Acta Genet Med Gemellol 46: 57-67 (1997)

Abstraction Skilfulness in Monozygotic and Dizygotic Twin Pairs

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Abstract. The computerized version of the Wisconsin Card Sorting Test (WCST) was administered to a sample of 96 subjects (Ss), constituted in equal parts by monozygotic twins (MZ), dizygotic twins (DZ), unique children and couples of "almost contemporary" brothers. The statistic tests (Analysis of principal components, ANOVA) underline, as far as the rapidity to define a category is concerned, a statistically significant difference between DZ and singletons, independently from the fact that the latter may be unique children. A significant difference emerged neither between MZ and singletons, nor between MZ and DZ.

Key words: Abstraction, Principal components analysis, Twins

INTRODUCTION

A large series of studies conducted on MZ and DZ pairs [1, 11, 12, 13] show that there is a strong intrapair agreement for MZ (r = .850 – .900) regarding the cognitive efficiency assessed through global measures of intelligence, and a smaller intrapair agreement for DZ (r = .500 – .600). The same type of results holds for a conspicuous part of the factors of intelligence and particularly for the primary abilities of Thurstone [14], except for the numerical ability, for which the coefficients of intrapair correlation for MZ and DZ pairs are very similar and of the order of .450 .500 [9]. The hypothesis of the genetic determination of intelligence appears therefore confirmed by the high coefficients of couple correlation for MZ that by definition have the same genetic patrimony, and by the lower coefficients of correlation for DZ, that by definition share only a half of their genetic patrimony. The evidence that there are some factors of intelligence, like the numerical ability, for which the couples of MZ and DZ do not differ between them, does suggest that there are aspects of cognitive activity that are not under the influence of heredity in a conclusive way, and that they depend to a certain extent on the environment. It could be useful, accordingly, to resort to the distinction between "fluid" intelligence and

"crystallized" intelligence [2, 3]. The first, that corresponds to the ability to elaborate any type of matter, disregarding any familiarity that the subject has acquired with it, is likely to be linked to hereditary factors. The crystallized intelligence, connected with scholastic and cultural learning, is instead clearly tied up to environmental factors.

Following this direction of research a recent work [5] investigated a sample of 88 Ss constituted in equal parts by MZ and DZ couples (all females), couples of sisters almost contemporary and female singletons joined randomly. The tests employed were the *Embedded Figures Test* (RFT) which assesses the field-dependent vs. field independent cognitive style, and the computerized version of the *Wisconsin Card Sorting Test* (WCST) used to assess the ability of abstraction and conceptual change. Data processing (mainly intrapair correlations) produced evidence which favoured the genetic determination of field-dependence, that in the MZFF couples is accompanied by global strategies in performing the WCST that favor specific mistakes of conceptualization as well as the perseveration in such mistakes. In this regard, it is interesting to note that some authors [15, 4] associate the part of variance common to the EFT and to another test employed to assess the field-dependence/independence: the *Rod and Frame Test* (RFT) with the fluid intelligence.

The main aim of the present work is that of studying the nature and origin of the cognitive abilities measured by the WCST, putting aside the field-dependence/independence matter as well as the mere study of the intracouple correlations. More precisely, in order to investigate the ability of abstraction and conceptual change in MZ and DZ twins, the authors decided to analyze and compare the performance of subjects belonging to four different groups to the WCST:

1. group of the MZ, raised together, characterized by a high concentration of hereditary factors, each couple sharing the same genetic patrimony;
2. group of DZ raised together, characterized by a halved concentration of hereditary factors, because each couple shares the 50% of the genetic patrimony;
3. group of fully grown (FQC) formed by couples of brothers almost contemporary, who besides having in common 25% of the genetic patrimony on average, were also raised in a similar family environment, being born in an interval of time inferior to 24 months;
4. group of fully grown unique children (FU) for whom the concentration of hereditary factors was the least and corresponds to the genetic patrimony of the Italian population.

