Acta Genet Med Gemellol 41: 335-352 (1992)

Seventh International Congress
on Twin Studies

The Effects of Two EFL (English as a Foreign Language) Teaching Approaches Studied by the Cotwin Control Method: A Comparative Study of the Communicative and the Grammatical Approaches

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Abstract. The present study compared two different types of English-language teaching approaches, the grammatical approach (GA) and the communicative approach (CA), by the cotwin control method. This study has two purposes: to study the effects of teaching approaches and to estimate genetic influences upon learning aptitudes. Seven pairs of identical twins (MZ) and 4 pairs of fraternal twins (DZ) participated in the experiment along with 68 other nontwin fifth graders. Each cotwin was assigned to the GA and CA respectively and received 20 hours of lessons over a 10-day period. The behavioral similarities between MZ cotwins were statistically and descriptively depicted. No major effect of either teaching approach was noted, but the genetic influence upon individual differences of learning achievement was obvious. Furthermore, an interesting interaction between the teaching approaches and intelligence was found, that is, that the GA capitalises on and CA compensates for intelligence. This interactional pattern could be interpreted as an example of genotype-environment interaction. The relationship between genetic factors and learning aptitudes is discussed.

Key words: Cotwin control method, Heredity, Environment, Aptitude-Treatment Interaction, Communicative approach

INTRODUCTION

The twin method has provided a unique methodology for psychology studies since the time of Galton. The purposes of the twin method in psychology may be divided into three main groups [33]: (a) to study twins themselves and/or the relationship between

them, (b) to compare differences of MZ pairs with those of DZ pairs, and (c) to study the differences between MZ cotwins. The purpose of (a) is to clarify the uniqueness or ideosynchronity of twinship. This kind of study is particularly popular in Japan [1, 16-21]. Twinship is thought of as a special case of sibling relationship and so it is suggested that this type of study might provide a valid contribution to the study of individual human perceptions [29]. The twin method, however, has been more substantial in relation to the last two issues, (b) and (c), which are known as the "nature/nurture problem" [5,27]. Recently this classic issue has been challenged by "human behavioral genectics", which attempts to arrive at a well-founded theory.

Glancing through current topics on human behavioral genetics, three interesting findings are to be noted. First, that from several large-scale longitudinal adoption studies conducted, such as the Colorado Adoption Project [25, 26] the perspectives of "developmental behavioral genetics" [24] have emerged. Second, that the Louisville Twin Study, a longitudinal twin study, revealed the developmental synchrony of intelligence and temperament [34, 35], and third, that the University of Minnesota conducted a large study of twins reared apart and discovered the astonishing similarity between pairs of twins [6,13]. These findings shed new light not only upon genetic influences on human psychological characteristics, but also upon the important role of environmental effects.

However, despite the many developments in behavioral genectics and twin studies over the years, there is a type of strategy which has rarely been conducted in the past two decades, namely "the cotwin control method", whereby one cotwin is given treatment A and the other, treatment B (or sometimes no treatment, as in a control condition), and then the differences between the two are compared to estimate the plasticity of target characters or behaviors. The cotwin control method has the potential to provide more information about the relationship between heredity and environment than the ordinary behavioral genetics methodology, in which, contributions or variances of genetic and environmental influences are estimated primarily upon the intraclass correlations of MZ and DZ pairs. Consequently, it can be said that the main results of behavioral genetics have been static estimates of "heritability" on quantitative characteristics, despite the thousands of twin pairs studied. In the ordinary twin method, both genetic and environmental effects are measured in terms of their relative variances or path coefficients only, thus not shedding light on the problem of "how" – the question repeatedly posed, beginning with Anastasi in 1958 [2]. For this reason, investigation of the nature/nurture problem has sometimes been criticized and regarded as fruitless by many educational researchers, even though it is a fundamental aspect of human development and education. On the other hand, the cotwin control method can deal simultaneously with the function of genetic factors as well as educational implications; it provides the possibility to describe and to control environmental conditions in detail and, in some cases, to even possibly explain the dynamic aspects of the interactional process between heredity and environment.

The most famous example of the validity of the cotwin control method was the infant ladder-climbing behavior experiment by Gesell and Thompson [11]. This provided strong support for the "maturation theory" and has had a great impact on modern developmental psychology. However, few cotwin control studies have been reported since. One of the few recent examples of cotwin control study was Plomin's and Willerman's

training experiment conducted to examine the plasticity of reflection-impulsivity in children [23].

One reason why cotwin control studies have not been regularly pursued could be their technical difficulty. For example, a long-term training session is needed in order to get clear results, but it is difficult to find subjects willing to participate in such a special training program just for its own sake. In Japan, there is a junior/senior high school attached to a national university which selectively accepts many twin students for the sake of academic investigation. However, within the existing educational system in Japan, it is almost impossible to conduct such a long-term experiment, as a compulsory educational course evidently includes a lot of nontwin students and has a typically busy curriculum. A more serious reason for the lack of cotwin studies may be its ethical connotations. From a scientific point of view, it is theoretically interesting to assign two different experimental treatments to twins. However, such procedure could be deemed unethical, in that the scientific purpose is given priority over the subjects' personal emotions.

