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Qualitative and Quantitative Aspects on Mathematics Achievement in MZ and DZ Twins

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Abstract. Mathematics achievement test results have been collected for 22 MZ and 24 DZ same-sex twin pairs in the Swedish compulsory school. The twins were approximately 11-13 years of age and attended grades 4, 5, or 6. The twin pairs were part of a larger collaborative study between Israel and Sweden (the KAM-project). Teachers were asked how they planned and evaluated their work in the subjects Swedish and Mathematics. In addition to this, results for the twins on Maths tests given by the teachers in their regular work were collected. These tests were thus used by the teachers as an instrument to evaluate the educational process. Intrapair similarity for MZ and DZ twins has been compared for qualitative and quantitative aspects of the Maths tests. Different tests were used by the teachers but the same criteria have been used in the comparison. MZ twins are somewhat more similar than DZ twins for both the qualitative and quantitative aspects. Only one quantitative aspect, however, percentage of correct answers, shows a significant difference between the twin categories. A comparison was also made of intrapair similarity in classes, where the teachers differed according to planning and evaluation of their education. Irrespective of that, the MZ twins seemed to be more similar than the DZ twins in number of correct answers on the Maths tests. Educational implications are discussed.

Key words: Mathematics achievement, Education, School, Twins

INTRODUCTION

Sweden has a nine years comprehensive school, the purpose of which is, among other things to give all Swedish pupils an equivalent education. The curriculum stresses equality for all schoolchildren in the country. The importance of basic knowledge

is emphasized and should be the same for all pupils when they leave school. The differences between pupils are however large within subjects. The question is, what is the cause for this variation? Individual development is one important factor determining the possibility to profit from education. Ljung [10] has shown that there are differences between girls and boys concerning developmental growth. In a longitudinal study of schoolchildren aged between 10 and 14 years, Lindgren [9] has also found a relationship between physical and mental growth in both boys and girls. There is a sex difference too in growth spurt. In average, the female growth spurt begins about two years earlier than the male spurt.

Piaget emphasized learning as an active process, where biological factors interact with the training received. Kylén [8] has presented a developmental theory based on Piaget's thoughts. Abstract thinking is depending on biological maturity. The product of the interaction between biological maturity and individual experience shows the level of ability. Twin research offers a possibility to study influences of biological and environmental factors.

In a previous longitudinal Swedish twin study, Fischbein [3] found that MZ twins tend to react similarly to the same environmental influences while DZ twins tend to react differently in educational settings. In a permissive environment, this pattern was more obvious than in a restrictive one.

The training of different subjects at school is more or less permissive in the sense that the teacher or the textbooks give more or less room for pupil initiative. The mathematics subject is often quite restricted by textbooks and teacher instruction.

An interesting question is, therefore, what influences the childrens' ability to learn mathematics. Neuman [13] has studied how children learn to understand arithmetic problems. She also asked if there are styles of teacher instructions, which can avoid childrens' failures in mathematics learning.

Concerning the interaction of pupils' qualifications and instructional style of teaching, it is interesting to investigate how this interaction of biological factors and instructional style contribute to the pupil variation in mathematics learning. Twin studies offer one method to answer this question.

There are thus three different aims in this study:

1. To compare quantitative and qualitative aspects of mathematics achievement for MZ and DZ twin pairs.
2. To relate within-pair similarity in mathematics achievement to teaching style.
3. To relate within-pair similarity in mathematics achievement to twins' perception of teaching style.

MATERIAL AND METHODS

Subjects

The KAM-project (a cultural comparison of heredity-environment interaction)

started in 1985 in collaboration between Sweden and Israel. It is a follow-up study of a twin group in the Swedish compulsory school and in the Israeli kibbutz school. In addition to school data, information has been collected from twin parents and teachers [4,5]. In the Swedish part of the project mathematics achievement tests given by the teachers in their regular work were also collected. This study presents data only from the Swedish part of the project and therefore a description of that will be given here.

The Swedish twin sample was selected from a birth register comprising all twins born in the Stockholm area from 1973 to 1975. The criteria for selection of the twins were that they should be same-sexed pairs and both twins should be living with their mother (and most often also with their father). The mothers of 221 pairs were contacted and asked if they wanted to take part in the investigation. 127 were positive to this approach and of these 70 were chosen, whose children attended grade 4, 5 or 6 in the Swedish compulsory school. They were 11-13 years old. This study presents data from 46 twin pairs, whose mathematics tests were collected. The reason for not including all twin pairs is that many Swedish teachers do not use testing in their evaluation of pupil learning at this stage.