SUBJECTS

Ninety six subjects participated in the present research (20 M and 76 F) selected according to the concentration of hereditary factors, described in the introduction, and were selected into the following four groups:

MZ – 12 couples (10 FF, 2 MM);

DZ – 12 couples (5 FF, 5 MF, 2 MM);

FQC – 12 couples (7 FF, 5 MF);

FU – 12 fully grown couples chosen at random (11 FF, 1 MM).

The subjects volunteering to the research were students of different faculties of the University "La Sapienza" of Rome (N = 77) and working diploma recipient or graduates (N = 19), reached through personal acquaintances. The ages of the subjects were between 18 and 35 years; the mean ages of the 4 groups were roughly homogeneous.

METHODS

The material of the WCST, developed by Heaton [8], is formed by:

a) 4 stimulus cards, arranged from left to right in such a way to represent a red triangle, two green stars, three yellow crosses; four blue circles. Each figure is always drawn in the same way and all the figures are placed on each card according to standard criteria;

b) 128 response cards (two identical series of 64 cards each) similar to the previous ones, numbered in a progressive way and ordered so that two consecutive cards never have the same color, shape or same number of elements.

In the computerized version [7], the cards are shown on a computer screen along three horizontal bands. In the top band the four stimulus cards are lined up from left to right according to different combinations of color (C: red – green – yellow – blue), shape (F: triangle – star – cross – circle) and progressive number of elements (No 1 to 4). In the lower band the 128 response cards appear, one at a time in the course of the test administration, being assorted for color, shape and number of elements, so that they are associated with one of four target cards. The association is decided by the subject by pressing the key corresponding to the position of the selected card on a numerical keyboard.

Following each decision, the computer utters high "or low" acoustic signal which points out the positive or negative result of the decision, respectively. Each chosen card appears in the intermediary band of the screen, each under the correspondent target card. The test comes to an end automatically either when all the phases C/F/N/C/F/N have been completed (that is to say, six blocks of ten consecutive exact responses, according to the criterion of succession), or when all the 128 cards have been selected, even if an inferior number of phases (0 to 5) have been completed.

With the computerized version of the test one may obtain 12 different scores:

CC – total of completed categories (0 to 6);

NT – total number of responses;

CORR – total of correct answers;

ERR – total of wrong answers;

PR – total of persisting responses;

PE – total of persisting errors;

NPE – total of non persisting errors;

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% PE – % persisting errors;

TC1C – number of attempts to complete the first category;

% CLR – % answers of conceptual level;

FMS – failure to maintain the set;

% LL – % "Learning Learn".

The test does not only assess the ability of abstract reasoning implicated in the subject's decisions, but also the ability of the subject to form, maintain and change the cognitive set, as well as the ability to learn to use the feedback coming from the computer in order to modify his erroneous strategies. The WCST differs from other abstraction tests since it provides an objective measure not only of the global success, but also of particular causes of difficulty encountered in the task, e.g. the initial inability to conceptualize, the inability to maintain the cognitive set, or to learn through the different phases of the test.

Data Analysis

The scores obtained through the WCST allow to produce an individual profile. This is useful to make comparisons between partners of a MZ and DZ pair, a couple of siblings of almost the same age, or a fictitious couple of singletons. When the main purpose involves a comparison between group in a fairly large sample of Ss, a recoding of raw data is necessary before operating any statistical analysis.

This procedure is necessary also because the final score of WCST shows figures referring to heterogeneous measures (for example, absolute frequencies for the scores CC and CORR, and percentage values for the score % PE).

The recoding was performed in the following way:

1. to enhance the completeness of the profile of basic results, which coincide with the number and the type of errors and correct answers, the new variables "Number of Correct Persisting Answers" and "Number of Correct Non Persisting Answers" have been estimated, on the basis of the existing variables (particularly: NT, CORR, PR, ERR; see above). The distinction between persistence and non persistence, as far as errors are concerned, may be observed directly in the original scores of the test;
2. to standardize information codified in the scores CC and NT, a new variable "Average Number of Answers for Category" has been estimated, by dividing CC by NT. In this way the dimension measured by the variable (number of answers) is homogeneous with the other variables;
3. the original variable TC1C has been used without being recoded.