This ethical problem may be overcome by choosing as experimental treatments different instructional methods considered to be equally valuable but with different strategic qualities. The present study was originally planned to compare two different types of teaching methods using nontwin subjects (Ando et al in press; Kurahachi et al in press). The inclusion of twins as subjects enabled us to examine genetic influence on the learning process while at the same time avoiding any ethical dilemma.

The instructional methods used here are the grammatical approach (GA) and the communicative approach (CA) in teaching English as a foreign language (EFL). The former, GA, has been the traditional teaching style employed in Japan, whereby, grammatical rules are deductively taught to students as a group so that they may effectively learn how to read and write English. However, this system is highly criticized because students do not develop their listening and speaking (ie. communicative) abilities, despite several years of learning. In reply to such criticism, the latter approach, CA, in which grammatical rules are learned through meaningful communication activities, has lately attracted considerable attention. Nonetheless, since little direct instruction in reading and writing is given, especially in the initial period, students find it difficult to grasp the systematic concepts of grammar and other formal aspects of the language. It cannot be said that one method is absolutely better than the other. The interesting issue is which method is better for which aspect of linguistic ability or which method interacts more incisively with the learners' aptitude (ie. Aptitude-Treatment Interaction) [8,22,31].

The author and his colleagues have conducted two previous experiments concerning this problem. The participants were nontwin sixth graders as EFL beginners and some interesting results were observed. For example that in written tests, the GA capitalizes on and the CA compensates for verbal intelligence. This Aptitude-Treatment Interaction (ATI) pattern has proved to be a stable component throughout various experiments [5,10]. Therefore, the purpose of the present study is twofold: first, to examine the effects of the two teaching methods on learners' linguistic abilities, using the cotwin control method; and second, to study how learners' genetic aptitudes affect the process and results of learning.

METHOD

Subjects

Seven pairs of MZ twins (3 male and 4 female) and 4 pairs of DZ twins (2 male and 2 opposite-sex pairs) living in southwestern Tokyo were recruited for this experiment via direct mailing. Addresses were obtained from the residents' cards in the offices of Minato and Shibuya Ward (public information in Japan) and from the membership list of the local Twin Mothers' Club. All participants were fifth graders and had had no prior English instruction. As mentioned earlier, this study was originally designed to examine the effects of these instructional methods on singleton students, and so the study group included 68 nontwin subjects. The parents of all participants received a full explanation of the purposes and methods of this experiment and all agreed to allow their children to participate. Each of the 90 subjects were assigned to one of 8 classes (4 CA classes and 4 GA classes). Each class had 9 to 14 children with 1-4 cotwins among them.

Class Schedule

The experiment was conducted over 10 days, divided into two 5-day periods separated by one day off, during the summer vacation. Aptitude tests were administered on the first day and a post-test on the last day. Each class was held for 2 hours per day but net classroom activity was reduced to 90 minutes having allowed time for a break and daily tests. Two laboratories, specifically constructed on the university campus for psychological experiments, were used. Each class was divided into two groups almost equal in size and subjects were seated around two tables in randomly assigned positions every day.

Content and Characteristics of Teaching Methods

The grammatical rules taught were the same in the two different teaching approaches and consisted in the use of the present tense of the verb "to be" in an affirmative and a negative sentence, and the construction of affirmative, negative and interrogative sentences using the simple verbs "to have" and "to like" in the first and second person. Vocabulary used was also the same, with a few exceptions. However, in order to avoid interruption in the natural flow of each approach, the introduction of grammatical rules and vocabulary did not proceed on the same daily schedule. Each lesson was taught from a teaching plan compiled in advance by the group of participating teachers.

The characteristics of the two approaches are as follows. In the GA, a new grammatical rule was introduced using a brief skit. This was followed by an explanation of the rule, oral and written practice using the rule and, finally, a game incorporating the new rule. The grammar was explained in the students' mother tongue (Japanese) and the English sentences were frequently translated into Japanese. Sentence structure and rules on how to transform sentences into the negative, affirmative, etc., were presented deductively using a blackboard. Also in the games, grammatical structure was emphasized by

inducing students to make grammatically correct English sentences. In the CA, following the brief introduction of a new expression, communication activities (ie. games) using the new expression were performed and afterwards the students wrote down once the basic expressions learned in the lesson. There was no explanation about grammar and little translation into Japanese, except for explanation about the situation described in the sentences. The typical communication activity performed was that subjects exchanged personal information (eg. "What's your telephone number?" or "What food do you like?"). Guessing games were also played. The amounts of writing required were established to be the same in the two experimental groups.

Teacher

One female and three male investigators, including the author, played the role of teacher and each taught using both teaching approaches. Their previous teaching experience ranged from almost zero to 7 years, but prior to the experiment each 'teacher' received 10-20 hours training in the current curriculum. A Japanese university student assistant helped each teacher and an AET (Assistant English Teacher) participated on the second and last day.

Aptitude Measures

Thirty-one aptitude variables were measured. They can be divided into four categories as follows:

1. Intellectual abilities (13 variables): (a) general intelligence (7 variables) measured by the Tanaka AB Intelligence Test including 7 subtests divided into two categories, verbal and nonverbal intelligence; (b) 10 items from Raven's Standard Progressive Matrices to measure fluid ability; (c) amount of prior knowledge about the alphabet (subjects were asked how to pronounce certain letters of the alphabet in katakana or how to write certain letters expressed in katakana; (d) amount of prior knowledge about English words expressed in katakana (book = "hon" or "aka" = red); (e) Japanese grammar test (eg. knowledge of rules on how the subject corresponds to the object; (f) Working Memory Capacity (2) which was the Japanese version of Daneman et al [9] reading span test for children. Four to six short sentences constructed from two to four phrases were presented sequentially, phrase by phrase, and subjects were asked to remember the last phrase of each sentence. Two modality test types, visual and auditory, were administered. To note, (c) to (f) were constructed by the author and his colleagues.