Methods

The mathematics achievement test results have been compared within each twin pair and between MZ and DZ twin pairs, from both qualitative and quantitative aspects. Even though the twin pairs in different classes have completed different tests, the criteria on which the comparisons are based, are comparable. The comparisons are made for nine different kinds of criteria and two independent persons have classified the test results accordingly. The criteria of evaluation are the following:

- A. Number of correct scores;
- B. Number of mutual correct scores;
- C. Number of mutual correct scores with same solution;
- D. Number of mutual miscalculated scores;
- E. Number of mutual miscalculated scores with same solution;
- F. Similarity of handwriting;
- G. Similarity of presentation;
- H. Similarity of location on paper;
- I. Similarity in size of handwriting.

For criterion A, within-pair differences in number of correct scores have been calculated as a percentage of maximum differences on the mathematics achievement test. For criteria B-E, the within-pair concordance of the percent share was calculated. For criteria F-H, within-pair similarity was rated in a five-graded scale and I was rated in a dichotomous scale. Criteria A-E can be seen as quantitative and F-I as qualitative.

In the KAM-project the teachers were also asked how they planned and evaluated their teaching. They were requested to give a concrete example of a mathematics lesson. The answers were classified in three different categories:

1. Instruction to the whole class. Thereafter, the pupils work at their own pace;
2. Weekly task, which the pupils can complete in school or at home;
3. Varying methods of instruction.

The twins have been asked whether they felt that the teacher was telling them what to do during lessons. The answers could be classified in three categories:

1. Unanimous perception of teacher restrictiveness;
2. Unanimous perception of teacher permissiveness;
3. Disagreement about teacher influence.

RESULTS

Mathematics Achievements Tests

Criteria A-E

For criterion A, within-pair differences in number of correct scores have been calculated as a percentage of maximum differences. For criteria B-E the within-pair concordance percent share was calculated.

Table 1 presents the number of MZ and DZ twin pairs that show different degrees of concordance for criteria A-D.

For criterion A, we can see that particularly MZ twins tend to show very small within-pair differences in the number of correct scores.

As an average, MZ twins differ by 11% and DZ twins by 36% in the total mathematics achievement scores. This indicates a significantly larger similarity within the MZ twin pairs.

It is also of interest to see if the twins solve the same type of problems correctly and not only if they differ in total score. For criterion B, both MZ and DZ twins tend to differ more. MZ twins have a larger percentage of concordant correct scores (65%) than DZ twins (61%), but the difference is not significant.

If the twins solve the same type of problems correctly, it is interesting to investigate if they also use *the same strategy* to solve the problem. Criterion C also shows a wide dispersion of within-pair similarity for both MZ and DZ twins. As an average, MZ twins solve 8% more tasks in the same way than DZ twins, but the difference is not significant.

The twins sometimes solve the same type of problems correctly, and they also sometimes miscalculate the same type of problem.

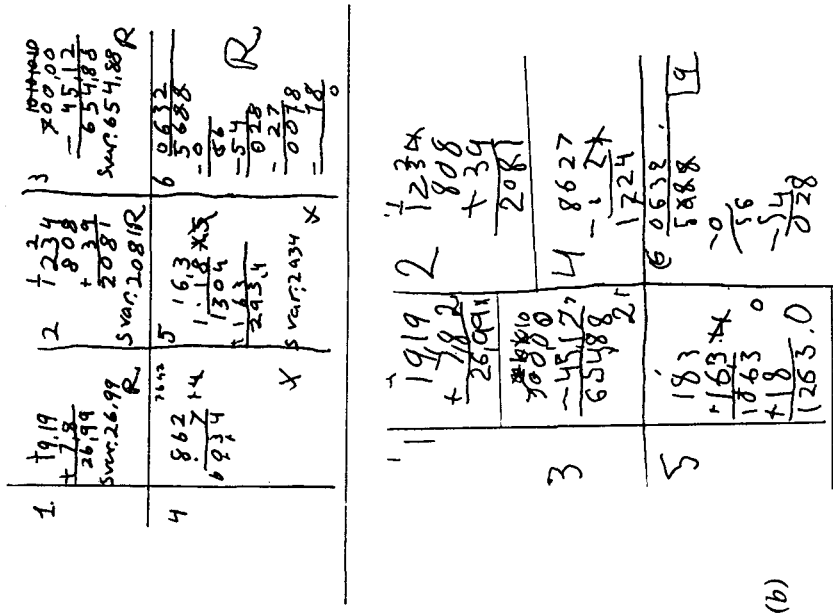
Both MZ and DZ twins tend to miscalculate the same problem fairly often. MZ twins miscalculate on average more often the same task (13%) than DZ twins (9%), but the difference is not significant.