6 variables have been used to define each individual profile:

a) "Number of Correct Persevering Answers";

b) "Number of Correct Non Persevering Answers";

c) "Number of Wrong Persevering Answers";

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d) "Number of Wrong Non Persevering Answers";

e) "Mean Number of Answers for Category";

f) "Mean Number of Answers to Complete the First Category".

In this study these variables will be identified using letters from "a" to "f".

The first step to operate a comparison between the considered groups (MZs, DZs, FU and FQC) is to reduce the dimensionality of the space of data, so that a reasonable interpretation of the relevant information contained in the same data may be obtained. The more adequate technique of data analysis for such a purpose is the Principal Components Analysis (PCA), that, fundamentally, "compact" the variables of origin in a small number of components (= variables), decorrelated between them, while preserving the maximum variability between the cases [10, 6].

Tables 1 and 2 and Figures 1 and 2 illustrate the data relevant for the interpretation of the results of the PCA performed upon the variables *a-f*. Only the first two Principal Components (PC), corresponding to the most important parts of variance explained (that is to say, respectively, 58,368% and 15.571% reaching a rough 74% of the total variance; cf. Tab. 1), were taken into consideration. The quality of the general representation of the variables *a-f* (first column of the Tab. 2) is farily high, with the partial exception of the

Table 1 - Eigenvalues, percent and cumulative percent of variance along the five PCs

Eigenvalue	Percent	Compercent
3.4656	58.368	58.368
0.9245	15.571	73.939
0.7273	12.248	86.188
0.4355	7.334	93.522
0.2412	4.062	97.583
0.1435	2.417	100.000

Table 2 - Recoded variables. *Qlt*: quality of representations along PCs; *C1* and *C2*: coordinates of variables in principal plane; *SqCor*: squared correlations between PCs and variables; *Contr*: contribute of variables to PCs. Values in thousandths for better readability

Name	Qlt	Cl	SqCor	Contr	C2	SqCor	Contr
a	496	376	494	41	–50	2	3
b	704	–406	578	48	–367	126	146
c	838	489	838	69	9	0	0
d	663	430	647	53	131	16	19
e	781	472	781	64	16	0	0
f	953	216	164	14	–919	789	914

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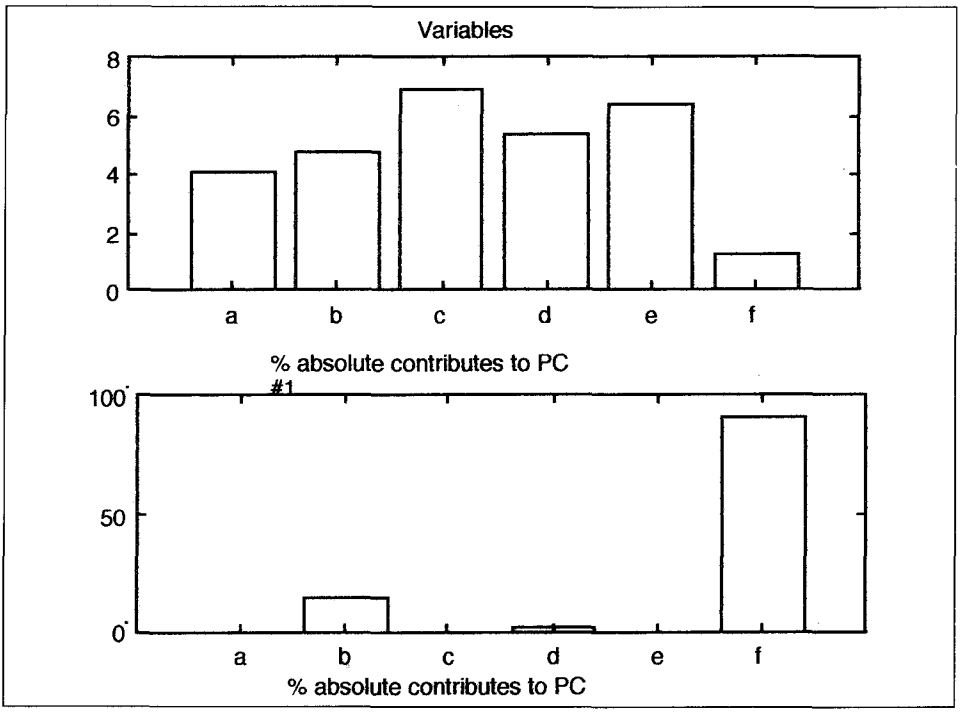

