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OSWALD BRATFISCH

A FURTHER STUDY ON SUBJECTIVE AND OBJECTIVE INTELLIGENCE FACTORS

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A FURTHER STUDY ON SUBJECTIVE AND OBJECTIVE INTELLIGENCE FACTORS*

Bratfisch, O. A further study on subjective and objective intelligence factors. Reports from the Institute of Applied Psychology, The University of Stockholm, 1971, No. 20. - Forty-three students participated in a laboratory experiment involving estimation of qualitative similarity between items sampled from ten conventional tests of intellectual performance. Estimated similarity could tentatively be described as a function of positive inter-test correlations as determined from another group of 123 individuals with the same level of education. The similarity matrix was treated as in multidimensional psychophysics - test items being regarded as stimuli. Five "subjective" factors were found, corresponding to the "objective" performance factors extracted from analyses of the correlational data. The results confirm the findings of a previous study by Bratfisch and Ekman.

Introduction and problem

A number of works have shown that modern psychophysical methods (as described by e.g. Stevens, 1960; Ekman and Sjöberg, 1965; Ekman, 1969) can be very useful tools not only when dealing with the ordinary sense modalities but also within other problem areas as, for example, studies on intrasubjective relations have shown (e.g. Eisler, 1960; Ekman, Engen, Künnapas and Lindman, 1964; Bratfisch, 1969; Ekman and Lundberg, 1970). Other instances are a recent study by Magnusson and Ekman (1970) applying psychophysical methods to the study of personality, and a number of investigations on physical performance (e.g. Borg, 1962) as well as on the perceived difficulty of test-items (e.g. Borg and Forsling, 1964; Borg, Bratfisch and Dornic, 1970; Bratfisch, Dornic and Borg, 1970).

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One of the most recent studies of the above-mentioned kind was concerned with the dimensionality of intellectual performance as perceived by the performing subject himself (Bratfisch and Ekman, 1969). In this study an attempt was made to integrate traditionally widely different approaches - research on intelligence based on the one hand, on correlational investigations, and, on the other hand, on multidimensional scaling techniques. The subjects (persons having elementary, i.e. 9 years of schooling only) were asked to estimate qualitative similarity of test items, i.e. the degree of qualitative overlap between items sampled from conventional tests of intellectual performance. Estimated similarity could be described, in a first approximation, as a function of intertest correlation as determined from 2 other, rather large groups of subjects. The analysis of the similarity matrix resulted in five "subjective" factors completely corresponding to the five "objective" factors extracted from the analysis of the correlation data.

The main purpose of the present study - which is a continuation of the above-mentioned work - was to investigate if the relation previously found between estimated similarity and inter-test correlation as well as the close correspondence of "subjective" and "objective" factors would be true even for subjects with a higher level of education. A tentative hypothesis was that there might emerge more "subjective" factors than "objective" ones when dealing with subjects having a higher level of education. We figured that the number of conscious "strategies" one uses when solving different intellectual tasks is likely to increase with increasing level of education, as people are being trained in these respects.

Method

The experiment was carried out in exactly the same way as in the previous study by Bratfisch and Ekman, which from now on will be referred to as "Study 1". The experiment was performed in Austria. As there was no German test battery available referring to the system introduced by Thurstone (1938, 1941) the test battery used in "Study 1" (The "Delta Battery" of the Institute of Applied Psychology in Stockholm; manual, 1971) was translated and standardized on a group of 123 students belonging to the same high-school and to the same grade as the experimental group. The coefficients of correlation for this group of 123 students will be used as comparison data.

The stimulus situation

Ten factor tests from the above mentioned test battery were used in the first part of the experiment. The tests were selected so as to represent five well-known factors of intellectual performance. All of the tests were conventional in character and may, hence, be characterized by names only. In the following presentation, the tests are arranged according to the factors they represent; the denotation of factors follows, as indicated above, the system introduced by Thurstone (1938, 1941).

