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Cotwin Closeness in Monozygotic and Dizygotic Twins: A Biasing Factor in IQ Heritability Analysis?

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Abstract. For 98 pairs of MZ twins, four measures indicating degree of cotwin closeness were correlated with absolute differences between IQ scores within pairs. In two different twin samples (40 MZ vs 40 DZ pairs and 169 MZ vs 174 DZ pairs, respectively), means and standard deviations in the closeness variables were obtained for MZ and DZ pairs. Whereas MZ cotwins were clearly closer than DZ cotwins, the relation between cotwin closeness and similarity in IQ seemed rather weak and ambiguous. "Years lived together in childhood home" were positively related to similarity in IQ ($P < 0.01$), whereas subjective feeling of closeness in contact tended to be negatively related to similarity in IQ.

Key words: IQ and environment, Twin method, Environmental similarity in twins

INTRODUCTION

Heritability analysis by comparing identical (MZ) and fraternal (DZ) like-sexed twins rests on a number of assumptions [2,3] The present paper deals with one of the most critical of these: That MZ and DZ twins have equally similar environments. To the extent that this assumption is violated, heritability estimates will be biased.

It has often been maintained that this assumption is untenable, and there is also some evidence to indicate that MZ cotwins are treated more alike and spend more time together than the DZ [8,4]. However, such aspects of shared environment have typically seemed unrelated to cognitive and personality differences within pairs [5,7].

In any case, a demonstration of such a relation would automatically lead to the expectation of a biased heritability estimate from twin comparisons. An excess treatment

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similarity in MZ pairs might be produced by the twins themselves, due to their identical genotype. In all known methods of estimating genetic and environmental variance components, variance due to such forms of interplay between genes and environment is included among genetic components (for a thorough discussion, see, eg, [3]).

Just like treatment, cotwin closeness may be primarily a result of genetic similarity within pairs. But in contrast to most treatment variables, such pairwise closeness is unique to twins. Accordingly, twins are not representative of the population at large in this respect. Thus, even if possibly greater reciprocal influence in MZ cotwins is due largely to their identical genes, the result is inflated genetic variance. In this study we have therefore tried to concentrate on the quantity, as well as the quality, of closeness between cotwins. Two hypotheses will be tested:

1) There are certain aspects of cotwin closeness which contribute to pairwise similarity (differences) in IQ scores;
2) In these aspects, MZ cotwins are closer than the DZ.

MATERIALS AND METHODS

Sample

The subjects were sampled by three somewhat different procedures. They were all drawn from a population-based panel of Norwegian like-sexed twins. Zygosity was determined by means of a questionnaire. Correct classification has been estimated at 97.6% [6]. Mean ages of all subgroups by zygosity and sex were 40-44.2, with SDs 7.14-8.92 in samples 1 and 3 and 3.15-3.71 in sample 2.

1. In the first subsample, 37.4% of the pairs responded positively to a request-letter (40.4% MZ, 34.8% DZ). The final subsample consisted of 40 MZ (19 male, 21 female) and 40 DZ pairs (19 male, 21 female).

2. The second subsample, 66 MZ pairs (23 male, 43 female), was taken from a MZ twin-family project in which the subjects were recruited by telephone. Due to circumstances not concerning the present study, only twins with children accessible for testing were approached. Response rate was about 50% . The first and the second subsamples were both drawn from Oslo's urban and suburban population.

3. The third subsample consisted of pairs in which at least one twin was living in the county of Trondelag. The whole twin population (except 20% who had not responded to the zygosity questionnaire) within the age group 30-60 years was requested by mail to answer a multithematic questionnaire. The population is partly rural, mainly from sparsely populated areas, and partly urban. At the time of data analysis, the response rate was about 57%, ie, both twins answered of 169 MZ (79 male, 90 female) and 174 DZ (92 male, 82 female) pairs.

