Analysis of Variance in Social Research: Problem of Qualitative Interpretation

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Abstract: The article considers the trends of variance analysis usage in social research, describes various approaches to interpretation of obtained results regarding the methodology of experiment organization. The correlation between experimental conditions and variants of qualitative interpretation of variance analysis results as well as the perspectives of its further realization in case of inadequacy of the essence of the analyzed phenomena are determined. The article gives examples explaining the meaning of the qualitative interpretations for different variants of mathematic-statistic results of the variance analysis and experimental conditions. A more profound qualitative interpretation of results of the analysis of variance is possible if the analysis is applied in combination with others methods of experimental data processing. In this case the analysis acts as an element of a specially developed scheme for the data analysis regarding the specificity of the research subject. The author considers possible ways of such qualitative analysis by the example of investigation of customers’ satisfaction with educational services. Taking into account the structure of data and results of the variance analysis, the author focuses on the directions of statistical analysis of primary data and interpretation.

Key words: Qualitative methods • Analysis of variance • Experimental conditions • Social research • Interpretation

INTRODUCTION

Contemporary sociology is a very complex system of concepts, hypotheses and methods of research and representation of social realities. Consideration of the process of sociological knowledge in terms of the scientific method of cognition brings into focus not only the description of social phenomena, but also their explanation and prediction. As a result, the range of sociological problems expands and their complexity increases. They become complex and multi-aspect, in different ways reflecting the specificity of sociology as a science and its subject. Efficient solution of these problems to a great extent depends on the appropriateness of combining intensive (qualitative) and formal (quantitative) approaches in different stages of sociological research taking into consideration the dominant role of the former approach [1,2]. It should be properly considered in the process of the mathematical apparatus use [3].

In this case the methods of experimental data processing focused on the qualitative character of social phenomena and processes are interesting. One of these methods is the analysis of variance that allows estimating the influence of qualitative parameters on quantitative variables. Moreover, the multifactorial analysis of variance estimating the influence of factor interaction is more constructive for sociological research than the monofactorial analysis. However, its implementation is caused by complication of qualitative interpretation of the obtained results. The article actualizes the problem of appropriate implementation of the qualitative interpretation of the monofactorial and multifactorial analyses of variance according to the methodology of scientific research, particularly, the systemic synthesis of qualitative and quantitative approaches.

Such interpretation is considered by the author as a separate conclusive stage of the analysis of variance which includes the following steps:

- Checking the adequacy of resulting parameter distribution for observations on each level (range) of factor;
- Checking the homogeneity of variances in case of unequal samples;
- Calculating the Fisher’s ratio to check a null hypothesis;

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Performing multiple paired comparison in case of null hypothesis dismissal;
Qualitative interpretation of results of averages comparison.

We shall mark out the stages of the variance analysis implementation, which characterize the essence of the previously described stage. Firstly, the analysis of variance is based on the presupposition that some variables may be considered as causes (factors or independent variables) and others may be considered as effects (dependent variables). The independent variables are sometimes called regulated factors because a researcher may vary the factors in the experiment and analyze the obtained results. If the factor is considered non-experimentally, the problem of justification of cause-effect relations arises [4]. Such a justification is, obviously, performed on the basis of the theoretical conception used by a researcher. Outside the conception, the interpretation of cause-effect relations may turn out to be untenable. Thus, the use of the analysis of variance, except for certain mathematical assumptions, presupposes preliminary formalization of a research subject and description of the limits of the applicability of obtained results. This condition strongly restricts the possibility of the qualitative approach use, as any formalization is related to abstracting and determining common qualities of the objects, while the qualitative analysis is aimed at the profound investigation of each object’s specificity.

Secondly, the difficulties in comprehension of the variance analysis results may be caused by the following reasons:

1. Identification of factors and a resulting parameter might not correspond to real conditions;
2. Controversy of substantive meaning of the averages difference;
3. Absence of scientific value (result triviality).

