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A CONTRIBUTION TO THE DISPUTE ON THE ORTEGA HYPOTHESIS: CONNECTION BETWEEN PUBLICATION RATE AND STRATIFICATION OF SCIENTISTS, TESTED BY VARIOUS METHODS*

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It was tested whether the publication rate of scientists as a rough measure of their "eminence", influences their stratification. The stratification is reflected in cooperation, in co-authorships, in the structure of the citations and in the distribution of publications among the various problem areas of a scientific discipline. The findings of these investigations was discussed as a contribution to the dispute among authors who accept or reject the Ortega hypothesis which states that the research done by average scientists substantially contributes to the advance of science.

Introduction and hypotheses

The Ortega hypothesis, which maintains that the research of average or mediocre scientists substantially contributes to the advancement of science,[1,2] its refutation through empirical investigations by *Cole* and *Cole*[3] and resulting from this the recommendations for a reduction in the size of science, have caused differing reactions among other scientists.[1,2,4,5]

Cole and *Cole* analysed the citation practices of university physicists in the United States. Authors of highly cited papers, they found, tend predominantly to cite the papers of other highly cited authors.

The assumption that citations are an adequate way to measure the quality of scientific work or intellectual influences on it, was the first prerequisite for refuting the Ortega hypothesis in the period that followed, and also for the conclusion that the number of scientists should be reduced.

Green[5] in the field of criminology and *Oromaner*[2] in the field of American sociology obtained the same findings as the *Coles* in the field of physics. Like the

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other authors, *Oromaner* stated that the results of his analysis provide little support for the Ortega hypothesis. He suggests that these data lend support to the Newton hypothesis concerning the importance of 'standing on the shoulders of giants'. *Snizek*[1] pointed out that the Dutch physicists generally tend to the same behaviour as physicists in the USA, although ". . . not of a magnitude to warrant complete rejection of the Ortega hypothesis" (p. 8).

In a letter, *Cole* and *Cole*[4] comment that the criticisms of their article fall into two categories:

(1) citations are an inadequate way to measure the quality of scientific work, and
(2) the conclusions they reach concerning the size of sciences are not warranted by the data.

Authors who support the first category give some reasons for it. One of the findings from research done by *Moravcsik* and *Murugesan*[6] (p. 91) is "A large fraction of the references are perfunctory. This raises serious doubts about the use of citations as a quality measure." (See also *Chubin* and *Moitra*[7]). *M. H.* and *B. R. MacRoberts*[8] consider "that only about 15% of the influence on a paper is contained in its references – a very small figure indeed considering the assumption underlying citation analysis."

Letters from *Goudsmit, Gervey* and *Yaes*[4] also contain critical remarks analogous to the two categories and *Oramaner*'s statement regards the controversial conclusion concerning the size of sciences.[2]

In addition, *Gervey*[4] also criticises the rejection of the Ortega hypothesis. That is why a third category is added to those by the *Coles* in the form of a question:

> Does the finding that authors of highly cited papers tend predominantly to cite works of other highly cited authors justify the refutation of the Ortega hypothesis?

In their papers, *Oromaner*[2] and *Snizek*[1] make a number of proposals for the future extension of empirical research to gain a better foundation for the acceptance or refutation of the Ortega hypothesis.

Although *Oromaner* carried out the same study as the *Coles*, which, in his point of view, provides little support for the Ortega hypothesis, he states (p. 9):

> "One limitation of this study is that it is restricted to highly influential articles. These data shed no light on the role of the work of influential, average, or mediocre scholars in the construction of articles of average or minor influence. . . . a comparative analysis of individuals and contributions referred to in sociological articles of high, average, and low impact should be concluded."

Snizek states (p. 4):

> ". . . no research has been done to assess the validity of the *Coles'* findings either outside the United States, or within the context of a multivariate framework."