Fig. 1 - Absolute percentual contributes to PCs.

variable *a* (a result which can be ascribed to the limited number of correct persevering answers). The contribution to the first PC results remarkable by part of all the variables, excepting the *f*, that alone furnishes the more relevant contribution to the determination of the second PC (see columns 4 and 7 of the Tab. 2). The quadratic correlations between variables and PCs (see coluns 3 and 6 of the Tab. 2), that are indexes of the quality of the representation of the original variables along each PC, are fairly coherent with the figures of the contributions.

In order to define a statistically significant difference between the four groups of Ss, a multivariate ANOVA has been performed, considering the two PCs as dependent variables and the affiliation to a determined category (FU, FQC, DZ, MZ), the sex (M or F) and the working condition (Student or Worker) as categorizing variables. The general model did not reach 5% of statistic significance (*Lambda of Wilks* = 0.985), while the effect of interaction between category and sex produced a *Lambda of Wilks* equal to 0.855 (p = 0.042), with univariate F statistically significant only for the second PC ($F_{3,83}$ = 10.222; p = 0.010).

The model was accordingly modified to a univariate (with the second PC like dependent variable) 4 (category) by 2 (sex). The ANOVA yielded a $F_{7,88}$ = 2.260 (p = 0.036) for the total model, a $F_{3,88}$ = 3.190 (p = 0.027) for the interaction category/sex and a $F_{3,88}$ = 3.930 (p = 0.011) for the effect caused by the variable category only (the F for the effect of sex having not reached 5% of statistical significance). The R^2 (i.e. the quota of

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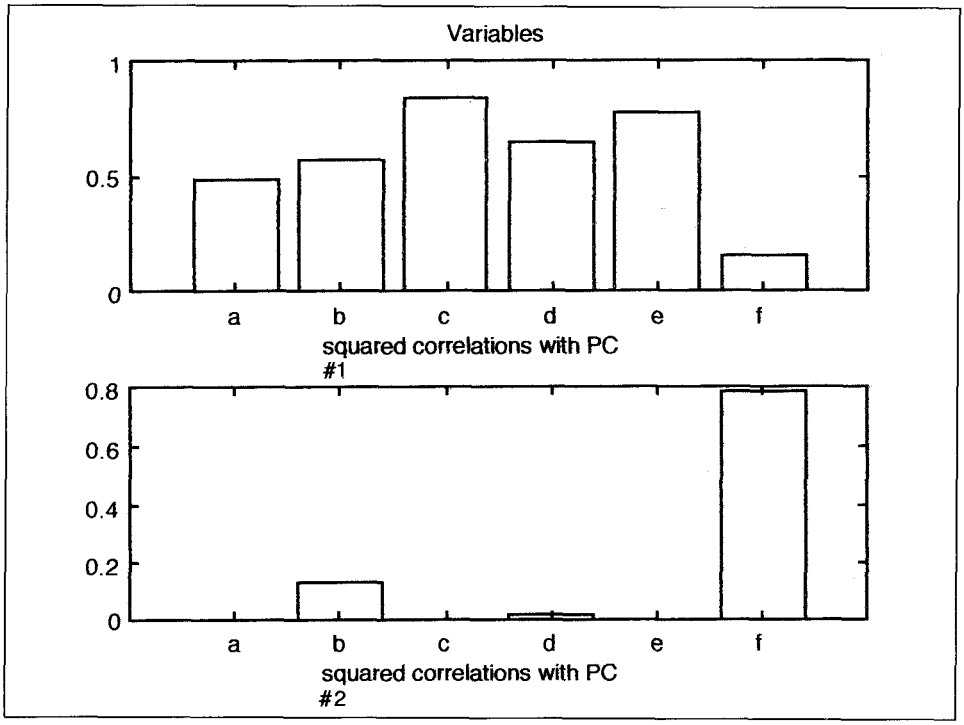