**Main Trends in Qualitative Interpretation of the Results of Variance Analysis:** First consider possible variants of results obtained in data processing by means of the one-factor analysis of variance and methods of their interpretation. It should be noted that the interpretation of non-experimental data might be ambiguous and insufficiently proved. Therefore, the variance analysis should be used as a preparatory procedure for either further testing of the sustainability of the obtained results or an experiment. The correlation of result and conditions of the experiment may be used as a scientific basis for appropriate and constructive interpretation excluding alternative explanations. Agree to understand the conditions of experiment as a structure of focused influence on the sample. Then, the experimental condition will be simple at a one-fold influence and complex – at multiple influence (at least two-fold influence).

Suppose that the factor influence was not identified (null hypothesis). The possible reasons for that are: small sample; the factor is not substantial; the factor is manifested only in interaction with another factor.

Suppose that the factor influence was identified. The experimental conditions are accounted in the interpretation of results. The possible variants are as follows:

**The Experimental Condition Is Simple:**

a. The qualitative interpretation is adequate. In this case the scientific and theoretical significance, as well as the practical value of the obtained result should be estimated from the point of view of the chosen research conception.

b. The qualitative interpretation is inadequate. It is necessary to perform the multifactorial analysis of variance, if it is allowed by the experimental design. Otherwise the research is considered unfinished. If division into groups does not correspond to the model of the multifactorial analysis, it is necessary to expand it (or choose the variant of the variance analysis with incomplete design). In this case this means that not all common values, inherent to the sample, are considered.

c. The qualitative interpretation is not clear. The possible reason is that the research conception and the corresponding methodology of experiment organisation are not complete.

**The Experimental Condition Is Compound:**

a. The qualitative interpretation takes into consideration the structure of the given condition. Consider two influences on one sample. According to the chosen approach the first influence is background, since the results of the second influence are considered in relation to the first one. Therefore, it is logical to distinguish the control group (differing from the experimental ones by a precondition, i.e. the character of the initial influence), the experimental group 1 (the homogeneous condition – the first and the second influences are equal) and the experimental group 2 (the heterogeneous condition – the first and the second influences are not equal). The
experimental result would be positive provided that the average in the first and the second experimental groups differs from the average obtained in the control group and both experimental groups do not substantially differ in analogous indicators. The presented result reflects the essence of the investigated phenomenon, as the differences in the results of the second influence are correlated with the character of the first influence. For planning such a structure of the experiment there should be a starting hypothesis on the character of factor realization. The research can be considered finished.

b. The qualitative interpretation is adequate, but it does not take into consideration the compound condition. Thus, the research conception as well as the methodology of the experiment should be corrected. The research is unfinished.

c. The qualitative interpretation is inadequate. It is necessary to perform the multifactorial analysis of variance, probably, after the correction of the research conception, because the condition should not necessarily be compound.

The analysis of variance may not be aimed at verification of a scientific hypothesis; therefore, the result of the analysis may not have scientific value. Thus, the naturalness of the obtained interpretations may make them directly useful for practice.

Examples of Qualitative Interpretation of Results of Monofactorial Analysis of Variance: Consider the example of the marketing research which is aimed at the determination of the most profitable points of product sales. The computer and office equipment manufacturer has designed a new product. The test sales of the product are organised in electronics shops and in specialised computer shops (5 sale outlets of each category were randomly picked up). The task is to find out the type of the shops in which the main sale should be organised. In the considered example the factor is “the shop” and the resulting (dependent) variable is “the quantity of items bought”.

It is obtained that \( F_{\text{emp}} > F_{\text{crit}} \) (because \( p = 0.021 \)), omit \( H_0 \) and take \( H_1 \) (\( p < 0.05 \)), i.e. the type of the shop with organized sales is influences the quantity of the items bought. Compare in pairs the shops on the average quantity of items bought with the help of the multiple Student's t-test. Taking into consideration that the average quantity of items bought in electronics shops authentically differs from the average quantity of items bought in supermarkets and other significant differences are not registered, it can be concluded that supermarkets are more preferable than electronics shops (the average quantity of items bought in supermarkets is larger). The inferred conclusion has a practical value and the method for obtaining the experimental data completely reflects the real situation.