Some factors of the multivariate approach appear important. For example (p. 9): "Data presented in this study concerning Dutch physicists indicate a significant inverse relationship (Beta = –0.2390) between the length of a source author's professional experience, and the frequency with which the reference authors used have been cited. If we assume that, in general, the probability of scientific 'eminence' increases with professional experience, such a finding would appear to counsel against rejection of the Ortega hypothesis."

Based on the statements by *Oromaner* and *Snizek* and the criticisms of these, that citations generally represent a valid indicator of influence, the following conclusions were drawn as the basis for this paper:

> The verification or falsification of a hypothesis is made possible sometimes through the particularities of the method used. Therefore, there should be a *variation of the methods* used for testing one and the same hypothesis.

1. There is a connection between the number of citations used for assessing the scientists and the number of publications (publication rate) therefore it can be used the number of citations as well as the number of publications to assess the scientists. However, there are objections of different nature against the using of the number of publications for this purpose. Therefore, a comparison of results that were gained by these two methods, would be useful. *Knorr, Mittermeir, Aicholzer* and *Waller*[9] point out that despite all objections against the number of publications as an indicator of performance there is a high or medium correlation between the number of publications of a scientist and the assessment of the quality of his work. They gave as an example, the Goodman-Kruskal coefficient of 0.63 which *Blume* and *Sinclair* found during a correlation between the assessment of the work of a scientist by experts, and the number of the publications of this scientist. The authors cite *Cole* who reports a correlation coefficient of r=0.72 *(Pearson's r)* that resulted from a correlation between the number of publications and the number of citations of the three most often cited publications of a scientist. In an investigation carried out by the author of this paper, an equally high correlation of r=0.82 was found between the number of publications of about 80 university philosophers and the number of their citations.

   The 'eminence' of a scientist was determined by the number of citations in the above cited empirical investigations for testing the Ortega hypothesis. Because of the high correlation between the number of publications and the number of citations plus the desired variation in the methods, it is now assumed that the 'eminence' of a scientist is connected with the number of his publications (publication rate). According to *Dobrov*[10] and other authors, the 'eminence' of a stientist increases proportionally to the logarithm of the number of his publications. This statement supports the variation of methods.

2. The limitation of the *Coles'* study, i.e. the restriction to high influential articles, is now removed. A comparative analysis of the impact of the contributions of *all* scientists – eminent, average and mediocre – was now carried out.
3. A multivariate approach was applied which, however, differed from that of *Snizek.* Communication between the scientists is reflected, not only in the *citations,* but also in their *cooperation,* their *co-authorships,* and in the *distribution of the publications* of authors among the various problem areas of a scientific discipline, etc. It should be emphasized that none of the four indicators named here correctly reflects the communication, but they are only the "tip of an iceberg". Therefore, the findings give information about *tendencies* which, when compared, make a statement possible.
4. According to a social psychological theory, groups with a rank order show less distance between members with the same rank than between members with different ranks (cited according to *Hofstätter*[11] i.e. the frequency of the contacts between partners with the same rank is highest and decreases with the growing distance between the ranks. It is important to realise that this stratification from was not only found in groups of scientists, but is generally valid for groups with rank ordes. This is a general rule. This means that the performance of such groups as a whole is increased by their stratification. Stratification appears to be an optimal form of contacts among the group members, whereby not only the more frequent contact between group members of the same rank is of importence, but also a less contact between the group members of different ranks. Only in this case the group as a whole exists. These considerations should be thought further, in order to be able to assess the Ortega hypothesis: Several authors refer to the stratification in groups of scientists.[7,12]

It could be valid in groups of scientists that the frequency of the contacts (as intellectual impact) has an influence on the four indicators named in point 3. In conclusion from the named four points, it was decided to test the following hypothesis in this paper:

> The publication rate of scientists as a rough measure of their 'eminence' is connected with their stratification. The stratification is reflected in the cooperation, the co-authorships, in the structure of the citation as well as in the distribution of the publications of the authors among various problem areas of a scientific discipline.