	Test	Factor	
(1)	Synonyms	Verbal comprehension	(V)
(2)	Opposites	- " -	
(3)	Identical letters	Perceptual speed	(P)
(4)	Identical numbers	- " -	
(5)	Multiplications	Numerical facility	(N)
(6)	Mixed computations	- " -	
(7)	Number series	Reasoning ability	(R)
(8)	Matrices	- " -	
(9)	Levers	Spatial ability	(S)
(10)	Surface development	- " -	

The tests were administered to the subjects under standard conditions. The testing session served, among other things, the purpose of making the subjects thoroughly familiar with the tests and, thus, providing them with a basis for judging what kind of performance was required by any particular test.

In the experiment proper, conducted one week later, sample items from the tests were presented to the subjects, one item from each test. The sample items had high and approximately equal solving frequencies, around 88 per cent.

Similarity estimation

The subjects were instructed to consider each pair of test items in turn, and to estimate the degree of similarity between the kinds of performance represented by these items. They were instructed to base their judgments entirely on qualitative similarity between the tasks, disregarding possible perceived differences in difficulty of the tests. This instruction is of particular importance with respect to the dimensional analysis, which will be presented later (cf. Ekman, 1963).

The estimates of similarity were to be given on a percentage scale, 100 representing identity and 0 denoting no similarity at all. The subjects were given a number of training trials, with items different from those of the main experiment, in order to ensure a correct understanding of the instructions.

The 45 pairs of test items were presented in two random orders, so that each subject produced two estimates of each pair and, thus, altogether 90 estimates. The experiment was conducted in a single session lasting 50 minutes on an average.

Subjects

Forty-three subjects participated in the experiment. The original group consisted of 49 persons, of which six were excluded because of extremely variable responses. This was done by calculating a coefficient of correlation between the first 45 estimates and the second 45 estimates for each subject separately. The coefficients thus obtained were regarded as a measure of the "individual reliability". Subjects with reliability lower than 0.50 did not qualify.

All subjects were students of a technical high-school in Vienna, Austria, in the last form. With but a few exceptions all subjects were male. Their age ranged from 17 - 26 years, the median age being 18 years.

Results

As in "Study 1", the results have been analyzed with respect to (a) the reliability of the similarity data, (b) the relation between correlation and similarity, and (c) the dimensionality of the perceived qualitative overlap between items as well as the dimensionality of "objective" performance.

Reliability of similarity data

In "Study 1" it was pointed out that a group of e.g. 30-50 individuals estimating similarity (which with regard to reliability could be considered relatively small) corresponds to a much larger sample used for determining coefficients of correlation. This is, among other things, due to the fact that the standard error of a central measure, other things being equal, is less than that of a coefficient of correlation. Thus the number of subjects in the present study, 43, can certainly be considered representative for this purpose.

Two other aspects of the reliability of the similarity data are demonstrated in Figs. 1A and B.

In Fig. 1A, the medians of the 43 subjects' first 45 similarity estimates are plotted against the medians of their second 45 similarity estimates. There is no systematic deviation between the two sets of data from the graph. The scatter is very moderate. The coefficient of correlation over the 45 estimates is + 0.95. Though we are aware that central measures generally yield higher coefficients of correlation than do raw values we think that the stability of estimation for the group as a whole can be regarded as highly satisfactory. Since the first and second estimates of similarity do not differ systematically, the mean of the two estimates was computed for each stimulus pair and for each subject. The medians of