The most interesting is the following case. Consider the example. S.A. Shapkin (1997) carried out the research of the phenomenon of “learned disability”, i.e. reduction of person’s ability to solve tasks, if s/he failed to succeed in the previous similar cases. The experiment consisted in the following. Three groups of respondents were offered anagrams. The first group of probationers in the preliminary series of tests tried to solve unsolvable anagrams, while in the main series of tests the respondents were also asked to solve anagrams but the solvable ones. The second group was also offered unsolvable anagrams in the preliminary series of tests, but in the main test series the probationers were asked to solve different (solvable) tasks – to determine regularities. The third group (control group) in the preliminary series of tests was not made to experience failure – they were offered solvable anagrams and in the main test series they solved both types of tasks (anagrams and tasks aimed at determining regularities).

In the presented example the factor is “the condition of task solving in the main test series, which was set in the preliminary series of tests,” the dependent variable is “the time of experimental task solving”. It is obtained that \( F_{\text{emp}} > F_{\text{crit}} \) (because \( p = 0.009 \)), i.e. reject \( H_0 \), accept \( H_1 \) (\( p < 0.01 \)). This means that the factor “the condition of experimental task solving” influences the dependent variable “the time of experimental task solving”. Perform multiple paired comparisons of averages to determine the character of this influence by the multiple Student's t-test. The difference between the averages in “homogeneous” and “heterogeneous” conditions turned out to be statistically insignificant, while each of the experimental conditions, authentically differs from the analogous parameter for “control” condition in the average time of task solving. Thus, the essence of the marked differences is named as “learned disability”. This result has a scientific value because the hypothesis of existence of “learned disability” was scientifically verified in the experiment.

If the research is incomplete (1b, 2b, 2c) it can be continued in the following ways:

1. Complication of the experimental design by the analysis of the factor interaction, i.e. transition from one-factor model to a two-factor one. This transition might result in a semicomplete or mixed experimental design (if a number of groups exceeds possible
combinations of factors) or a mixed design (inter- and intra-group factors are controlled at the same time). Then the special version of the analysis of variance with incomplete design is acceptable. Such data processing is expedient to use in pilot research. In case of factors interaction it is necessary to perform a complete investigation to clarify the result interpretation. At incomplete experimental design the interpretation is not completely clear. In case of mixed designs to obtain an adequate interpretation it is important to account the sequence of factor influence and all possible components of variance.

2. Complication of experimental conditions: use of a compound condition, the structure of which influences the resulting parameter.

3. Fixing the interaction between the factors belonging to higher than the first-order (in case of interaction between more than two factors). The substantive interpretation of the second-order or higher interactions is a difficult problem, the hierarchy of the interactions should correlate to that, which is set in the hypothesis and to experimental conditions.

Examples of Qualitative Interpretation of Results of Multifactorial Analysis of Variance: The interpretation of results of the multifactorial analysis of variance should take into consideration the noted trends. The provision of interpretation adequacy requires a detailed analysis of experimental conditions. If the effect of interaction between the factors is not registered, the interpretation of influence of particular factors is performed according to the scheme described above. If this effect is registered, the interpretation of the result of the analysis of variance becomes quite difficult. To understand the essence of the obtained effect interaction graphs are used.

Consider the example where the marketing research is carried out to find out the volume of jacket sales. The results of week sales are presented (in pieces). The hypothesis suggests that the quantity of jacket sales is influenced by two factors: factor A is the location of the shop (city centre or remote district), factor B is advertisement (advertisement in mass media or signboard). The task is to determine the influence of each factor and their interaction on the volume of jacket sales.