2. Cognitive styles (3 variables): (a) Field Independence by Embedded Figure Test, (b) Reflection-Impulsiveness, and (c) Effectiveness by Matched Familiar Figure Test. These three variables were measured in terms of the Cognitive Style Test (CST) by Sugaihar [32].

3. Personality (14 variables): (a) Yatabe-Guilford Personality Inventory (12), (b) anxiety, (c) extroversion. (b) and (c) were especially constructed by one of the author's colleagues to measure specific aspects in learning a foreign language.

4. Intrinsic Motivation (1 variable): Total amount of Intrinsic-Extrinsic Motivation Scale [28].

Of the above tests, numbers 1, 2, 3 (b) and 3 (c) were carried out in a group before the experiment began, while 3 (a) and 4 were carried out individually in each subject's home.

Assessment of achievement

Four kinds of assessments were carried out.

1. Observation: in order to describe the ideosynchratic similarities between cotwins, natural observation was conducted. Teachers, assistants and other observers in the classroom (in all, varying from 1 to 4, depending on the day) observed each cotwin and described freely his/her individual characteristics. Teachers and assistants alike were not allowed observe the other cotwin and the other observers had access to one member of each pair for the first 5 says. In this way, observers' could note their descriptions without bias and free of selective attention to any within-pair similarities or differences.

2. Post-test: this consisted of one oral and 4 written subtests – (a) translation of simple words from (J)apanese into (E)nglish (writing ability); (b) translation of simple sentences from E into J, by listening (listening ability); (c) translation of simple sentences from E into J, by reading (reading ability); (d) arrangement of randomly listed words into sentences (grammatical ability); and (e) oral interview conducted individually (speaking ability).

3. Learning Process Test: subjects were asked every day to write as many English sentences as they could (up to eight), using a given word list. The purpose of this was to ascertain how much the subjects had learned about the grammatical rules.

4. Retention Test: a retention test, ie. (b) and (c) of the post-test, was carried out 2 months later.

RESULTS

Similarity of aptitudes

Using the cotwin control method enables us to compare more accurately the effects of different teaching approaches, because the aptitude profiles of cotwins are much more similar to one another than those of any other pair of individuals. For example, the intraclass correlation for intelligence (g) in a pair of MZ twins reared together is almost the same as any given individual's test-retest reliability (correlation coefficient) at 2 different points in time [35]. Therefore, if a pair of MZ cotwins reared together are given different treatments it is, at least as regards intelligence, as though one person had two different experiences at the same time. Several other characteristics have repeatedly been reported to have high heritability expression, eg. sociability, extroversion and neurosis

[12]. A set of these relatively heritable charcteristics would make an MZ pair peculiarly similar to each other pair in their aptitude structures or "aptitude gestalts".

If these assumptions are correct, then two instructional treatments can be compared recruiting only a few pairs of twins instead of a large number of subjects, as is common in ordinary control experiments. In addition to this methodological advantage in comparing instructional treatments, the cotwin control study can be expected to provide us with a powerful instrument for examination of the interaction between aptitude and treatment at individual level, which is not available when statistical estimation of a large nontwin group is used.

In order to represent the extent to which a pair of twins is similar to each other, Pearson's product moment correlation coefficients (in this case, similarity coefficients) were calculated per each pair in terms of 31 aptitude variables. These were transformed into standardized scores among all the subjects, and were located in the distribution of 231 similarity coefficients, which were also calculated between all the combinations of 22 twin subjects to determine its relative size (Fig. 1). This figure has a typically normal distribution shape with a mean value of zero and indicates that the values of the MZs are located at the highest range. Those of the DZs are also located in a relatively high