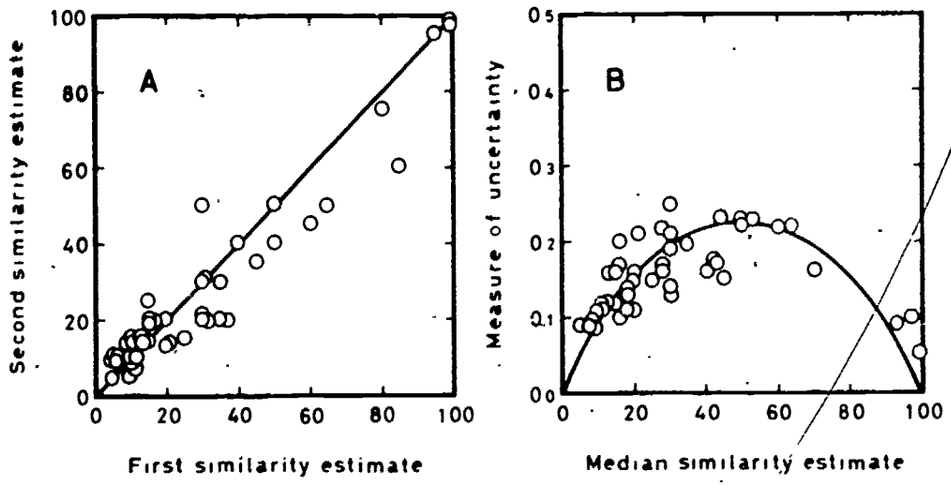

Fig. 1. Illustration of the reliability of the similarity estimates. Diagram A shows the medians of second estimates plotted against the medians of first estimates. Diagram B shows a measure of uncertainty plotted as a function of median similarity estimate: the curve represents a parabolic function.

these individual means, shown in Table 1a, will be used for all further analyses. For purpose of comparison the corresponding data from "Study 1", based on 31 subjects, are given in Table 1b. The figures 1 to 10 in Tables 1a and 1b refer to the tests denoted by these figures in the chapter "method" in this report.

Table 1 a. Similarity estimates (present study)

	1	2	3	4	5	6	7	8	9	10
1		99	35	30	5	11	8	18	8	10
2	99		40	25	8	12	10	20	10	10
3	35	40		97	16	21	15	28	15	12
4	30	25	97		28	28	16	30	20	16
5	5	8	16	28		92	54	30	18	18
6	11	12	21	28	92		60	30	30	20
7	8	10	15	16	64	60		52	45	42
8	18	20	28	30	30	30	52		44	50
9	8	10	15	20	18	30	45	44		70
10	10	10	12	16	18	20	42	50	70	

Table 1 b. Similarity estimates ("Study 1")

	1	2	3	4	5	6	7	8	9	10
1		100	68	75	20	25	18	20	10	16
2	100		75	60	16	23	25	35	10	13
3	68	75		95	30	25	35	35	10	23
4	75	60	96		50	49	33	44	15	23
5	20	16	30	50		95	70	30	25	26
6	25	23	25	49	95		65	20	33	30
7	18	25	35	33	70	65		60	45	50
8	20	35	35	44	30	20	60		48	53
9	10	10	10	15	25	33	45	48		90
10	16	13	23	23	26	30	50	53	90	

In Fig. 1 B, the mean differences (disregarding signs) between the first and the second similarity estimates are plotted against the medians of the similarity estimates. The trend of the data might tentatively be described by a parabolic function of the form

$$D_s = a\,(s - s^2), \qquad \text{——(1)}$$

where D_s denotes the intra-individual variability or uncertainty of estimates and s the degree of similarity (a is a measurement constant). Similar results have been obtained in other studies (e.g. Ekman and Künnapas, 1969; Eisler, 1960).

Similarity and correlation

Coefficients of intertest correlation for the group of 123 subjects are shown in Table 2 a. For comparison the same data for about an equally large group of 128 subjects, used in "Study 1", are presented in Table 2 b. The figures 1 to 10 in Tables 2a and 2b refer again to the tests denoted by these figures in the chapter "method" in this report.

Table 2 a. Coefficients of Correlation (present study)

	1	2	3	4	5	6	7	8	9	10
1		42	08	06	01	08	18	11	-02	07
2	42		24	04	10	12	24	16	04	07
3	08	24		53	53	53	12	-01	05	17
4	06	04	53		36	41	09	-12	06	-01
5	01	10	53	36		62	-12	-24	-03	-33
6	08	12	53	41	62		04	-12	17	-08
7	18	24	12	09	-12	04		36	21	31
8	11	16	-01	-12	-24	-12	36		20	39
9	-02	04	05	06	-03	17	21	20		41
10	07	07	17	-01	-33	-08	31	39	41	

Table 2 b. Coefficients of Correlation ("Study 1")

	1	2	3	4	5	6	7	8	9	10
1		78	40	33	23	28	45	40	-13	27
2	78		40	36	22	24	46	47	-11	27
3	40	40		66	30	32	44	51	-06	23
4	33	36	66		36	39	42	41	-15	11
5	23	22	30	36		74	27	18	-16	04
6	28	24	32	39	74		44	32	-04	13
7	45	46	44	42	27	44		67	22	43
8	40	47	51	41	18	32	67		23	36
9	-13	-11	-06	-15	-16	-04	22	23		45
10	27	27	23	11	04	13	43	36	45	

The coefficients of correlation between the tests in the present study are, compared to those in "Study 1", smaller throughout, as can be seen from Tables 2a and 2b. Inspite of this fact the same trend with regard to the relation between similarity and correlation appears as in "Study 1".