The results of data processing by the two-factor analysis of variance resulted in the following conclusions:

1. The quantity of the week sales of jackets depends on advertisement (the influence of factor B is registered).
2. The quantity of the week sales of jackets does not depend on the shop location (the influence of factor A is not registered).
3. The interaction between factor A and factor B does not influence the quantity of the week sales of jackets.

As a result the analysis of variance is reduced to the use of the two-sample Student’s t-test. The preliminary prognosis that it is suffice to use the Student’s t-test, is impossible, since the focus of the research was on the interaction between factors. However, if we depict the interaction in question on the interaction graph, we can see at once that the interaction between the factors does not influence the independent variable. Consequently, the result of the marketing research indicates only the effectiveness of advertisement use in mass media.

In real practice the more complicated cases constantly arise, when there are more than two factors and their gradations. In these cases at multiple comparisons of averages the excessive volume of data requires special summarising of the results of factor influence or interaction between factors. First of all, the interaction graphs are analysed, marking the first-order influences indicated with the cross-points of the graphs. However, the essence of these interactions in case of a larger number of the factor gradations may seem unobvious which requires special structuring of the received data.

Consider a more complicated variant, in which there is a larger number of factor gradations. Analyse the following example. At four enterprises (B₁, B₂, B₃, B₄) the three production technologies (A₁, A₂, A₃) of single-type products were tested. The data of labour productivity are presented. The task is to determine the influence of the technologies (factor A) and the enterprises (factor B) on labour productivity.

Formulate the null hypothesis regarding the interaction between factor A and factor B: the influence of the technologies on the labour productivity is equal for all enterprises and vice versa.

As a result of the two-factor analysis of variance the influence of the factor “technology” and the interaction between the factors “technology” and “enterprise” on the labour productivity is registered.

The multiple paired comparisons reflecting the character of influence of the factor interaction on the resulting variable Var₁ are appropriate to present in the interaction graph (each curve denotes the certain technology A₁, A₂, A₃; numbers 4, 5, 6, 7 denote the enterprises: B₁, B₂, B₃, B₄; the vertical axis shows the averages of labour productivity Var₁).
The presented graph shows how the labour productivity for different technologies correlates with the certain enterprise. For enterprises 4 (1) and 7 (4) the most efficient is the third technology, while for enterprises 5 (2) and 6 (3) the second and the third technologies are almost similarly efficient. The least efficient is the first technology. One can prove that analyzing the results of the multiple paired comparisons in the groups one can suggest that for enterprise 4 (1) the more preferable are the second and the third technologies, if they are compared to the first technology and the more preferable is the third technology, if it is compared to the second technology.

For enterprise 7(4) there are no preferences regarding the first and the second technologies, but the more preferable, in comparison with the other points, is the third technology. As it follows from the results of the comparison of averages, for enterprises 5 (2) and 6 (3) is less preferable the first technology in comparison with the second and the third technologies, while the second and the third technologies are practically similar.

The presented interpretation seems lengthy, because the researcher simultaneously accounts for the influence of the factor “technology” in analysing the twelve groups (the experimental design is complete). However, the complexity of the experimental design is related neither to the scientific, nor to the practical value of the result. One can consider simpler variants of the analysis of variance including the realisation of different quantitative and, above all, qualitative methods, which may turn out to be more prospective.

Interpretation of Results of Analysis of Variance in the Structure of the Scheme for Complex Data Processing:
A more profound qualitative interpretation of results of the analysis of variance can be performed, if the analysis is considered in combination with others methods of experimental data processing. In this case the analysis acts as an element of a specially developed scheme for the data analysis regarding the specificity of the research subject. Consider the possible ways of such qualitative analysis by the example of investigation of customers’ satisfaction with educational services [5].

Presently the developed conceptions of consumer satisfaction correlate, in general, with services. The basic model of the European Customer Satisfaction Index (ECSI) is a structural model including latent variables, which finally connect the customer’s satisfaction with his/her loyalty. The value of the ECSI falls within the range of –1 and +1.