Tests and Questionnaire

All subjects were asked four questions, presumed to indicate cotwin closeness, which may well have led to reciprocal influence in IQ:

1) During your entire life, how close do you feel that you and your cotwin have been? Compare to your impression of closeness between ordinary siblings:
   1 Less close than ordinary siblings
   2 As close as ordinary siblings
   3 Somewhat closer than ordinary siblings
   4 Much closer than ordinary siblings
2) How many years did you spend in the same class in school?
3) At what age did you leave your childhood home?
4) How far from each other (in km) do you live now?

In the further analysis, mean pair values were applied for variables 1, 2, and 4. The responses to question 3 were transformed into "years common in childhood home", using the lowest of the two values in the pair.

Sample 1 was individually tested with a complete WAIS IQ-test. Sample 2 was individually tested with 5 of the 11 WAIS subtests: Information, Similarities, Digit span, Digit symbol, and Block design. On the basis of these, a "short form IQ" with ordinary mean and SD was computed. The computation procedure was based on the 160 scores in sample 1. The correlation between full scale and short form scores was estimated to be 0.93. For the present purpose, this correlation is sufficiently high to treat the two scores as identical measures. Sample 3 was not accessible to IQ testing and was included in this study only to have a more powerful test of the hypothesis of an excess MZ closeness.

Method

To quantify a relation between similarity in IQ scores and cotwin closeness, the four variables indicating closeness were correlated with absolute IQ differences within MZ pairs. In addition, multiple regression analysis of the closeness variables on absolute IQ differences was performed to have a single composite of reciprocal influence. Only the MZ scores were analysed, in order to avoid concounding genetic influence. In the MZ, of course, phenotypic differences within pairs (and correlations between closeness and phenotypic differences) are purely environmental whereas in the DZs they may result from genetic differences within pairs.

To test whether MZ cotwins are closer than the DZ for aspects which affect IQ, mean differences between MZ pairs and DZ pairs were obtained for alla closeness variables and for the multiple regression composite.

RESULTS

Means, SDs, and intraclass correlations (t) for IQ are shown in Table 1. No differences across zygosity or subsamples approached significant values. The 7.3-point sex difference is probably due mainly to a 5-point sex difference in the population, which appeared in a recent normation of the Norwegian WAIS version [1].

The three variables, "felt closeness", "school together", and "childhood together", did not deviate substantially from a normal distribution. The distribution on the fourth variable, "distance between residences" was extremely skewed, with a tail upwards. Intuitively, the relationship between cotwin closeness and the distance between their residences is hardly lineal: clearly, a difference between 0 and 10 km is of greater importance than a difference between 290 and 300 km. To strengthen face validity of this variable, and to have an approximate (and testable) normal distribution, the square roots were applied in further analysis.

Correlations between the cotwins answers (for all subjects) were 0.53, 0.96, and 0.91 for variables 1, 2, and 4, respectively. No reliability measure is available for variable 3, where the subjects answered for themselves only.

Table 1 - Means, Standard Deviations and Intraclass Correlations in IQ

	N	X	SD	t_{MZ} (N = 106)	t_{DZ} (N = 40)
Male pairs	61	105.3	15.2	0.86	0.48
Female pairs	85	98.0	15.1	0.83	0.41
Total	146	101.0	15.6	0.85	0.47

Table 2 - Correlations Between Closeness Variables and Absolute IQ Differences Within Pairs

	Male pairs (N = 38)				Female pairs (N = 60)				Total (N = 98)			
	2	3	4	ΔIQ	2	3	4	ΔIQ	2	3	4	ΔIQ
1 Felt closeness	0.43**	0.40**	−0.23	0.15	0.03	−0.06	−0.15	0.17	0.30**	0.14	−0.14	0.17*
2 School together		0.35**	−0.09	−0.13		0.18	−0.14	−0.15		0.25**	−0.11	−0.13
3 Years lived together			−0.38**	−0.26*			−0.32**	−0.32**			−0.34**	−0.30**
4 Distance residence (Square root)				0.08				0.16				0.07

ΔIQ = absolute IQ differences within pairs.

