0.24[c]	−0.05	−0.04	0.03	0.02	0.07	0.08
Dress alike	0.04	0.04	−0.07	−0.07	−0.02	−0.04	−0.01	−0.01
Look alike	0.05	−0.05	−0.01	−0.04	0.06	0.04	0.07	0.04
Mistaken	0.02	0.00	−0.00	0.01	−0.16[c]	−0.11	−0.05	−0.06
Twin zygosity	0.01	−0.00	0.02	0.02	0.12[a]	0.11	0.08	0.09
Physical								
Skeletal age		0.03		−0.12[b]		0.03		−0.06
UAC		0.04		−0.06		−0.12		−0.09
TSFT		0.06		0.00		−0.04		−0.02
Sitting height		0.08		0.01		0.10		−0.02
Weight		−0.07		0.15[b]		0.18[c]		0.18[c]
RFH		0.15[c]		−0.05		0.16[c]		−0.08
Stature		0.01		0.03		−0.04		−0.04
R^2	0.07	0.11	0.01	0.03	0.03	0.09	0.02	0.05
Shrunken R^2	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F	3.21[b]	1.95[a]	0.38	0.56	1.28	1.60	0.94	0.95

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.001$.

degrees of genetic similarity among the DZ twin pairs. Perceived differences were represented by the twins' own perceived zygosity, the three questions about similarity in appearance, and the average of the eight ratings of zygosity. Physical differences were represented by the average absolute difference ($|\bar{d}|$) of cotwins on seven physical measures.

In Table IV the regressions of cognitive score differences are given for the MZ pairs only. Four of the five tests did not yield significant equations for the effects of perceived differences or the effects of perceived and physical differences on cotwin differences in test scores. The Raven Matrices score differences were significantly predicted by differences in appearance, as rated by eight psychologists, and by differences in skin color (RFH). Both coefficients were in the predicted direction indicating that MZ twins who appear particularly similar are more similar in Raven scores. The variance accounted for by the combined measures of perceived similarity was only 2.3%, adjusted for shrinkage, and 0% for the perceived and physical differences. In the prediction equations for the other three cognitive tests, none of which was statistically significant, there were two significant coefficients in the wrong direction (less similar twins were more similar in tests scores) and four in the predicted direction. Thus there is evidence for a negligible amount of bias in perceived and physical similarity creating greater cognitive similarity among MZ twins.

For comparison, the same equations are given for the DZ pairs in Table V. In addition to the equations for perceived differences and for perceived and physical differences, a third equation including perceived, physical, and blood group differences is given. Five of the 12 equations were statistically significant, three for the Raven scores, and one each for the PPVT and the Benton. For the DZs, larger differences in Raven scores were significantly related to greater similarity in appearance, as rated by eight psychologists and by the twins themselves. Greater physical differences in weight and skeletal age were related to smaller Raven score differences, whereas greater difference in sitting height was related to greater difference in test scores. The largest coefficient was for number of blood group differences, which predicted larger test score differences for the DZ pairs.

For the PPVT, cotwin differences in scores were related to smaller differences in skeletal age and weight and to larger differences in stature, sitting height, and blood groups. For the Columbia, twin differences were positively related to differences in sitting height and blood groups and negatively related to differences in weight and being mistaken for each other. Finally, differences in Benton scores were related to looking less alike but being more often mistaken for one another, a peculiar combination of predictors.

The set of results for the DZ twins yielded a mixed picture, with the exception that number of blood group differences was usually predictive of cognitive score differences. The best combinations of predictors always included some coefficients in positive and some in negative directions.

To test for the relative efficacy of perceived, physical, and genetic differences in predicting twin test score differences, the MZ and DZ groups were combined and all of the predictors entered into the equation simultaneously. Table VI gives these results for the four cognitive tests. As in the analyses of DZ twins, the best predictors of cognitive test score differences among the MZ and DZ twins were genetic differences. In fact, differences in Raven Matrices and Figural Memory scores were greater among the twins with more similar appearance, once true zygosity was controlled. For the Matrices, four of the five coefficients for perceived similarity were negative, and Raters' Zygosity significantly so. For the PPVT, all of the perceived similarity coefficients were small, and three of them negative. For the Figural Memory test, perceived differences were largely positive predictions of score differences, but the only significant one was negative. Thus it does not appear that perceived similarity, by either self or others, contributes to the greater similarity of MZ than DZ twins. If anything, the more similar-appearing twins performed more differently on the cognitive

Table V. Regressions of Twin Differences in Cognitive Test Scores on Measures of Perceived, Physical, and Genetic Differences (DZ pairs only, $N = 122$)