Table 1 - Within-pair differences (%) for MZ (19 pairs) and DZ twins (20 pairs) for criteria A-D

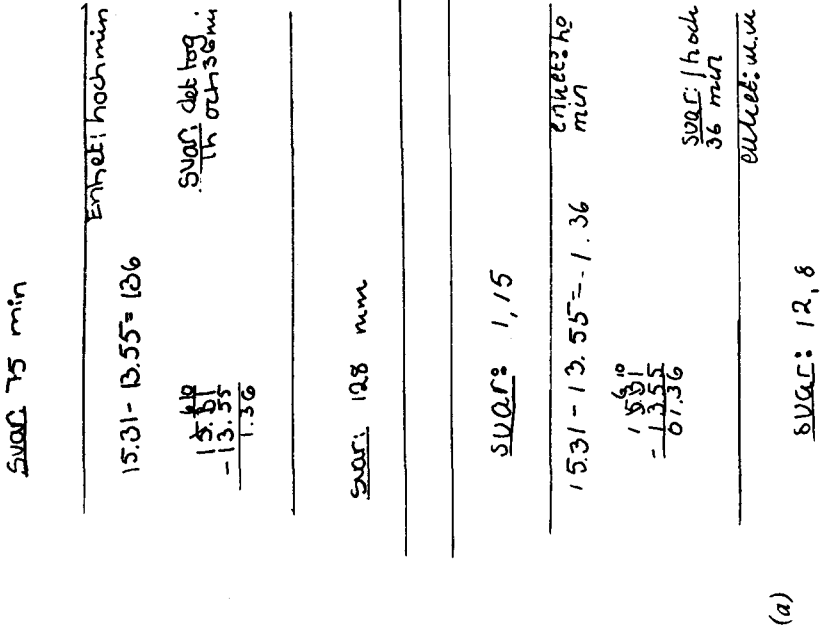
Criteria	Number of pairs in each percent class																					
	10%		20%		30%		40%		50%		60%		70%		80%		90%		100%			
	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ		
A. No. correct scores	11	9	5	4	5	5	5	5														
B. No. of mutual correct scores			1	2	2	1	3	4	1	3	3	4	4	4	2	3	3	3	3	3	3	3
C. No. of mutual correct scores with same solution			1	2	2	1	1	2	3	5	1	2	1	3	4	2	1	1	1	3	2	2
D. No. of mutual miscalculated scores	11	13	2	5	3	1	1	2	1	2	1											

Table 2 - Ratings of within-pair similarity for MZ (21 pairs) and DZ twins (23 pairs) for criteria F-H

Criteria	Number of pairs in each similarity class											
	Very similar		Rather similar		Neither similar nor dissimilar		Quite dissimilar		Very dissimilar			
	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ	MZ	DZ
F. Ratings of handwriting	2	8	9	11	11	3						
G. Ratings of presentation	4	2	9	7	4	8	1	3				
H. Ratings of location on paper	1	1	8	5	8	8	1	4				2



(b)



(a)

Figure. Example of handwriting from a MZ (a) and a DZ (b) twin pair.

It is interesting to see if the twins miscalculate a problem and use the same kind of solution. In criterion E, MZ twins have miscalculated problems with the same solution in 5%, and DZ twins in 3% of the total number of tasks, the difference being not significant.

Criteria F-J

In the first three grades, Swedish pupils are taught by the teacher to form letters in a certain way and to write tidily. When the children grow older, their handwriting will become more individual. Also, in mathematics, the answer gives the solution to a problem, but it can be presented in different ways. Some pupils show their answers clearly, for instance, with lines underneath the figures or with a separate sentence. Others do not mark the answers at all. Individuals also tend to express themselves differently in speech as well as in writing. This is evident not only from formulations, but from the use of the paper as well. A rating has been made by two independent persons (both teachers) of within-pair similarity according to handwriting (criterion F), presentation of answers (criterion G) and how the twins place the specifications, calculations and answers on the sheet (criterion H). The rating is made on a 5-point scale, where 1 indicates a very large within-pair similarity and 5 a very small similarity. Table 2 shows the dispersion of similarity ratings for criteria F-H.