The given approach is realised by the author regarding an elementary educational service which is viewed as an educational programme implemented under certain conditions of educational process and aimed at the development of certain personal and professional qualities, having social significance and economic potential. The properties of educational service, important for a learner, are separated by the author into the blocks “conditions”, “process” and “result”. As a result we have denoted 11 integrative characteristics of an educational service specified as 40 questions which were correlated with all basic components of the educational process:
target, content, stimulating-motivational, procedural and activity oriented, control and regulating and reflexive. Thus, the completeness of description of the process of educational service rendering is achieved.

Consider the Scheme for the Analysis of Results (For an Elementary Educational Service):

1. Calculating customer satisfaction index for each customer type.
2. Comparison of averages for the indicators of particular satisfaction factors and their blocks, characterizing “conditions”, “process” and “results”.
3. Comparative analysis of satisfaction indicators for individual customer groups.
4. Assessing degree of customer consensus on the whole and on particular groups.
5. Assessing the degree of conformance of indicators of satisfaction in the service and its importance.
6. Correlation of indicators of satisfaction in rendering the service with customer loyalty assessments.
7. Factorial analysis of satisfaction indicators aiming at identifying the latent factors, determining their interrelations.
8. Multifactorial analysis of variance to estimate the influence of customer characteristics on their satisfaction indicators (or identified in factorial analysis latent factors).

Analysis of the Survey Data Allows for Deducting the Following:

1. Advantages and disadvantages of a particular educational programme or the complex of programs.
2. Specific preferences of different customer groups.
3. Role of the identified latent factors of satisfaction on the whole and for particular customer groups.
4. Influence of different factors on satisfaction indicators.
5. Factors, determining customer loyalty.

For some kinds of education, for example skill improvement, implying mastering the programme of a particular discipline, it is necessary to analyse one (elementary) educational service. At higher educational institutions students, as a rule, are provided with a complex of elementary educational services. In this case it is appropriate to conduct the unifactorial analysis of variance to determine the influence of the “Discipline” factor on characteristics, reflecting the educational service properties.

Consider the fragment of realisation of the named analysis scheme regarding the results of anonymous questioning of the second-year students, studying the specialty «Economics» at one of Russian universities, including three subjects “Probability Theory”, “Development Physiology” and “Philosophy”. The questioning testified that the satisfaction index for all the named disciplines is below zero in all the factors (integrative characteristics of the educational service), except for the factors reflecting the possibility of real-time interaction with the participants of the educational process (first of all – with a teacher) and psychological comfort of such an interaction. Moreover, the lowest rates in the Probability Theory are for the factor “image of educational institution”. On the whole it can be stated that students’ hopes were a little bit unjustified, if we account for the values of the satisfaction index. One may perform the comparative analysis of average indicators of satisfaction for the blocks “conditions”, “process” and “result”. Anyway, the general situation in this case is already comprehensive.

By means of the analysis of variance it was registered the influence of the factor “Educational discipline” on such aspects of the educational service as “Resource provision”, “Availability of material presentation”, “Effectiveness of didactic methods and means” and “Cost”. It turned out that the average values of all the named resulting factors authentically differ for the Probability Theory and Development Physiology, while the average value of the factor “Resource provision” also differs for the Probability Theory and Philosophy. Moreover, the average values for the Probability Theory are lower, i.e. rendering of this educational service is worse in comparison with the other named disciplines.

Since the satisfaction index for all the disciplines in the factors in question is negative, this means that rendering of all educational services needs correction and first of all – teaching “Probability Theory”. Partially successful is realisation of the procedural and activity-oriented component of the educational process in the given sample of students.