	Test											
Differences	Raven Matrices			PPVT			Columbia			Benton		
Perceived												
Eight raters	−0.35[c]	−0.34	−0.42[c]	0.05	0.03	−0.04	0.05	0.04	−0.01	−0.08	−0.05	−0.03
Dress alike	0.06	0.05	0.06	−0.02	−0.04	−0.03	−0.02	−0.02	0.01	0.03	0.05	0.05
Look alike	−0.02	−0.03	−0.17[a]	−0.00	0.00	−0.12	−0.01	−0.03	−0.10	−0.24[c]	0.23[c]	0.25[c]
Mistaken	0.03	0.02	0.01	0.07	0.08	0.07	−0.13[a]	−0.13[b]	−0.14[b]	−0.21[c]	−0.21[c]	−0.21[c]
Twin zygosity	0.07	0.08	0.02	0.04	0.06	0.00	−0.07	−0.06	−0.10	−0.09	−0.08	−0.07
Physical												
Skeletal age		−0.02	−0.20[c]		−0.21[c]	−0.37[c]		0.02	−0.09		0.09	0.12
UAC		−0.07	−0.04		−0.07	−0.17		0.01	0.07		−0.01	−0.03
TSFT		0.03	0.06		0.04	0.07		0.01	0.03		−0.03	−0.04
Sitting height		0.01	0.35[c]		0.12	0.43[c]		0.04	0.24[c]		0.11	−0.16
Weight		0.04	−0.20[b]		−0.08	−0.29[c]		−0.04	−0.19[c]		−0.09	−0.05
RFH		0.04	0.05		−0.04	−0.04		0.00	0.01		−0.02	−0.03
Stature		0.01	0.02		0.16[c]	0.18[c]		0.08	0.10		0.10	0.10
Genetic differences												
Numbers of blood group differences			0.47[c]			0.42[c]			0.28[c]			−0.08
R^2	0.11	0.12	0.23	0.01	0.06	0.15	0.03	0.04	0.08	0.07	0.10	0.10
Shrunken R^2	0.07	0.02	0.14	0.00	0.00	0.05	0.00	0.00	0.00	0.03	0.00	0.00
F	4.78[c]	2.01[a]	4.11[c]	0.42	1.06	2.52[b]	1.04	0.58	1.15	3.04[a]	1.70	1.62

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.001$.

Table VI. Regressions of Twin Differences in Cognitive Test Scores on Measures of Perceived, Physical, and Genetic Differences (MZ and DZ pairs combined, $N = 226$)

	Test			
Differences	Raven	PPVT	Columbia	Benton
Perceived				
Eight raters	−0.23[a]	−0.02	−0.05	0.03
Dress alike	0.11	−0.08	−0.02	0.02
Look alike	−0.00	−0.02	0.03	0.15
Mistaken	−0.06	0.09	−0.18[b]	−0.19[a]
Twin zygosity	−0.05	0.10	0.03	0.03
Physical				
Skeletal age	−0.03	−0.16	0.00	0.04
UAC	0.04	−0.04	−0.05	−0.08
TSFT	0.01	0.05	−0.01	−0.03
Sitting height	0.01	0.11	−0.03	0.09
Weight	−0.09	0.08	0.09	0.03
RFH	0.07	−0.04	0.05	−0.04
Stature	−0.01	0.11	0.04	0.05
Genetic				
Number of blood group differences	0.44[c]	0.37[c]	0.08	0.21[a]
Dizygosity	0.01	0.34[c]	0.04	−0.09
R^2	0.11	0.09	0.04	0.06
Shrunken R^2	0.05	0.03	0.00	0.00

[a] $p < 0.05$.
[b] $p < 0.01$.
[c] $p < 0.001$.

test, once true zygosity was taken into account. The measures of physical differences were not significantly related to cognitive differences. The coefficients were small, and about equal numbers were positive and negative.

To reduce the number of variables that measure perceived similarity, we factor-analyzed the two ratings of zygosity and answers to three similarity questions. With a principal components program and a varimax rotation, a first factor accounted for 52.2% of the variance in the perceived difference scores. The loadings of the five variables, shown in Table VII, were nearly in the order with which they predicted actual zygosity. Although we did not predetermine the predictive value of the factor, it emerged well-weighted for the prediction of true zygosity.

True zygosity and the perceived differences factor scores were next used in a multivariate test. Since there were approximately equal numbers of true MZ and DZ twins with all necessary data, the perceived differences factor scores were simply divided around the median value to establish the perceived MZ and DZ groups. The average absolute differences for the four groups of correctly and incorrectly identified twins are given in Table VIII.

Univariate analyses of variance were calculated for cotwin differences in cognitive and personality tests scores and physical measures. Multivariate tests were applied to the cognitive, personality, and physical sets of measures. Table VIII gives the mean absolute differences between cotwin scores by true and perceived zygosity and the associated *F* tests for true, perceived, and true × perceived zygosity.

When perceived zygosity was assigned by the median value on the perceived differences factor, true zygosity (established by blood grouping) and the interaction of true and perceived zygosity were significantly associated with cotwin differences on two of the four cognitive tests. On the Raven Matrices and the Benton Figural Memory test, true MZs were more similar than true DZs, but the twins who were confused or wrong about their zygosity were more different, on the average, than the correctly diagnosed DZs. Thus there was an interaction between true and perceived zygosity.