Even if the most similarly rated pairs with regard to handwriting are MZ and the least similarly are DZ, we can see that most of the pairs, both MZ and DZ are rated as rather similar or neither similar nor dissimilar.

An illustrative example of a very similar handwriting by a MZ twin pair can be seen in the Figure (a). Both twins have a round and distinct way of writing. In b the Figure shows an example from a pair of DZ twins, where one twin writes illegible and irregular figures and the other is much more orderly.

With regard to similarity of presentation of answers in the mathematics test, MZ twins tend to be rated somewhat more similarly than DZ twins. There are, however, both very similar DZ pairs and very dissimilar MZ pairs. The average rating of MZ twins is 2.0 and that of DZ twins 2.6, which is not a significant difference.

The rating of how the twins place their answers on paper also indicates how the whole sheet of paper is used, which gives the writing a tight or airy impression. With regard to this criterion (H) MZ twins are also more similar than DZ twins, the average rating being 2.6 vs 3.1 and the difference being not significant.

Within-pair comparisons concerning the size of handwriting show that more than 50% of the pairs (both MZ and DZ) write with letters of the same size. The MZ twins are somewhat more similar than DZ twins but the difference is not significant.

In summary, within-pair similarity in mathematics achievement tests tends, on average, to be higher in MZ than DZ twins, the difference being significant, however, only for the number of correct scores. Therefore, we have used criterion A when comparing twin pairs in relation to different teaching styles.

Teaching Style

As already mentioned, the twin teacher has given a description of the teaching style. The twin pairs have thus been classified according to type of teacher instruction in the class they attend. Within-pair comparisons of number of correct scores were made for MZ and DZ twins separately.

As shown in Table 4 MZ twins seem to be more similar than DZ twins in mathematics achievement test scores irrespective of the type of teacher instruction.

Table 3 - Within-pair rating concerning the size of handwriting for MZ and DZ twin pairs

	Similar size	Different size
MZ pairs	14 (67%)	7 (33%)
DZ pairs	15 (62%)	9 (38%)

Table 4 - Within-pair differences in number of correct scores by teaching style

	Instruction of whole class	Weekly task	Varying method of instruction
MZ pairs	6 (8%)	7 (12%)	6 (14%)
DZ pairs	7 (15%)	5 (15%)	7 (23%)

Table 5 - Within-pair differences in number of correct scores in relation to the twins' perception of teaching style

	Restrictiveness	Permissiveness	Twins disagree
MZ pairs	10 (11%)	2 (16%)	7 (10%)
DZ pairs	7 (20%)	6 (18%)	6 (17%)

Pupils' Perception of Teaching Style

Some cotwins were of the same opinion concerning permissiveness-restrictiveness of teacher instruction, but others were of different opinion. Thus, the twins' answers have been classified according to the number of correct scores on the maths tests.

Table 5 shows that MZ twins differ less than DZ twins, within-pair differences being smallest where both twins agree on the teacher's permissiveness. The number of twins included in this category is very small, however.

DISCUSSION

The aim of this study has been to compare the similarity within MZ and DZ twin pairs concerning qualitative and quantitative aspects on mathematics achievement tests. This has also been studied in relation to the teachers' statement of own instruction and in relation to the pupils' perception of teaching style.

The criteria of evaluation on mathematics tests can be seen from a quantitative aspect and from a qualitative one. For all criteria, MZ twins tend to be somewhat more similar than DZ twins, significance being reached, however, only for the number of correct scores.

Similarity of handwriting, presentation, location on paper and size of handwriting are rated for qualitative aspects. These are probably more influenced by the teachers' instruction than the quantitative aspects and we can see that MZ and DZ pairs don't differ significantly for these criteria, the only significant difference being in the number of correct scores. The latter has therefore been used to investigate the within-pair similarity in relation to the type of teacher instruction. Irrespective of the type of teacher instruction, MZ twins seem to be more similar than DZ twins in the number of correct scores on mathematics achievement tests.

The same result is found concerning the pupils' opinion on permissiveness-restrictiveness in the teaching process in the classroom. It seems, in this study, that the teachers' statement of own instruction or the pupils' perception of teaching style do not matter. MZ twins are on average more similar than DZ twins in their mathematics achievement. The hereditary factor thus seems to play a role. It should be remembered, however, that only teachers giving tests to their pupils are included in this sample. There are good reasons to assume that the variations in the qualitative criteria are more influenced by the training pupils receive from their teachers, for instance, how to write or how to present the results.

A follow-up study is planned.

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