In Fig. 2 A the medians of the similarity estimates have been plotted against coefficients of correlation. Similarity is obviously growing with correlation, the form of the trend being obscured by a considerable scatter. To bring out the trend more clearly, the median similarity estimates of Fig. 2 A have been averaged for equal successive intervals of the correlation coefficients. The range of coefficients was divided into seven equal intervals, the interval width being 0.136. The average data are shown in Fig. 2 B.

The trend of the data was examined only on the basis of points over the positive part of the axis representing correlation.

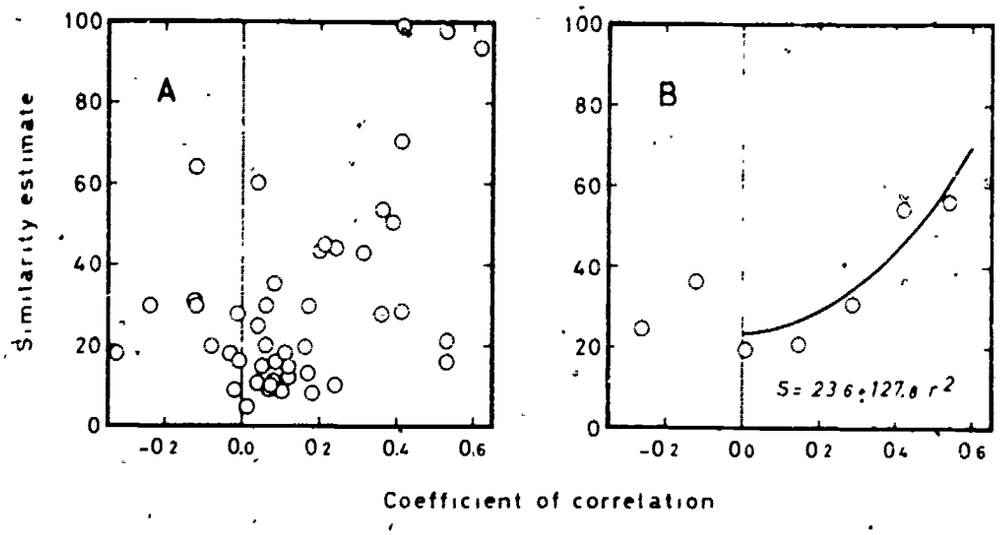

Fig. 2. Medians of similarity estimates plotted against correlation coefficients. Diagram A shows similarity estimates averaged for equal successive interval of the correlation coefficients. The curve drawn represents Equation 2.

The relation between similarity estimates corresponding to positive coefficients of correlation has again, as in "Study 1", been described by the equation

$$S = a + b\,r^2 \qquad (2)$$

where S refers to similarity and r to correlation; a and b are empirical constants. Obviously, alternative functions could have been fitted to the present data. However, with but 5 points available as a computational basis it was considered adequate to apply the function found in "Study 1".

Dimensionality of "subjective" and "objective" data

The same straighforward procedure as in "Study 1" was applied for analysing the dimensionality of the two sets of data, i.e. the matrix of similarity estimates was factored (without any transformation of the estimates into cosines) by the method of principal components, the first five factors being rotated to simple structure by the Varimax procedure.*

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* As a theoretical discussion concerning the use of the "method of similarity analysis", developed by Ekman (1954), and revised by the same author (Ekman 1965), was given in "Study 1", no further theoretical reasoning in this respect will be offered here.

The correlation matrix was treated in a similar manner. The two matrices are shown in Table 3. For comparative reasons the corresponding data of "Study 1" are given in Table 4.