Fig. 2 - Squared correlations of variables with PCs.

variance explained by the model) resulted equal to 0.153, and was not modified by the introduction of the variable age (in years) as a covariate. Figure 3 shows graphically the averages of the varied categories in relation to sex.

The consideration that the representation of the sexes is decidedly unbalanced in the sample of Ss here considered (cf. the section Subjects; for instance in the category FU ghe men were 2 and the women 22), led to the decision to verify only the differences between categories (without considering the sex); a univariate model (always with the like dependent variable) 1 (second PC) by 4 (category) did not reach 5% of statistic significance. The examination of Figure 3, through which the difference between DZ and the two groups of singletons emerges rather patently, induced to formulate the hypothesis that the MZ group does not present any meaningful difference with respect to the other categories (also FU and FQC do not differ significatively between them), reducing therefore the variability of the model. The hypothesis was verified at first by testing a model 1 by 2 (twin/singletons), that resulted statistically significant ($F_{1,95} = 4.139$; $p = 0.040$), then examining the differences between the categories through single *post hoc* comparisons. The only significative differences were those between DZ and, respectively, FU ($F_{1,46} = 4.185$; $p = 0.047$) and FQC ($F_{1,46} = 6.586$; $p = 0.014$).

Finally, no statistically significant difference was assessed by the ANOVA taking the item %LL (that for his conceptual value was considered apart for the interpretation of results) of the WCST as the dependent variable.

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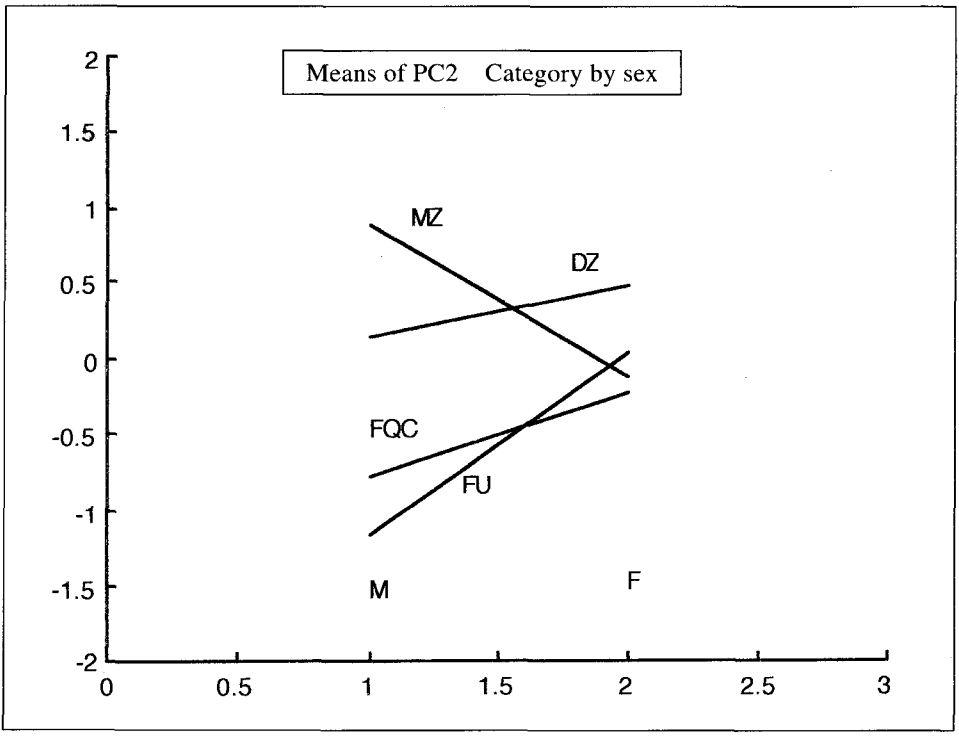