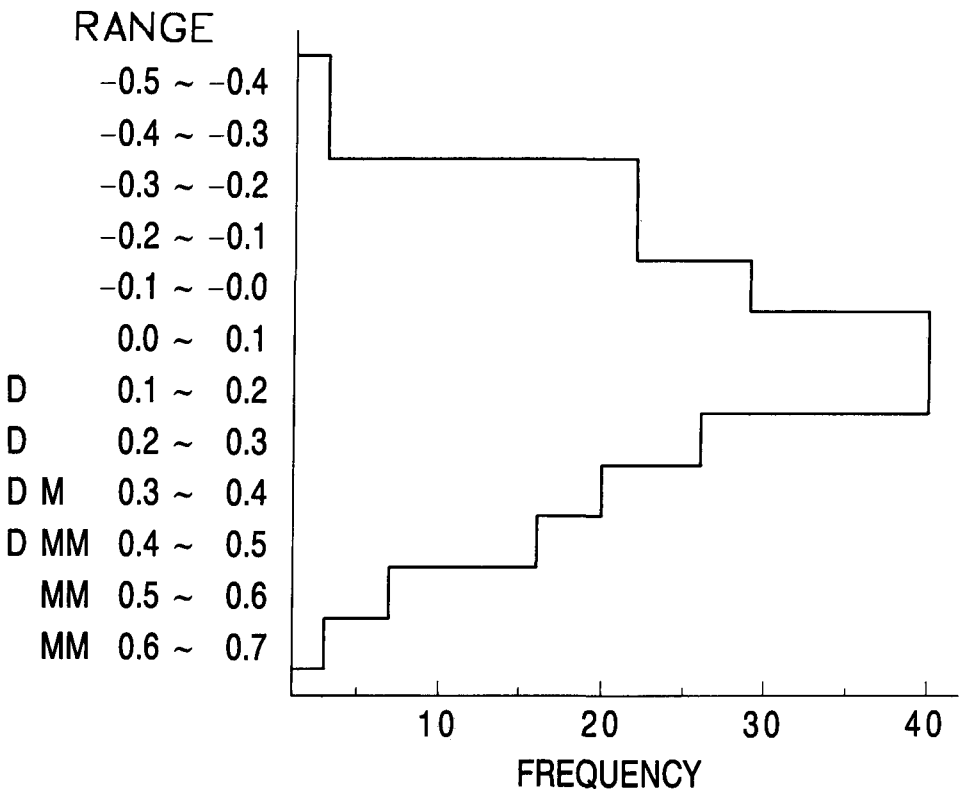

Fig. 1. Distribution of similarity coefficients and location of MZ and DZ. Twins M indicates the location of the similarity coefficient of an MZ (identical twin) pair and D indicates that of a DZ (fraternal twin) pair.

range, but lower than the MZs. Thus, similarities between the MZ cotwins were relatively high. However, it also indicates that an MZ twin can sometimes have a more similar counterpartner than his or her own cotwin according to these similarity coefficients. Of course, MZ cotwins usually have more surprisingly similar individualities with each other which cannot be represented by statistical coefficients. Therefore, in order to depict their individual similarities more explicitly and concretely, the descriptions obtained through natural observation of the learning situation were compared. Table 1 is a list of these showing such ideosyncratically similar attitudes or behaviors among MZ pairs. Because each statement was independently described by different observers for

Table 1 - Descriptions of similarity between cotwins in identical twin pairs.

Pairs	Sex	r*	Cotwin in CA	Cotwin in GA
MZ 1	f	0.67	very quiet, works at her own pace, listening carefully to the teacher, sometimes looks about restlessly.	quiet, not conspicuous, paying careful attention to the teacher, looking around restlessly, works at her own pace.
MZ 2	f	0.57	has atmosphere of composure, staring at the teacher, writing a lot on tests, answers slowly but steadily.	keeps her composure listening as hard as she can, looking at the teacher with upturned eyes, can answer clearly.
MZ 3	f	0.44	serious but lack of active attitude, sometimes smiles, hides letters at test.	seems not to be involved in learning, looks serious, usually smiles, hides her paper with her hand.
MZ 4	f	0.37	not loud, looks shy, head hanging downward, doing her best.	small voice, shy, quiet but steady.
MZ 5	m	0.40	sometimes says "I can't do it" walks around a lot, typical child.	says "I don't understand it", restless, can't concentrate, sometimes stands up, childish.
MZ 6	m	0.61	small voice, looks like a baby, becomes active and talkative.	quiet, immature child, becomes expressive and talkative.
MZ 7	m	0.51	nihilistic and expressionless, doesn't get involved in lesson, has good handwriting, frightening because looks strong.	sullen, looks expressionless, a clear and careful handwriting, frightening eyes.

* Similarity coefficient

https://doi.org/10.1017/S000156600000218X Published online by Cambridge University Press

each pair of twins, we believe the similarities to be valid. According to this list, some individual similarities of learning attitude which are sometimes closely related to the effectiveness or quality of learning are to be found. On the contrary, behaviors between DZ cotwins ranged from the very similar to the very different.

It must be noted that all of these similar psychological characteristics between MZs are not necessarily genetically based. They could stem from a shared environment, or from various kinds of genetic-environmental correlations, or indeed a kind of resonance peculiar to twin pairs. Here, we felt it was adequate to ascertain the strong similarity in the MZ pairs in order to compare the instructional approaches. The question of genetic influences is taken up in the discussion.

Post-test

Analysis of the post-test scores were based on the raw scores and on the standardized scores calculated in the classes any one teacher taught because there were sometimes significant differences in the students' raw scores from teacher to teacher. Table 2 shows the comparison of subtest scores between the GA and the CA. No significant differences were found in any subtest, ie. there were no major effects identifiable with either teaching approach nor was there any evidence that one approach is superior to the other for linguistic skills. Although one could hypothesize that the GA would be more beneficial for reading, writing and grammatical ability, and the CA for listening and speaking abilities, no evidence supporting these hypotheses was found.

Intraclass correlations, on the other hand, were higher in MZs than in DZs: r(MZ) = 0.81 and r(DZ) = 0.07 for raw scores, and r (MZ) = 0.85 and r(DZ) = 0.20 for standardized scores. This shows that genetic factors rather than environmental ones contribute more to the individual difference of the learning outcome. However, the small sample size made heritability calculations meaningless.