A far-reaching agreement between all four sets of data can be seen by inspection of Tables 3 and 4. This agreement is further illustrated by the sample of factor plots shown in Fig. 3. For each analysis, there are ten plots of which three are chosen so that each factor is represented at least once. The two points representing the highest loadings of a factor are represented by filled circles at which the particular test numbers are indicated. The corresponding configurations of Fig. 3 are rather similar.

Table 3. Rotated principal factors (present study)

	Factor obtained by											
	Similarity analysis						Correlational analysis					
Test	V	P	N	R	S	h^2	V	P	N	R	S	h^2
1 Synonyms	98	15	01	05	03	99	89	10	-09	-01	02	80
2 Opposites	98	15	04	06	04	1.00	77	-04	21	27	-02	71
3 Identical letters	23	96	07	08	05	98	11	70	48	15	04	76
4 Identical numbers	12	97	15	07	09	99	00	86	21	-06	00	78
5 Multiplications	02	11	96	08	04	95	03	22	86	-15	-13	83
6 Mixed computations	07	13	95	01	14	94	06	31	79	-04	18	76
7 Number series	03	00	67	45	34	76	16	16	-03	76	08	64
8 Matrices	10	17	19	88	30	94	04	-15	-10	81	15	72
9 Levers	03	09	15	08	92	88	-01	-07	15	09	92	89
10 Surface development	05	04	07	27	87	84	04	28	-37	38	64	78

Table 4. Rotated principal factors ("Study 1")

	Factor obtained by											
	Similarity analysis						Correlational analysis					
Test	V	P	N	R	S	h^2	V	P	N	R	S	h^2
1 Synonyms	93	34	11	-04	07	1.00	84	20	14	13	04	77
2 Opposites	96	26	07	16	03	1.00	83	22	09	20	03	78
3 Identical letters	48	83	11	18	05	96	23	76	15	17	07	69
4 Identical numbers	40	86	31	13	07	1.00	17	74	25	17	-07	67
5 Multiplications	02	21	95	13	08	97	12	18	83	19	04	77
6 Mixed computations	11	14	96	-02	18	98	11	19	83	00	-07	74
7 Number series	12	03	66	60	27	88	31	28	27	58	35	71
8 Matrices	13	21	09	87	33	93	28	37	11	62	29	70
9 Levers	04	-01	16	16	95	96	-17	-11	-08	18	71	58
10 Surface development	04	11	13	23	93	95	24	13	05	07	71	59