Methods and results

Stratification in the structure of citations in journals

In an analysis of the structure of citations in the journal *Deutsche Zeitschrift für Philosophie* – DZfPh[13] the prestige of an author is determined by the number

of his publications in the course of 25 years of that journal (1953–1977). The references were taken from publications from the years 1975 to 1977. Self-citations were not included. One result of the investigation was the connection between the difference of logarithms of the publication rates of authors and the relative frequency of their mutual citations, i.e. the frequency of citations which the authors obtained per publication was highest if the authors have the equal publication rates. The relative frequency of the mutual citations of the authors decreases if the difference of logarithms of the number of their publications increases. This result reflects the stratification of the scientists.

This result can be depicted in another form, different to Fig. 1, in the form of citations matrices, see Table 1. In the matrices, it is no longer registered the frequency of citations per publication (relative frequency), but the *absolute frequency* of the citations.

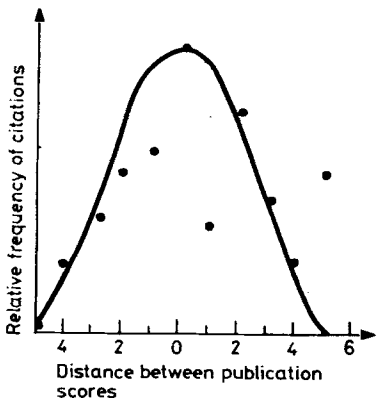

Fig. 1. Relationship between publication performance and mutual citation (in DZfPh)

Previous findings on a relationship between publication activity of cited and citing authors have now been tested for four journals in social sciences, in medicine and physics.[14] Publication scores were taken from the 1977–1980 issues of *Psychiatrie, Neurologie und medizinische Psychologie* (P. N. med. Ps.), from the 1981–1984 issues of the *Czechoslovak Journal of Physics* (Czech. J. Phys.), from the 1974–1985 issues of the *Zeitschrift für Sozialpsychologie* and from the 1953–1977 issues of the *DZfPh.*

Citation counts are from the lists of references in 75% of randomly selected 1977–1980 publications in *P. N. med. Ps.* From all lists of references of the *Zeitschrift für Sozialpsychologie* 1974–1985 and in non-conference 1984 publications in *Czech. J. Phys.*, self-citations are omitted. The first author in a co-authored publication appears as citing author, as cited authors all persons from the lists of

Table 1

Citation matrices for author groups in four journals (x_i– publication rate of citing authors, y_j– publication rate of cited authors, x_{ij}– citation counts. The diagonal numbers in brackets mean computed statistical expectation values)

DZfPh (cf. Ref. 14)

x_i	y_j 1	2–3	4–7	8–15	16–31	32–64
1	68 (54)	57	61	53	28	28
2–3	40	64 (44)	40	42	20	23
4–7	53	55	64 (55)	43	48	31
8–15	42	35	34	48 (39)	41	28
16–31	34	45	43	26	55 (34)	18
32–64	10	6	12	18	13	23 (9)

$C = \Sigma\Sigma x_{ij} = 1349$, $\chi^2 = 88.12 > \chi^2_{0.001}$

P. N. med. Ps. (cf. Ref. 14)

x_i	y_j 1	2–3	$\geqq 4$
1	115 (90)	75	18
2–3	124	176 (147)	34
$\geqq 4$	88	82	44 (27)

$C = 756$, $\chi^2 = 35.13 > \chi^2_{0.001}$

Czech. J. Phys. (cf. Ref. 14)

x_i	y_j 1	2–3	$\geqq 4$
1	135 (109)	53	23
2–3	36	31 (27)	23
$\geqq 4$	36	36	29 (19)

$C = 402$, $\chi^2 = 31.56 > \chi^2_{0.001}$

Zeitschrift für Sozialpsychologie

x_i	y_j 1	2–3	$\geqq 4$
1	91 (95)	80	41
2–3	117	93 (96)	47
$\geqq 4$	72	61	25 (28)