** P < 0.05 * P < 0.10, two tailed tests.

MZ pairs of samples 1 and 2. Eight cases dropped due to missing data.

Table 3 - Means and Standard Deviations for the Closeness Variables, Sample 1

	Male pairs						Female pairs						Total					
	MZ (N = 19)		DZ (N = 19)				MZ (N = 21)		DZ (N = 21)				MZ (N = 40)		DZ (N = 40)			
	X	SD	X	SD	t	P <	X	SD	X	SD	t	P <	X	SD	X	SD	t	P <
Felt closeness	3.26	0.67	3.11	0.77	0.67	/	3.90	0.44	3.10	0.89	6.02	0.001	3.60	0.64	3.10	0.83	3.02	0.005
School together	8.42	3.95	7.92	3.82	0.40	/	9.71	2.45	7.76	2.56	2.52	0.05	9.10	3.27	7.84	3.18	1.75	0.10
Years lived together	21.05	3.75	20.58	3.31	0.41	/	21.48	4.11	21.00	3.15	0.43	/	21.28	3.90	20.80	3.19	0.60	/
Distance residence	14.92	19.69	9.36	11.32	/	/	9.24	15.30	16.93	22.32	/	/	11.94	17.53	13.34	18.15	/	/
Square root	3.01	2.49	2.58	1.69	0.62	/	2.15	2.21	3.39	2.39	1.75	0.10	2.55	2.36	3.01	2.10	0.91	/
Component (by regress.)	6.21	1.74	6.26	1.95	0.10	/	6.82	1.96	6.08	1.81	1.28	/	6.53	1.86	6.16	1.86	0.88	/
Component, males	6.47	2.45	6.66	2.57	0.24	/	/	/	/	/	/	/	/	/	/	/	/	/
Component, females	/	/	/	/	/	/	6.54	1.80	6.17	1.47	0.73	/	/	/	/	/	/	/

Table 4 - Means and Standard Deviations for the Closeness Variables, Sample 3

	Male pairs						Female pairs						Total					
	MZ (N = 79)		DZ (N = 92)				MZ (N = 90)		DZ (N = 81)				MZ (N = 169)		DZ (N = 174)			
	X	SD	X	SD	z	P <	X	SD	X	SD	z	P <	X	SD	X	SD	z	P <
Felt closeness	2.96	0.68	2.50	0.60	4.65	0.0001	3.47	0.60	2.86	0.64	6.39	0.0001	3.23	0.69	2.68	0.65	7.71	0.0001
School together	9.43	2.67	7.86	2.22	4.17	0.0001	8.77	2.16	7.83	2.32	2.74	0.01	9.08	2.43	7.82	2.28	4.93	0.0001
Years lived together	19.79	3.94	18.52	3.31	2.23	0.05	18.20	2.91	18.00	3.92	0.39	/	18.93	3.50	18.27	3.60	1.70	0.10
Distance residence	232.9	309.2	302.6	318.8	/	/	245.0	295.1	309.6	340.6	/	/	239.7	300.9	307.7	328.3	/	/
Square root	11.12	10.52	13.81	10.64	1.65	0.10	12.06	10.07	13.96	10.78	1.19	/	11.62	10.26	13.94	10.67	2.05	0.05
Component	6.09	1.79	6.14	1.67	0.20	/	7.64	1.37	6.90	1.81	2.98	0.005	6.92	1.75	6.52	1.78	2.09	0.05
Component, males	6.50	2.45	6.27	2.35	0.59	/	/	/	/	/	/	/	/	/	/	/	/	/
Component, females	/	/	/	/	/	/	7.37	1.24	6.84	1.66	2.34	0.05	/	/	/	/	/	/