A scattergram between total score and intelligence is shown in Fig. 2. Here, the typical ATI pattern can be seen, in which the CA is beneficial for lower intelligence subjects and the GA for higher intelligence subjects. Although the interaction is not statistically significant in itself, this result gives us a good example of genetic-environment interaction because general intelligence is one of the most heritable psychological characters. For the DZs, on the contrary, no such interaction pattern was found (Fig. 3).

Learning Process Test

This test, constructed specifically to assess the process of learning, showed an interesting similarity between MZ cotwins. Table 3a shows the representative examples of three MZ pairs (MZ1, MZ2, MZ7) and Table 3b of one DZ pair, in which, data were selected from the third, sixth and eighth day. In MZ1, the amounts of writing are relatively large for both cotwins and it can be seen that they always tried to use new rules. Variations of rule usage were very poor in that they only mechanically substituted a small part of a sentence (eg. the subject) within a limited sentence structure. On the other hand, MZ2, who were both very good learners, wrote the maximum number of sentences each day,

Table 2 - Means and standard deviations (in parenthesis) for Post-test and Retention test.

Sample	Raw Score				Standardized Score			
	MZ (7 pairs)		MZ + DZ (11 pairs)		MZ (7 pairs)		MZ + DZ (11 pairs)	
	CA	GA	CA	GA	CA	GA	CA	GA
Post-test								
Writing	0.57	1.14	0.63	1.36	47.39	54.61	47.78	48.04
	(1.13)	(1.46)	(1.03)	(1.29)	(22.61)	(26.24)	(18.05)	(9.71)
Reading	5.00	3.57	4.45	4.55	55.17	48.51	51.48	48.54
	(2.82)	(3.50)	(3.20)	(3.14)	(11.98)	(16.67)	(12.72)	(9.17)
Listening	7.00	6.42	7.18	6.91	48.78	43.84	49.51	45.20
	(1.63)	(2.07)	(1.40)	(1.81)	(15.78)	(19.55)	(13.31)	(14.30)
Grammar	2.28	2.43	2.18	2.73	55.66	58.18	54.57	50.68
	(1.38)	(2.76)	(1.40)	(2.41)	(12.75)	(22.09)	(11.06)	(10.08)
Written	15.00	13.57	14.55	15.55	48.55	43.11	48.30	52.37
Total	(6.14)	(8.70)	(6.25)	(7.34)	(23.44)	(31.22)	(19.40)	(21.00)
Speaking	11.14	9.50	10.68	9.85	52.05	46.99	51.30	47.58
	(3.20)	(2.80)	(3.06)	(2.55)	(15.23)	(10.29)	(13.77)	(9.79)
Retention test								
Reading	4.29	3.29	3.91	3.45	64.32	57.09	59.24	50.05
	(3.50)	(3.35)	(3.21)	(2.98)	(24.51)	(22.16)	(21.12)	(12.80)
Listening	7.43	7.57	7.55	7.27	44.81	46.33	46.33	50.99
	(1.51)	(1.40)	(1.36)	(2.72)	(6.28)	(4.62)	(6.01)	(14.75)
Total	11.71	10.86	11.45	10.73	52.56	50.50	51.87	51.19
	(4.86)	(4.53)	(4.16)	(5.22)	(12.57)	(11.51)	(10.51)	(12.95)

and with rich variation. Especially notable was that the cotwin in CA expressed meaningful question and answer interactions, peculiar results for the CA. This table, therefore, demonstrates that both cotwins of this pair proceeded through classes with perfect understanding. In the last example of Table 3a, MZ7, the cotwin in CA wrote nothing and the other in GA wrote very poor sentences even on the last day. They were very passive in the classroom and got poor scores also in the post-test.

Table 3b is the example of the most similar DZ pair though similarities were still less than those of MZs. Generally, the similarities between the DZ cotwins were very different in both amount and content.

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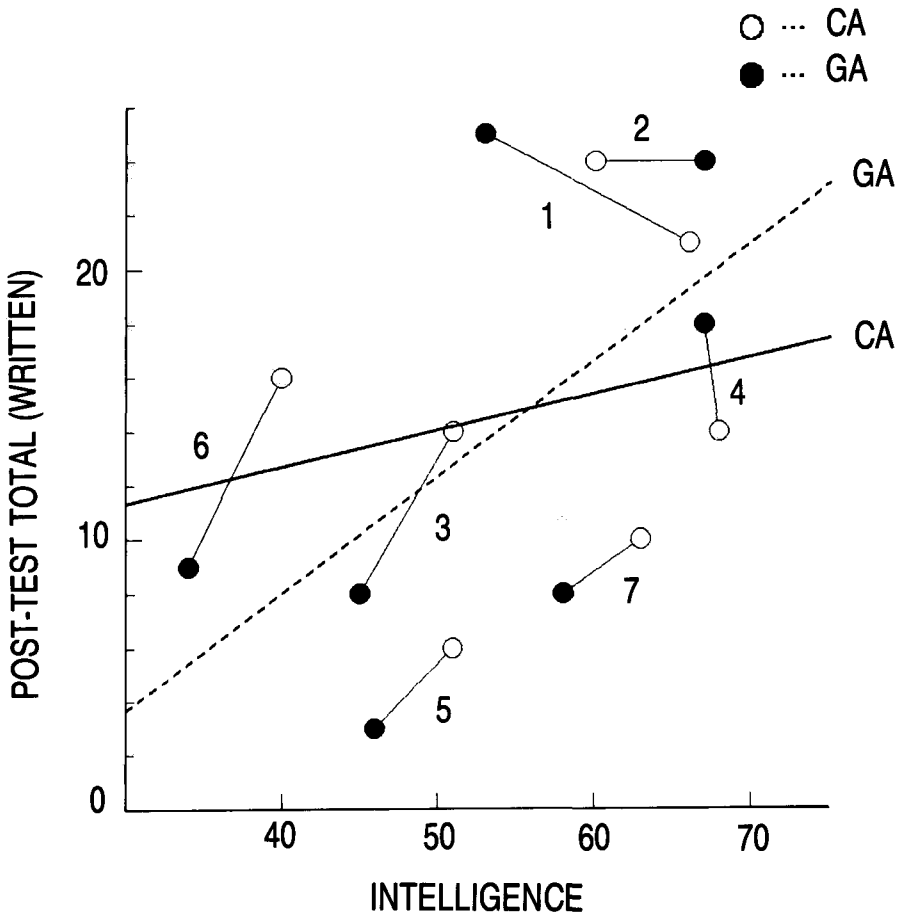