Fig. 3 - Means of PC #2, sex by category.

DISCUSSION

Figure 4 (compare with the columns 2 and 5 of the Tab. 2) allows to analyse the meaning of the two PCs in a coherent way.

The first PC (horizontal axis of Fig. 1) is characterized by the opposition of the variable *b* to the others, in other terms, by the opposition of the number of correct non persisting answers (this being the largest number of correct answers produced by the sample of Ss) to the errors in general, the other correct answers and the average number of answers for each completed category. The variable *f* is not taken into consideration for the interpretation of this PC, on the basis that it is poorly represented by the PC. The fact that the variable *a* is grouped with the other variables opposed to *b* could seem at first sight counterintuitive; really this position of *a* is explainable by its scarce incidence in defining the PC (cf. columns 3 and 4 of Table 2), as well as by the fact that the PC, rigorously speaking, would not be interpreted as "correct not systematic answers vs. errors," but on the contrary as "measure of conceptual rigidity". A careful examination of Figure 4 (see also column 2 of Table 2) allows to determine that the errors and average number of necessary answers to complete each category are placed to the right along the axis (the persisting errors being themselves to the right of non persisting errors), therefore in positive sense, while the correct non persisting answers are con-

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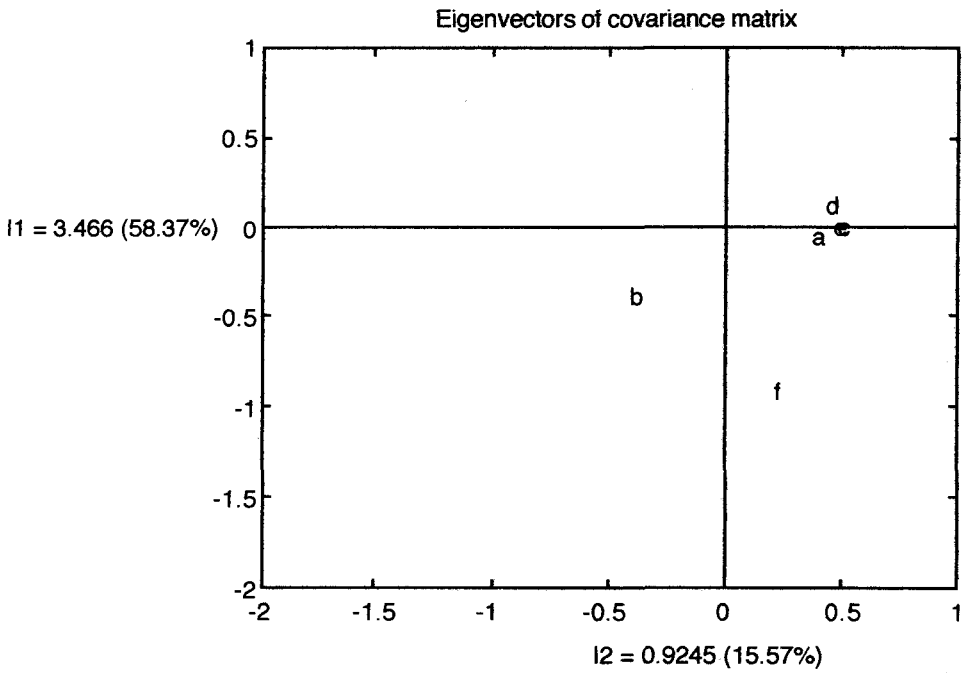