For the personality tests, only true zygosity was predictive of cotwin score differences on the EPI scale, introversion-extraversion. Similarities in self-esteem were not significantly associated with either true or perceived zygosity, but the means were clearly in the direction of true zygosity effects.

The physical measures differed between cotwins according to both true and perceived zygosity, and sometimes the interaction of the two. MZs were physically more similar than DZs, but those MZs who were more different were perceived and perceived themselves more often as DZs, and those DZs who were physically more similar were more likely to perceive themselves and to be perceived as MZs. The interactions of true and perceived zygosity resulted from particularly small physical differences among DZs who mistook themselves and were mistaken for MZs. As the blood group differences show very clearly, the DZs who were mistaken for MZs had fewer blood group differences than other DZs—nearly 2 SD from the DZ mean. Although the DZs mistaken for MZs had on the average less than one blood group difference on the 12 loci included in this report, all pairs had at least one *replicated* difference on the 12 to 23 loci tested in the study. The implication of the small number of blood group differences among DZs

Table VII. Perceived Similarity Factor, the First Principal Component

Factor I[a]	Loading
Twin's perceived zygosity	0.842
Rater's perceived zygosity	0.813
Mistaken for each other	0.741
Look alike?	0.722
Dress alike?	0.112

[a] Eigenvalue = 2.61, percent variance = 52.2.

Table VIII. Average Absolute Differences Between Cotwins on Cognitive, Personality, and Physical Measures by True Zygosity and Perceived Differences as Rated by Twin Pairs and Others (Median Split in Perceived Differences for Perceived MZ and DZ)

	True zygosity–perceived zygosity										
	MZ–MZ (N = 84)		MZ–DZ (N = 19)		DZ–MZ (N = 15)		DZ–DZ (N = 86)		F_t	F_p	$F_{t \times p}$
Measures	m	SD	m	SD	m	SD	m	SD			
Cognitive tests									1.74	1.08	1.66
Raven	0.66	0.50	0.80	0.70	1.11	0.78	0.82	0.69	4.24[a]	0.17	3.23[a]
Columbia	0.91	0.68	0.83	0.76	1.04	0.62	0.84	0.72	0.06	1.01	0.21
PPVT	0.58	0.52	0.60	0.38	0.51	0.47	0.67	0.51	0.78	0.87	0.56
Benton	0.61	0.50	0.97	0.62	0.89	0.87	0.83	0.79	2.70[a]	1.77	2.70[a]
Personality tests	(N = 97)		(N = 20)		(N = 19)		(N = 109)		1.78	0.01	0.38
EPI extraversion	0.84	0.68	0.75	0.46	0.88	0.76	1.00	0.78	2.68[a]	0.01	0.75
Coopersmith self-esteem	0.85	0.62	0.84	0.63	0.96	0.66	0.96	0.76	1.43	0.00	0.00
Physical measures	(N = 88)		(N = 20)		(N = 19)		(N = 103)		12.98[a]	3.21[a]	1.10
Stature	0.42	0.43	0.43	0.41	0.46	0.38	0.69	0.69	9.47[a]	1.48	1.27
Skeletal Age	0.30	0.30	0.38	0.30	0.44	0.31	0.75	0.55	43.68[a]	6.22[a]	2.40[a]
UAC	0.45	0.37	0.77	0.58	0.53	0.43	1.02	0.69	35.20[a]	17.18[a]	0.70
TFST	0.46	0.34	0.66	0.61	0.56	0.40	0.85	0.72	17.46[a]	6.17[a]	0.21
Sitting height	0.35	0.36	0.40	0.34	0.42	0.32	0.77	0.64	28.19[a]	5.12[a]	2.79[a]
Weight	0.37	0.35	0.56	0.43	0.33	0.30	0.89	0.67	32.94[a]	16.81[a]	4.20[a]
RFH	0.30	0.30	0.24	0.31	0.36	0.45	0.45	0.41	8.98[a]	0.05	1.38
	(N = 81)		(N = 18)		(N = 13)		(N = 87)				
Blood group differences	0.00	0.00	0.00	0.00	0.69	0.48	2.98	1.32	456.23[a]	32.74[a]	42.64[a]

[a] $p < 0.05$ (or less). Analyses by SPSS ANOVA, option 9 (regression approach).

confused for MZs is that they are genetically more similar in general than other DZs, a result which can explain their greater physical similarity.

DISCUSSION

Perceived similarity is not an important bias in studies of genetic variance in intellectual skills. For personality variables, perceived zygosity may have some effect on fraternal pairs who believe themselves to be monozygotic. Similarity in personality may be, however, like observable, physical traits, a basis for the twins' perceptions of their zygosity. Furthermore, the blood group data indicate that DZ pairs who have fewer genetic differences are the ones who believe themselves to be monozygotic.

The critical assumption of equal environmental variance for MZ and DZ twins is tenable. Although MZ twins generally experience more similar environments, this fact seems to result from their genetic similarities and not to be a cause of exaggerated phenotypic resemblance.

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