Fig. 2. Scattergram and regression lines for MZ pairs (post-test). Numeration refers to MZ pair numbers shown in Table 1.

Retention Test

In the retention test there was no main identifying effect of either teaching approach, as in the post-test. The interaction between intelligence and the outcome discovered at post-test disappeared (Fig. 4) and the correlation coefficient between intelligence and retention test scores became positive in both experimental groups (r(CA) = 0.59, r(GA) = 0.58). Intraclass correlations for MZ and DZ were r(MZ) = 0.85, r(DZ) = 0.17 for raw scores and r(MZ) = 0.85, r(DZ) = −0.18 for standardized scores. Here again genetic influence was evident.

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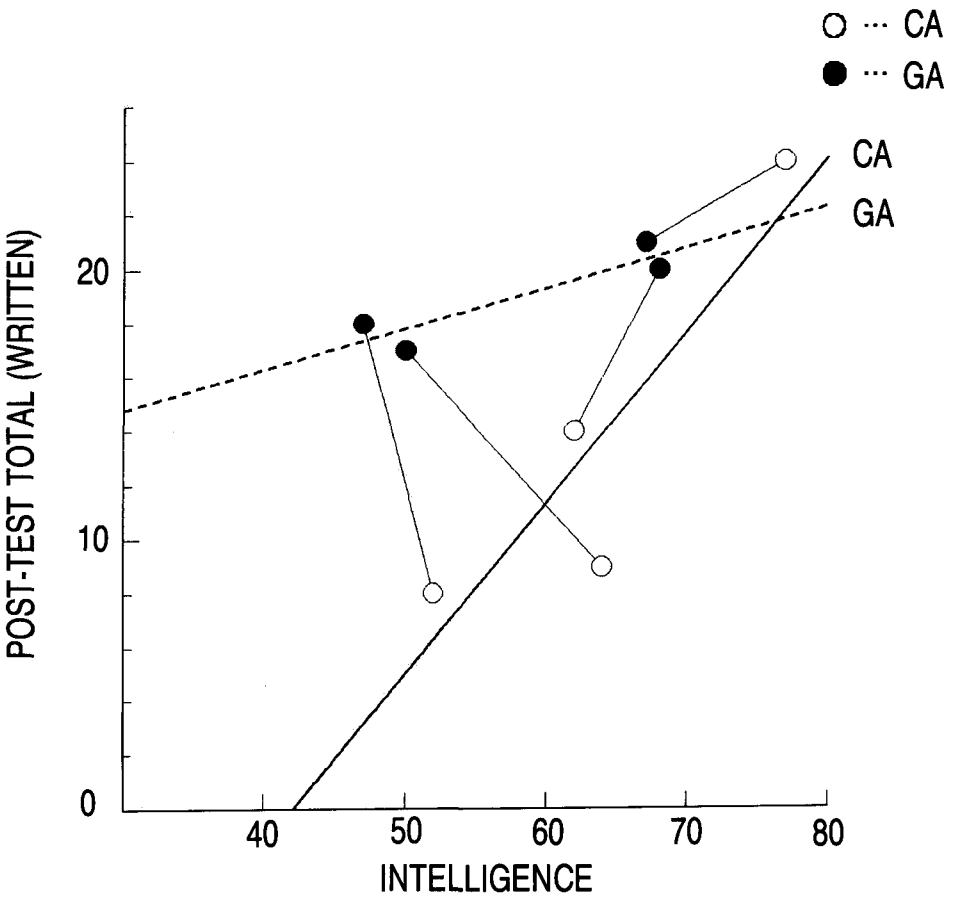

Fig. 3. Scattergram and regression lines for DZ pairs (post-test).

DISCUSSION

As mentioned previously, the purpose of the present study included both genetic and environmental aspects. In other words, it was designed to examine the learning effects of specific instructional approaches, as well as the genetic influences affecting these learning effects. In addition, the interactional effect was also focused upon. This combination presents a new perspective of the nature/nurture problem which is neither one of hereditarism nor environmentalism, and not even interactionalism where genetic and environmental factors are an amalgam that cannot be divided. In other words, it is fundamentally based upon the traditional paradigm of behavioral genetics, where individual differences in behavior are related to both genetic and environmental influences that can be divided by controlling the genetic factors using twins or adoptive families.