Fig. 4 - Projection of variables on the plane defined by the first two PCs. I1 and I2: eigenvalues (proportion of variance explained by each PC in parentheses).

noted by negative coordinates along the axis. The correct persisting answers are next to the origin, along the positive coordinates, as if, in a sense, the small flexibility was privileged with respect to the correctness as an element defining the axis. By the way, as it has already been observed in the section "Data analysis", no meaningful difference along this component was observed: neither with respect to categories, neither to the sex or working condition.

The second PC is almost completely defined by (and highly correlated with) the number of answers needed to reach the definition of the first category, that is to say with the variable *f*; (cf. lines 6 and 7 of Table 2). One may only notice that, in a sense, since *f* has a negative coordinate along the second axis (cf. Figure 4 and column 5 of Table 2), this axis might represent the "rapidity to define the first category", on the basis of considerations similar to those exposed for the first PC. It should be also noticed that the remaining variables [*a-e*] are all next to the origin along the vertical axis (Fig. 4), having therefore scarce influence in determining it.

The tests of comparison of the central tendencies between the categories show that a statistically meaningful difference between the categories of the sample (FU, FQC, DZ and MZ) is present only along the second principal component. In other words, the "rapidity to define the first category" constitutes the principal difference between twins (mainly DZ, that furnished the overall best performance) and singletons.

Future studies should look upon the importance of interaction between categories

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and sex previously established, also carefully considering the disparity between the number of male and female subjects in the sample studied.

The real meaning of the results, i.e. their validity external to the sample, should be assessed through further investigations. The main consideration which induces to caution is about the relatively small quota of variance explained by the second PC used as dependent variable during the data analysis (about 15.6% of the overall variability of the sample).

It is necessary to highlight that the second PC does not overlap the variable that mostly defines it (i.e. e TC1C). In fact the main component [10] maximizes the direction of variability of the sample. This is what each original variable, by itself, necessarily does not do. The ANOVA test, performed upon the variable TC1C, also produced a difference statistically significant only between DZ and FQC ($F_{1,46} = 6.491$; $p = 0.014$) and not between DZ and FU.

CONCLUSIONS

The results obtained can be synthesized into two points:

1. in the studied sample the twins tend to show a higher rapidity to complete the first category than singletons (cf. Fig. 3); female subjects tend to present the same characteristic as male subjects (Fig. 3). The importance of these data is limited because of the small number of either MZ and male singletons present in this study;

2. the greatest difference between twins and singletons may be ascribed to the best performance provided by the DZ group as long as with regard to the rapidity to complete the first category. There is no significant difference between singletons and MZ and DZ twin pairs.

The rapidity to complete the first category of the WCST should not be considered a genetically determined ability. The best performance provided by DZ twins, who share 50% of their genetic patrimony, independently from the assortment of the couple (MM, FF, MF), is likely to depend on an optimal interaction between hereditary and environmental factors. The results achieved through the employment of the EFT in the work cited in the introductory part perfectly comply whit this hypothesis [5]: the field-dependence of the DZ vs. MZ, FQC and FU emerged clearly, despite the surely genetic origin of field-dependence in the MZFF.

As far as the cognitive abilities measured by the WCST are concerned, it seems useless either to assess the importance of hereditary factors and environmental factors, and to reason in terms of fluid intelligence and crystallized intelligence. It is essential to spot the most relevant influence among the multiple environmental ones, also taking into consideration the relationship between partners of a DZ couple. In the future, research should aim at discovering the causes of the differences between DZ twins and singletons.

In our work we could only exclude, thanks to the ANOVA test, that the birth order – which has a different meaning for DZ and FQC – bears any significant effect.

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