$C = 627$, $\chi^2 = 1.02 < \chi^2_{0.05}$

publications. The ratio of single-author to multi-author publications in the *DZfPh* was 1:0.14, in *P. N. med. Ps.* it was 1:1.6 and in *Czech. J. Phys.* it was 1:1.6

The relationship between publication rates of citing and cited authors is valid for three journals with probability errors better than 0.1% (Table 1) and for the subgroups better than 1% or 0.1% (Table 2). Authors with about the same number of publications cite each other more often than statistically expected (cf. the experimental and expected diagonal values). The *Czech. J. Phys.* sample enabled to probe matrices for three subsets according to the provenience of the authors (Table 2). No stratification could be found in the *Zeitschrift für Sozialpsychologie.* Because of the small number of journals, an interpretation is not yet possible, why stratification is reflected in some journals and not in others.

Table 2
Citation matrices for author subgroups in the Czech. J. Phys. (Ref. 14)

Nationals cite nationals				Nationals cite forigners			Foreigners cite foreigners		
x_i	y_j 1	2–3	≧ 4	x_i	y_j 1	≧ 2	x_i	y_j 1	≧ 2
1	44	32	10	1	34	1	1	44	6
2–3	15	24	5	≧2	27	11	≧2	2	20
≧ 4	28	20	21						
$C=199, \chi^2=15.71>\chi^2_{0.01}$				$C=73, \chi^2=9.03>\chi^2_{0.011}$			$C=72, \chi^2=41.20>\chi^2_{0.001}$		

Stratification in the co-authorships of journals

For both the authors of the *DZfPh* and the authors of the *Czech. J. Phys.* the stratification of the scientists in accordance with the number of their publications, which reflects in the distribution through co-authorships, was tested. For the *Czech. J. Phys.* the number of publications of the authors was taken from 1981–1984 issues and the co-authorships were taken from the publications of the 1984 issues. For the *DZfPh* the number of publications was taken from the 1953–1977 issues and a random test of co-authorships was made for the same period. For the authors of the *Zeitschrift für Sozialpsychologie* (1974–1985) the stratification was tested too. The investigation method is similar to that previously described for the structure of the citations.

If the authors A and B jointly publish an article, this relation between them is entered twice, once from the viewpoint of author A in the direction of author B, and once from the viewpoint of author B in the direction of author A. Therefore, the matrix of relationships through co-authorships is definitely symmetrical.

Example:

When authors A, B, C and D jointly publish an article there exists for the author with x_i publications a relationship to the author with y_j publications (analogous to x_i – publication rate of citing authors, y_j – publication rate of cited authors).
a) from the viewpoint of author A: one relation to B, one to C, one to D;
b) from the viewpoint of author B: one relation to A, one to C, one to D;
c) from the viewpoint of author C: one relation to A, one to B, one to D;
d) from the viewpoint of author D: one relation to A, one to B, one to C.
Altogether, A has one publication, B one, C three and D six. Cand D have also single-author publications. The result in the distribution of relations through co-authorships, see Table 3.

Table 3
Example: Matrix of relationships through co-authorships.
(x_i, y_j – publication rate of authors)

x_i	y_j 1	2–3	⩾ 4
1	2	2	2
2–3	2		1
⩾4	2	1	

The relations between the publication rates and the stratifications are valid for both journals with probability errors better than 0.1% (Table 4). The strong difference between both journals is that the *DZfPh* in contrast to the *Czech. J. Phys.* has mainly single-author publications and the multi-author publications are written almost solely by two authors, only very few by more than two. Regardless of this, for the co-authorships there exists the same form of stratification as for the citations: authors with the same number of publications are most often joined through co-authorships (cf. the experimental and expected diagonal values).

Stratification in the cooperation

The appendix in Ref. 15 shows in which way the scope of cooperation between two scientists was determined through a questionnaire. A random test was made with about 450 scientists divided into 56 research groups. The cooperation between the scientists was investigated only within the research groups. We wanted to know whether the stratification of scientists is reflected in the "invisible college" as well as in "institutionalized' groups.