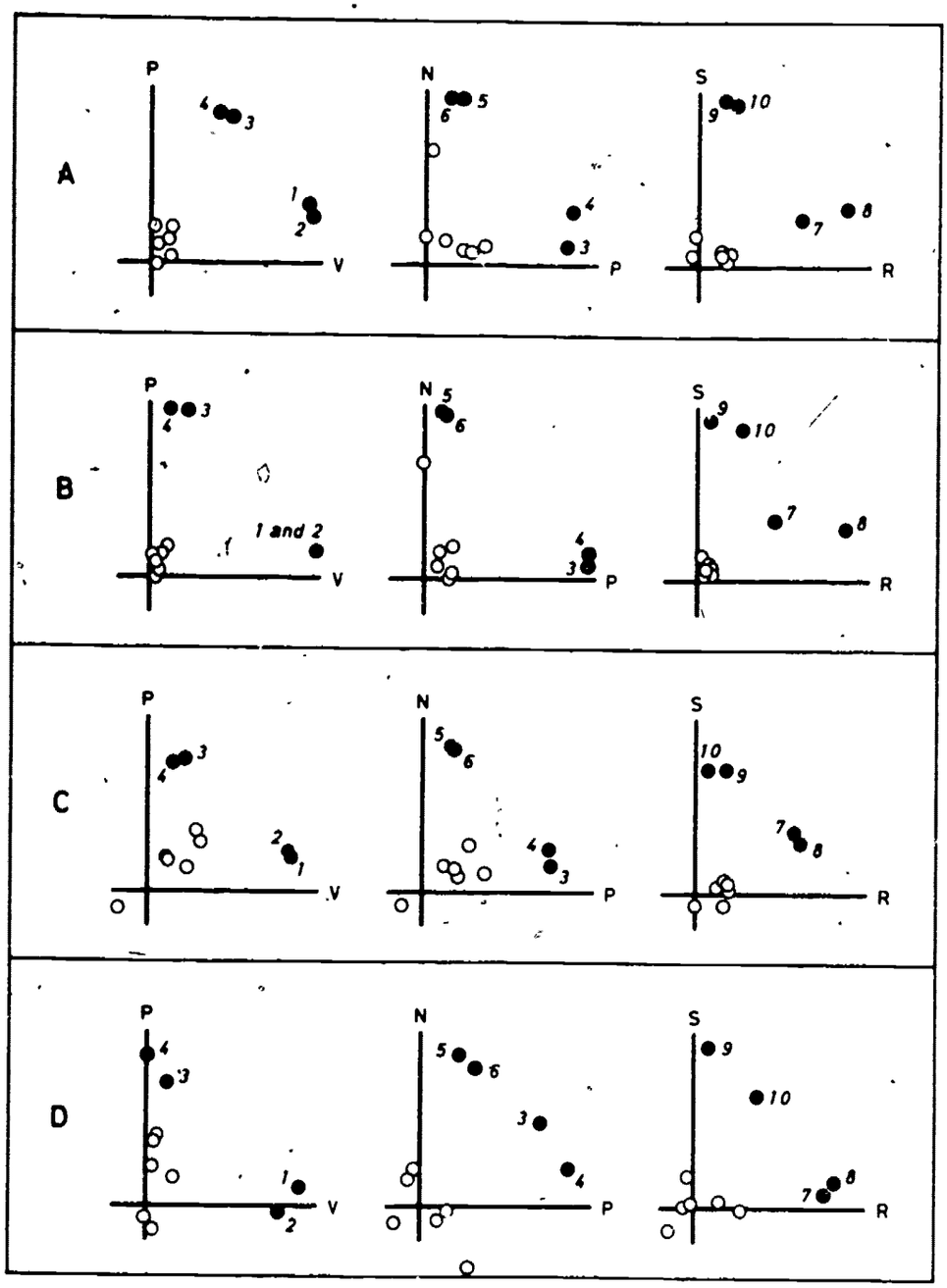

Fig. 3. Samples of factor plots. Diagram A illustrates the results obtained by similarity analysis in the experimental group of "Study 1". Diagram B shows the corresponding results of the present study. Results obtained by factor analysis of correlation matrices from "Study 1" and those of the present study are represented in Diagrams C and D respectively.

The identification of each of the five factors from Tables 3 and 4 is self-evident in each case. In each analysis the Verbal (V), Perceptual (P), Numerical (N), Reasoning (R), and Spatial (S) factors emerge, represented by the same tests. The main results from all analyses have been summarized in Table 5.

Table 5 Identification of rotated factors by tests with highest loadings

Factor identified as	Test	Factor loadings obtained by			
		Similarity analysis (present study)	Similarity analysis ("Study 1")	Correlation analysis (present study)	Correlation analysis ("Study 1")
V = Verbal comprehension	1 Synonyms	98	93	89	84
	2 Opposites	98	.96	77	83
P = Perceptual speed	3 Identical letters	.96	83	70	76
	4 Identical numbers	.97	.86	86	74
N = Numerical ability	5 Multiplications	.96	95	.86	83
	6 Mixed computations	.95	.96	79	.83
R = Reasoning ability	7 Number series	.45	60	76	58
	8 Matrices	.88	.87	81	.62
S = Spatial ability	9 Levers	.92	.95	92	71
	10 Surface development	.87	93	64	71

Discussion

The findings of the present study show a close correspondence to the results obtained by Bratfisch and Ekman (1969).

The tentative hypothesis that more "subjective" factors than "objective" ones should emerge for subjects with a higher educational level did not come true. This is, in a way, surprising. In higher education usually a certain amount of training in different ways of solving intellectual tasks is introduced. One is likely to expect that this training, certainly conscious to the students, should also be reflected in their perception of what kind of ability they use when coping with different intellectual tasks. However, according to the present results, that is not the case. Similarity analysis yielded the same results as conventional factor analysis of correlation data. In other words the features of intellectual performance as experienced by the subject himself appear to be characterized by the same dimensionality as objective test performance. This seems to be true for both people with ordinary, compulsory education and people with a somewhat higher level of education. It would be interesting to investigate both still higher and maybe also lower educational levels in this respect. (We are, however, aware of the difficulties the experimenter would probably encounter with the latter group as the task to estimate qualitative overlap between items is rather intellectually demanding.)