To completely present the results of the analysis of variance in this case it is appropriate to integrate indicators for all characteristics reflecting the process of education service rendering. In this case it leads to an interesting comparison of influence of the factor “Educational discipline” separately on each the integrated characteristic “resources”, “process” and “result”. Taking into consideration the results of the a posteriori comparison of averages, we are able to outline the strategies of improvement of the educational process in university.
The results of the correlation analysis of all the named characteristics testify the existence of direct significant relations between all the factors, except for the factors “cost of educational service” and “image of educational institution”. It may be supposed that students do not correlate the real educational process with the factors in question. To explain the relations between the factors the factorial analysis was made. As a result one common factor or the latent variable (weight 60%) was determined which has significant negative correlation coefficients with all the characteristics, except for “Cost”, “Image”, “Possibility to monitor personal line of educational development” and “Effectiveness of didactic methods and means”. Therefore, this factor is natural to interpret as “Deficiency of educational service features”, i.e. the higher the factor values, the lower the values of parameters of educational service properties.

Then, customer satisfaction is correlated with his/her loyalty which is estimated by the nominal scale (i.e. the researcher presupposes the choice of statements reflecting loyalty).

The obtained quantitative results of mathematical data processing are easy to interpret qualitatively. The qualitative conclusions allow for outlining the programme of improvement of educational services in university and individual approach to customers.

However, in this case the focus is on the procedure of data processing itself, its variability allowing for extending and intensifying the data analysis not only by means of a more detailed consideration of obtained results but also by additional structuring of parameters at each stage of the analysis. In the given example – by carrying out the analysis of variance. It may manifest as the appropriate combination of qualitative and quantitative approaches.

We will consider the directions of establishment of influence of interaction of factors of customers’ satisfaction with educational services. Investigation of influence of interaction of factors of the second order on quantitative variable is problem formulation. Take into account the structure of data and results of analysis of variance, we can focus directions of statistical analysis of primary data and method interpretation.

1. The factor can be quantitative, transferred to a rank scale. We get more exact result, if one use as an independent in a regression analysis. In the adequate equation coefficients of regression are interpreted, in particular, in linear model, taking into account a contribution of other unaccounted factors. Such interpretation (and in case of nonlinear regression) can serve as important addition to results of analysis of variance. On the basis of the received equation it is possible to carry out more adequate ranging of this indicator and to provide its expedient variations.

2. If mathematical assumptions of the regression analysis aren't carried out, use nonparametric methods (Dzhonkir, Kruskala-Wallice's criteria, etc.). It is focused first, when influence of one factor is investigated. Secondly, it allow to reveal nature of influence of a factor only partially (interpretation of result is indeterminacy). Therefore we can to consider combinations from three factors to all selections at once, having integrated them in the form of one generalized factor. Then the received result will also have indeterminacy. There is an inconsistent situation: "Not to consider a normality of distribution of a variable and to apply parametrical methods (in particular analysis of variance) or to use nonparametric methods?". Our point of view consists in the reasonable combination of parametrical and nonparametrical methods in a complex, taking account in consequences of not performance of mathematical restrictions. In certain cases (for example when empirical distribution differs from normal) they don't lead to serious distortions of the received result, but one allow to get more constructive conclusions or one to specify hypotheses.

3. We suggest taking account all essential factors and typical conditions in which they can act. Besides, any specific factor (even latent), acting, for example, as the catalyst of interaction of directly observed essential factors, separately be considered.

CONCLUSIONS

Within the framework of the article the problems of use of the analysis of variance with incomplete or mixed designs, as well as interpretation of results of assessment of interaction between the higher order factors, are just outlined. In real practice such situations are quite frequent [5-10]. They may be considered as a source for formulating new scientific hypotheses, the proving of which requires the use of complete experimental design allowing for making quite certain substantial conclusions. Even in these cases, however, the search for scientific value of obtained results is inalienably determined by the structuring of experimental conditions and developing a complex scheme for experimental data processing on the basis of the exploited research conception.

Therefore, it can be stated that the use of the analysis of variance provides additional opportunities for improving social studies by means of a specially
organised experiment allowing for varying and controlling various factors (or considering the certain conditions, in which the factor effect is considered) and then – estimating the character of the factor influence on dependent variables. The adequate qualitative interpretation of the obtained result is the basis for estimating its scientific novelty and practical value.

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