The scope of cooperation of a scientist A with a scientist B was assessed once by A as part of his total work, and once by B as part of his total work. As these are

Table 4
Matrices of relationships through co-authorships. (The diagonal numbers in brackets mean computed statistical expectation values. x_i, y_j – Publication rate of authors)

D.Z.F.Ph.

x_i	y_j 1	2–3	⩾4
1	138 (110.1)	63	53
2–3	63	42 (35.4)	39
⩾4	53	39	96 (60.31)

$\Sigma\Sigma x_{ij}=586$; $\chi^2=51.59>\chi^2_{0.001}$

Czechoslovak Journal of Physics

x_i	y_j 1	2–3	⩾4
1	346 (310)	120	37
2–3	120	104 (72.34)	19
⩾4	37	19	14 (6)

$\Sigma\Sigma x_{ij}=816$; $\chi^2=42.66>\chi^2_{0.001}$

Zeitschrift für Sozialpsychologie

x_i	y_j 1	2–3	⩾4
1	162 (136.96)	49	22
2–3	49	34 (28.05)	22
⩾4	22	22	12 (7.98)

$\Sigma\Sigma x_{ij}=393$; $\chi^2=26.97>\chi^2_{0.001}$

two different values, the values in this matrix are not symmetrical, unlike those in the matrices of the relations through co-authorships.

Analogous to the citations or the relations through co-authorships, the scope of cooperation between two scientists each was the starting point here. The sum of the values between all scientists of two groups each was calculated analogously to the citation count or the sum of relations through co-authorships. The number of publications per scientist was taken over a period of five years.

The relation between the publication rates of cooperating scientists is statistically significant with a probability error of 1% (Table 5). A stratification of the scientists exists. However, the cooperation between scientists with the same number of publications is not so marked as in the previous examples. This can be explained with the peculiarities of this random test, or through the stratification being particularly strong through the "invisible college". In institutionalized groups, the cause could be that scientists are forced to cooperate in order to solve joint tasks.

Table 5
Matrix of the cooperation. (The diagonal numbers in brackets mean computed statistical values. x_i – publication rate of assessing scientist, y_j – publication rate of assessed scientist)

x_i \ y_j	0–1	2–3	⩾4
0–1	834.13 (780.15)	216.52	740.89
2–4	288.54	93.16 (95.36)	365.84
⩾4	1224.16	377.83	1248.22 (1245.45)

$\Sigma\Sigma_{ij}=5389.19; \chi^2=16.36>\chi^2_{0.01}$

Stratification in the distribution of publications of the authors among various problem areas

It was to be determined whether the frequency of communication among authors of different 'eminence' influences the choice of topic, i.e. the contents of the publication of an author. The investigation took place both for the *DZfPh* and in the field of bacteriology. The authors were divided, in both cases, into six groups each in accordance with the number of their publications. (1st group – authors with 1 publication, 2nd group – authors with 2 or 3 publications, 3rd group – authors with 4 to 7 publications, 4th group – authors with 8 to 15 publications, 5th group – authors with 16 to 31 publications, 6th group – authors with 32 or more publications). For the *DZfPh* we covered the period of 25 years and for the field of bacteriology, ten years.

If the choice of topics of authors depends on the closeness of contact with other authors, then the distribution of publications among various problem areas should diverge more widely, the looser the contact is. Thus, the correlation between the number of publications per problem area among the six groups should decrease, the further the groups differ in their publication rate per scientist, *i.e. scientists of higher and lower numbers of publications work in different problem areas.*

As an example for the following method, 64 publications from the first three groups were distributed on 7 different problem areas (see Table 6).