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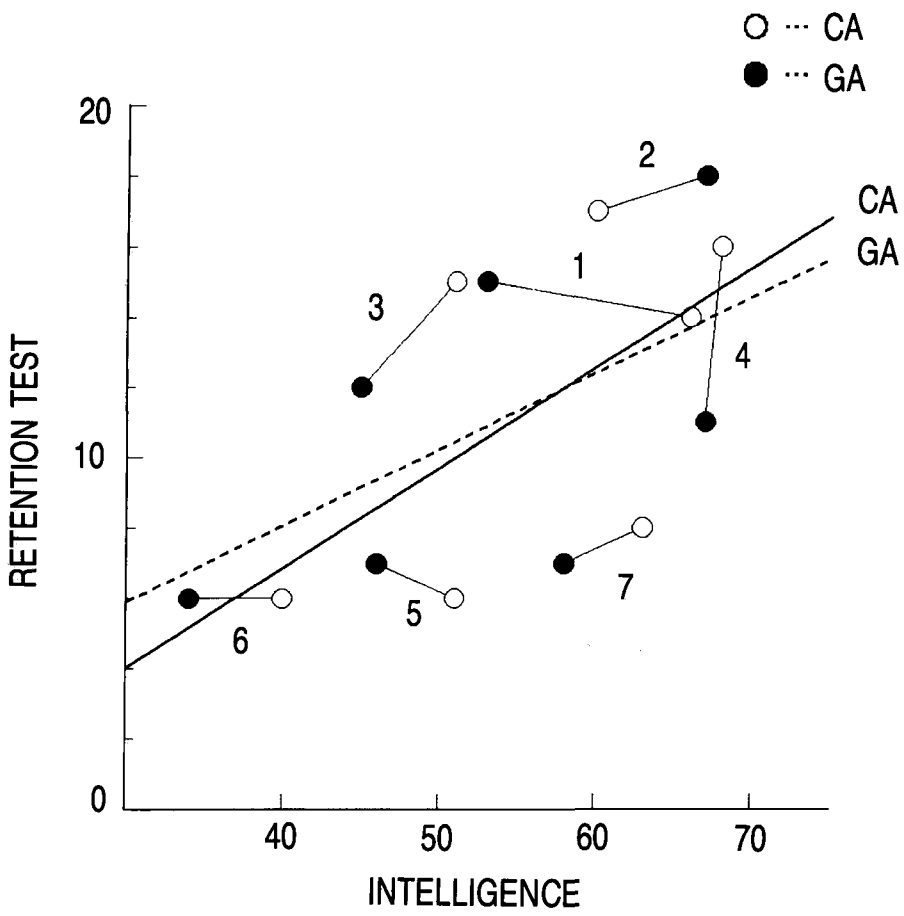

Fig. 4. Scattergram and regression lines for MZ pairs (retention test). Numeration refers to the MZ pair numbers shown in Table 1.

Nonetheless, the approach used in this study is to describe a dynamic pattern of the concrete relationship between both factors in a limited learning situation. It is different from the ordinary methodology of behavioral genetics in which total variance is divided into various kinds, such as genetic, shared environment, non-shared environment and so on.

As regards environmental effects, ie. the main effects of the teaching approaches in this study, there was no evidence that either CA or GA is more beneficial to learning. This result was repeatedly shown in both the immediate post-test and the retention test conducted 2 months later, as well as in all subskills. On the contrary, for genetic effects, a fairly strong influence of heredity was shown. The most interesting finding was the ATI pattern, in which the CA compensates for, and the GA capitalizes on, intelligence. This pattern had been consistently observed by the author in prior studies using nontwin

Table 3a - Representative examples of the Learning Process Test (MZ).

	MZ 1		MZ 2		MZ 7	
	CA	GA	CA	GA	CA	GA
	It's a book	a big book	I'm (student's name)	a big book		2 books
		a short notebook		2 short rulers		3 books
3rd		3 long rulers			(4th)	a book
		a red pen				
		2 blue pens				
	It's a notebook	My mother	This is my mother	She is good girl		
	It's a big book	My tather	How old are you?	This is my mother.		
6th	It's an egg	My sister	My telephone number is (student's			
	It's a pen	Are you a (sibling's name)	number)			
	It's a small cup		This is my family. What your telephone number?			
	They are books	I have a book	Do you have any	I have a pencil		a sereo
	They are eggs	I like pizza	brothers or sisters?	You have a pencil		
8th	It's a big egg	You have a notebook	Yes, I do	I like spaghetti	(9th)	
	It's a small egg	You like cake	I have 2 sisters	You like spaghetti		
	It's a long pencil	I like spaghetti	No, I don't	He is my father		
	It's a short pencil	I like cake	This is not my family	She is my mother		
	They are big cup	I have a ruler	He is 7 years old?	I like pizza		
		You have a pen	Shi is 12 old?	This is my eraser		

(a) Errors, such as misspellings, are uncorrected and listed exactly as they were written by the subjects.
(b) In the case of MZ7, no sentence was written on the 3rd and 8th day, so data from 4th and 9th day are listed instead for reference.

subjects [5,10]. In these nontwin experiments, the ATI pattern emerged for letter-driven tasks only, such as writing, reading and grammar but not for listening ability which was shown to be highly correlated with intelligence in both teaching approaches. The same result was seen in the analysis of the nontwin data in this study (Ando et al in press).