Correlations IQ Differences-Closeness

As shown in Table 2, correlations between closeness variables and absolute differences in IQ scores are generally moderate. Although they are in the expected direction, only one, IQ difference - "childhood together", reaches a significant value. This correlation may seem surprisingly high and opens up for various speculations. A plausible one could be that variations in years of childhood together are mainly a result of IQ differences. If so, educational attainment is a likely mediating variable, since it is undoubtedly related to IQ, and probably in some way to departure from the childhood home. This parameter was recorded in sample one, quantified as sum of years in school and later education. To test the possible influence of educational attainment, a partial correlation analysis was performed, controlling for sum and/or difference of educational attainment within MZ pairs. This modification had virtually no effect on the original correlation value; the maximum difference was 0.02.

The positive correlation between "felt closeness" and absolute IQ differences is rather surprising, although just marginally significant ($P < 0.10$). If reliable, this correlation means that those MZ pairs feeling closest are the ones with the greatest discrepancy in IQ scores.

Applying regression analysis, only variable 3, "childhood together", contributed significantly in the expected direction ($P < 0.005$). However, variable 1, "felt closeness", contributed significantly in the opposite direction of the a priori expectations ($P < 0.05$). (In other words, when controlled for the remaining closeness variables, the positive correlation between variable 1 and IQ differences attained a significant level). Variance in absolute IQ differences accounted for by the closeness variables was 15% (11% adjusted). The composite was determined by the standardized regression equation,

$$C = 0.24\ V1 - 0.12\ V2 - 0.31\ V3 - 0.01\ V4$$

where C denotes the composite and V1 to V4 closeness variables. Analyzed for both sexes separately, the tendencies were very similar, but the contribution of variable 1 was not significant (males: $P < 0.10$, females: $P < 0.20$). The standardized equation for males was:

$$C = 0.34\ V1 - 0.15\ V2 - 0.41\ V3 - 0.17\ V4$$

and for females:

$$C = 0.17\ V1 - 0.09\ V2 - 0.27\ V3 + 0.08\ V4$$

Mean Differences Between MZ and DZ Pairs

For some variables, there are significant mean differences within zygosity and sex between all subsamples, probably due to sampling differences as well as subpopulation differences. Therefore, comparisons between MZ and DZ pairs are performed separately for each subsample (sample 2, which contains MZ pairs only, is excluded from this comparison.) Tables 3 and 4 show the results for samples 1 and 3. Generally, MZ cotwins feel much closer than the DZ, and spend more years together in school. There are tendencies in both subsamples that the MZ spend more years together in the childhood home, but this difference is significant only for males, sample 3.

Due to the large difference between MZ and DZ cotwins in "felt closeness", which is

positively related to absolute IQ differences, the values of the composite which predict IQ differences are generally greater for MZ than DZ twins, although significantly so only in the largest subsample.

CONCLUSIONS

The results are not fully conclusive. Clearly, in many ways MZ cotwins are closer than like-sexed DZ cotwins, but whether such closeness is related to similarity in IQ, is more uncertain. The face validity of the four variables as pure indicators of cotwin closeness may leave something to be desired. Further, different semantic interpretations or other sources of error may be specific to zygosity. In addition, the statistical indications of relations between IQ and closeness are rather weak. Only one of four correlations is clearly significant, and the partial correlation between variable 1 and IQ differences appears to be against the expectation. Nonetheless, these findings are at variance with previous results [5,7] which failed to show any relation between treatment closeness and similarity in cognitive measures in MZ cotwins. One possible explanation of this discrepancy is the much younger age of the twins in the previous studies.

With all possible reservations, we think the results suggest a rather complicated picture: Clearly, MZ cotwins are closer and spend more time together than DZ cotwins. In some respects, this may lead to greater similarity in IQ in MZ cotwins, but in other ways closeness may lead to greater differences in IQ, possibly due to some form of competition or functional complementarity. The results do not indicate, however, any dramatic effect on heritability analysis of such a possible bias.

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