Comparing the among the 7 problem areas distribution of publications of groups 2 and 3 (Table 6), it can be stated that a large number of publications of group 2 is assigned to a large number of publications of group 3. The same is valid for the small number of publications, i.e. the distribution is similar. This gives rise to a high correlation. When comparing groups 1 and 3, a stronger difference in the distribution

of publications among the problem areas becomes visible, therefore, the correlation becomes smaller.

The publications of authors of the *DZfPh* were spread over 29 problem areas. This was shown in register of authors published by the journal[16]. For 6 of the author groups each, the number of publications were determined which were assigned to 29 problem areas. 1 300 publications from 1953–1977 were taken into the random test. The number of publications per problem area was correlated between two of the six groups of authors each.

Table 6
Distribution of publications of groups 1, 2 and 3 among the 7 problem areas

Ordinal number of the group	Problem area						
	1	2	3	4	5	6	7
1	2	3	4	5	4	3	2
2	3	4	5	4	3	2	1
3	4	5	4	3	2	1	0

D – difference between the ordinal numbers of the groups
r_{12}=0.6363 correlation (Pearson's r) between group 1 and group 2, (D=1),
r_{23}=0.8459 correlation between group 2 and group 3, (D=1),
r_{13}=0.1224 correlation between group 1 and group 3, (D=2),
$r_{D=1}$=0.7411 average for the two correlation coefficients which are assigned to D=1,
$r_{D=2}$=0.1224 only one correlation coefficient is assigned to D=2.

As a result, the averages of the correlation coefficients, assigned to the same difference between the ordinal numbers of the groups, are depicted:

$r_{D=1}$=0.842
$r_{D=2}$=0.808
$r_{D=3}$=0.757
$r_{D=4}$=0.6
$r_{D=5}$=0.5

Some of the correlation coefficients are statistically significant in their differences.

The same investigation was carried out in a bibliography by *Raettig*[17] with 1440 publications from the years 1957–1965 for the field of bacteriology:

$r_{D=1}$=0.594
$r_{D=2}$=0.423
$r_{D=3}$=0.32
$r_{D=4}$=0.29
$r_{D=5}$=0.28

As *Oromaner*[2] proposes, in the investigations in this paper there is no limitation to highly influential articles, but the whole work of all scientists was analysed. It is suspected that the elaboration of the most-cited articles of an author is not independent of the whole of his work. Therefore, the totality of his relations to other authors is of importance even if they are no longer directly visible in the references of the most-cited article.

The results of this investigation also prove that eminent authors tend to cite other eminent authors to a greater extent, which supports the Newton hypothesis. The results also show that the Newton hypothesis does not exclude the Ortega hypothesis. Eminent scientists also cite average and mediocre scientists to a certain extent. Following the general social psychological theory for groups with rank orders, which makes possible an optimal performance of the whole group, it has been found that authors tend to quote other authors of the same rank is not only valid for eminent scientists, but also for average and mediocre scientists. This stratification appears in the citations as well as in other forms of communication.

The stratification can already be proved through cooperation and through co-authorships. The contacts here are also very personal. This then continues in the distribution of the work among the various problem areas, whereby authors with a high degree of eminence prefer to work on problem areas that are different to those of the other scientists. This, alone, could cause a certain percentage of the special structure of the citations. Both the *personal* relationships between the scientists and the *contents* of their works could explain that the citations are not a clear quality measure, but that there exist citations which are only perfunctory or redundant.

As a whole, the findings show that on the one hand, a special preference for citations and other forms of communication exists among scientists of the same rank, and on the other hand, a certain amount of contacts exists among the rank orders. If influential articles with new ideas and hypotheses are to be encouraged through communication between 'eminent' scientists (Newton hypothesis), comprehensive scientific routine work is necessary to be done by average scientists in order to be able to prove the validity of these ideas and hypotheses. The majority of scientists help the general advance of science through solving these and other necessary tasks (Ortega hypothesis). The validity of the Ortega hypothesis should not be derived solely from the findings through formal indicators, but also from an analysis of the contents and of the economic processes. These different forms of analysis could complement each other.

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