The reason why the CA can compensate for lower ability learners may be explained by the observation of the MZ's learning behavior (Table 1). The MZ5 pair, for example, were active boys who didn't get involved in lessons, sometimes left their seats, did unrelated activities and spoke privately with children next to them; interestingly enough, their best friends were also an MZ pair, MZ6. For these children, the GA might not facilitate their learning because it requires that they listen passively to the explanation given by the teachers and learn the grammatical rules deductively. On the other hand,

Table 3b - A representative example of the Learning Process Test (DZ).

	CA	GA
3rd	a book	b book 2 books 3 books ⋮ 7 books 8 books
6th	It'sabook	astrong boy astrong girl astrong grand ther your sister your brother my sister my brother
8th	It'saneraser It'sacup.	I have a cup.

Errors, such as misspellings, are uncorrected and listed exactly as they were written by the subjects.

the CA may, to some extent, stimulate "question and answer" activities in ordinary classroom situations and so facilitate these children to learn more and to be more motivated. Take the MZ1 pair for whom the GA resulted more beneficial; both had high intelligence and could understand logical rules of grammar through classroom lessons. However, they were very quiet and expressed their emotions poorly, so the CA approach did not suit their learning requirements. This shows that in MZ pairs, with an extremely similar aptitude structure, the same aptitudes interact with the different kinds of instruction treatment and lead to different outcomes.

Although the aptitude dimension of intelligence only was shown in Fig. 2, this interaction may be related to other aptitudes which affect a learner's overall attitude to learning. For instance, both members of the MZ2 pair were always active in the classroom, eager to study at home and showed high intelligence levels. As a result, they received high grades in the post-test and retention test for both the CA and the GA. The MZ7 pair were not necessarily of low intelligence but were always "outsiders" in the learning situation and only active in games, so the CA was more beneficial in their case. The beneficial effect of the CA disappeared, however, at the retention test. The reason may be that these lower ability learners could not deduce any grammatical or formal rules from concrete activities, but rather had to memorize various expressions, by rote association with certain situations (eg. if asking someone's address, say "what is your address?"); this association may have disappeared by the time of the retention test 2 months later. The higher ability students, on the other hand, could deduce some rules, even from the CA, and so tended to get higher grades also at the retention test.

While it is helpful to make use of similarities in MZ twins to examine the characteristics of teaching approaches, what about the heritability of these similarities? In other words, to what extent are they affected by genetic factors? As stated above, the ideosynchratic similarities in identical twins do not all stem from genetic factors alone, but from shared environment, from passive, reactive and active genotype-environment correlations or from a kind of resonance which may occur even between unrelated individuals living together. Of these, the genotype-environment correlation similarities could be classified as genetic influences in a broad sense. Of the others, however, it is impossibile to identify which aspects of similarities are genetic and which are environmental.

In recent literature on human behavioral genetics, characteristics of considerably high heritability, eg. intelligence, specific cognitive abilities and some EAS traits (emotivity, activity, sociability) etc., have been reported [7,27]. Even though heritability may be moderate a set or "gestalt" of these characteristics becomes a "flexible structure" (in an architectural sense) which can adapt to various inputs from the outer world and yet maintain its basic structural quality. For example, a flexible structure such as a skyscraper will flex under certain circumstances but it has immobile or "ideosynchratic" points which remain fixed. In this context, a pair of MZ twins who share a common basic genetic structure also demonstrate an extremely ideosynchratic similarity in part of their behavior. A study of MZ twins reared apart, conducted at the University of Minnesota, presented the new concept of "emergenesis" to explain this kind of similarity, ie. a high-order interactional effect of genes [15]. Such similarity or "ideosynchratic similar behavior" needs further study to fully explore the conditions of its emergence and function in the developmental processes of the organism as a whole. The behavioral similarities, as reported here, may be considered the maximum estimation of genetic behavior.

From an educational point of view, genetic influences have been treated habitually as a resriction to educational intervention. There is strong concern that this may lead to a dangerously fateful pessimism. The interactional trend discovered in this experiment, however, presents a possibility to counter this pessimism. Even if the similarities discovered between the MZ cotwins are entirely genetic, they can interact differently, because learning aptitudes in different environmental conditions can result in different outcomes. Therefore, genetic individuality is thought to play the role of a peculiar interface between organism and environment. Although most human behavior is the epigenetic result of the interaction of the organism with its environment, its way of interacting is affected by genotype [30]. While formed behavior can show strong heritabilites, it does not necesarily make learning impossibile but rather offers a resource of individuality which can contribute to the formation of one's efficacy. The present study offers a positive explanation of genetic influence in an educational context.

It should be noted, of course, that these interactions are inconsistent, as many ATI studies to date have shown, and that they may also interact with other unknown factors. The effect of genotype/environment interaction has, in traditional behavioral genetic studies, been considered marginal compared to our measure here. This is because in natural situations, such interactions, if they occur, are so unstable that they can hardly crystalize into stable effects. The results of the retention test in this study showed the absence of interactional effects. Further studies are necessitated to examine the stability or change in interaction over a long period.

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