It might be argued that the subjects, due to their education, had some knowledge about psychological intelligence theory and that they had given their estimates thereto. We do not feel that this is likely to have influenced the subjects' responses, in any case not to a noteworthy extent, as we feel that only a thorough knowledge of psychological intelligence theory would block or influence one's perception in these respects.

Furthermore it might be argued that the subjects were estimating the difficulty of the tasks and reporting similarity in accordance with this kind of perc . s in "Study 1", a separate analysis was carried out t present data to prove that this was not the case. For each subject and each pair of tests, the difference between the two standard scores on the tests was calculated; as was mentioned above, the full tests had been administered to the subjects prior to the experiment proper. If the degree of similarity reported by subjects did reflect individual difficulty, these data would show a decreasing similarity with increasing difference (disregarding signs) in standard scores. Plots of the 43 x 45 = 1935 points thus obtained showed a very considerable random scatter, but there was practically no trend for similarity to decrease with increasing performance differences. These data are summarized in Table 6.

Table 6. Frequency of individual similarity estimates as related to individual differences between standard test scores

Standard score difference	Similarity estimates										
	05	15	25	35	45	55	65	75	85	95	N
0	81	47	33	29	20	14	14	10	20	31	299
1	167	82	52	58	56	35	25	26	31	42	574
2	105	60	44	37	55	27	25	20	22	31	426
3	71	56	34	33	19	15	22	24	14	17	305
4	40	31	2	12	11	16	11	9	7	12	170
5	21	18	13	10	5	6	11	4	3	6	97
6	12	6	5	4	7	3	5	5	3		50
7		3	2		1	1				2	9
8		3	1							1	5

Moreover, the similarity estimates were divided into two classes (0-50 = low; 51-100 = high) as were the differences between the standard scores (0-3 = low difficulty; 4-8 = high difficulty). The coefficient of correlation based on this thus obtained fourfield table was as low as 0.021. Hence, it can be concluded that judged similarity between the tasks required by the different tests is hardly affected by the individual difficulty of these tests, and certainly not to any noteworthy extent. In other words, the estimates of similarity reflect qualitative attributes of the tasks as perceived by the subjects.

As has been said before the close correspondence of the results of the present study to those from "Study 1" is remarkable if one considers that the two groups of subjects had different levels of education. On the other hand there is no psychological evidence that the two groups were different as far as level of intelligence is concerned. The two groups showed by and large the same kind of performance level on the tests used. No difference in the "objective" factor structures could be noticed, which could have been expected as e.g. the factors Numerical ability and Perceptual speed tend to covary to a higher extent at higher educational levels and thus often emerge as one factor only. However, one cannot deny that subjects with only 9 years of elementary education ("Study 1") are likely to be regarded as having a lower level of education than do subjects with 13 years of elementary and high school education (present study).

The relation between similarity and correlation has tentatively been described mathematically, the computations being based on positive correlations only. From Fig. 2 B it is quite obvious that the two negative points - if included - would have changed the particular form of the mathematical function chosen. Something seems to be "wrong" with the estimates corresponding to negative correlations. We do feel that the explanation is to be found in the rating technique applied. Similarity estimates can, according to the instructions, only vary between 0 (no similarity at all, i.e. no covariation att all) and 100 (identity, i.e. perfect positive correlation). Thus, the estimates can never indicate a negative overlap between percepts. This problem could probably be solved by giving subjects a rating scale which ranges from -1 to +1 as defined in correlational terms. However, this is a scaling problem worthwhile to be studied more thouroughly.

The results of the present investigation confirm in all major points the results of Bratfisch and Ekmans' study. However, many problems, besides those discussed above, remain to be illuminated more closely. In particular, future research should aim at investigating what effect similarity in layout could have had on the estimates of qualitative overlap between the items. This could be done e.g. by giving different intellectual tasks purely verbal formulations. Furthermore the relation between qualitative and quantitative overlap between items should be examined. Finally, it would be of interest to extend the problems studied here in other areas, e.g. motor skills.

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