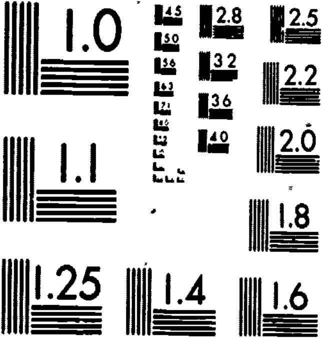
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ABSTRACT

The Instructional Process Analysis Project (IPA) is a study jointly undertaken by the Nordic countries in 1967. The present study discusses a methodological problem area of very narrow scope within the IPA project. The general aim of the study is to examine the factor-analytical method of sequence analysis and to produce variables that measure the appearance of sequential tendencies. Also, the study will measure the process from the starting point of transition probabilities between the elements. The specific aims fall within three main areas: a) the reliability of measures of classroom behavior and their practical utility, b) the inverse factor analysis of sequences of interaction that may occur within the framework of lessons and that characterize only the lessons of a certain type, and c) the factor analysis of sequences of interaction that occur within the framework of lessons and whose basic form remains the same but whose relative frequency varies from lesson to lesson. The first part of this report summarizes the contents of earlier reports. (JA)

Erkki Komulainen

INVESTIGATIONS INTO THE INSTRUCTIONAL PROCESS

VIII. On the Problems of Variable Construction from Flanders' Interaction Matrix with Special Emphasis on the Stochastic Nature of Classroom Communication

Institute of Education
University of Helsinki
1973

Contents:

Preface

This study is part of a larger research project called Instructional Process Analysis. This project was initiated by Professor Emeritus Matti Koskenniemi, and the work is continuing under his leadership at the Institute of Education, University of Helsinki.

I owe deep gratitude to the leader of the project, Professor Matti Koskenniemi for his encouragement and help during my work. I have received inspiring guidance both from our personal discussions and from his extensive scientific production.

The manuscript has also been checked by Associate Professor Paavo Malinen, who made several significant remarks and suggestions. Professor Ned A. Flanders has given me valuable support in correspondence and personal meetings. Mrs. Anna-Kaarina Falck and Mr. Pentti Holopainen have offered their valuable assistance in different phases of my work. Associate Professor Johannes Alikoski, Dr. Juhani Jussila, Mr. Juhani Hytönen, Mr. Pertti Kansanen and Mr. Kari Nurmi have also lent me a helping hand in methodolological questions particularly. My subjects - as well as teachers and pupils - have been very co-operative in collection of the study material. Mr. Pekka Korhonen, Mr. Jorma Torppa and Mr. Harri Wetterstrand have taken care of the statistical analyses at the Computing Centre, University of Helsinki. The previous reports of this study have been translated by Mr. Jaakko Railo. The translation of this final report has been provided by Mr. Hal Martin. My sincere thanks to these persons and to the staff of the Institute of Education, University of Helsinki.

The Nordic Cultural Foundation and the Humanities Research Council of the Academy of Finland have given financial aid to the project. Since the beginning of 1972 I have been employed as research assistant of the Academy of Finland. I am grateful for this opportunity.

Finally, I express my gratitude to the head of the Institute of Education, Professor Eelis Aurola for publishing my work in the Research Bulletin series.

Helsinki, October 1972

Erkki Komulainen

1. Background

1.1. IPA Project

The Instructional Process Analysis Project (IPA) is a study undertaken jointly by the Nordic countries in 1967. The group of investigators has included Professor Bjerstedt (Malmö, Sweden), Professor Stukåt (Gothenburg, Sweden), Dr. Rasborg (Copenhagen, Denmark), Professor Sandven (Oslo, Norway) and Professor Koskenniemi (Helsinki, Finland). Collaboration between the institutions mentioned has dealt with methodology and general exchange of information. Each institution has been responsible for its own research design, and collection of material and analysis. The present report is a part of the research directed by Prof. Koskenniemi, in which intensive follow-up study of a single class is the approach used. The first phase of the IPA project in Helsinki dealt with the attempt to define what variables can and do operate in teaching. If successful, the future application of variables describing significant aspects of interaction will help to determine in what degree measures of classroom communication can be used to indicate essential intervening mechanisms when changes in the behaviour of pupils are examined.

The following is a summary of the author's earlier publications:

1. Koskenniemi M. and Komulainen E. and others. 1969. Investigations into the Instructional Process: I. Some Methodological Problems. Res. Bull., Inst. of Education, Univ. of Helsinki, No. 26 (Oct. 1969).
2. Komulainen E. 1970. Investigations into the Instructional Process: II. Objectivity of Coding in a Modified Flanders Interaction Analysis. Ibid., No 27 (Dec. 1970).

3. Komulainen E. 1971. Investigations into the Instructional Process: III. P-techni~~que~~ Treatment of Observational Data. Ibid., No 28 (Jan. 1971).
4. Komulainen E. 1971. Investigations into the Instructional Process: IV. Teaching as a Stochastic Process. Ibid., No 29 (Feb. 1971).

To create a synthesis of the earlier reports, supplementary results relating to certain methodological questions are given. Then main principles of the analyses performed may be clear from the present report, although I naturally recommend readers to acquaint themselves with the above publications[1], especially with that part that describes the methods empoyed. Studies by Koskenniemi, Komulainen and Falck 1969, by Komulainen 1970c, by Koskenniemi, Komulainen and others 1972, and by Koskenniemi 1972b also explain the research strategy.

1.2. Place of This Investigation within the Study Field of the Instructional Process

The present study discusses a methodological problem area of very narrow scope within the IPA project. The aim is, therefore, to present a theoretical frame of reference by condensed reference to relevant literature. It is clear that in any methodological investigation the background theory of the category system with its attendant concepts and constructs is implicitly present. It should be stressed, therefore, that methodological problems are not to be seen separately from the broad and rapidly growing field of research into and theory of instruction. The general literature on this subject is extensive, and a number of bibliographies are also available. I assume the reader's awareness of the main features of this research area with regard to the following trends:

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1) Publications 2, 3 and 4 are also available from the ERIC document Reproduction Service, P.O. Drawer O, Bethesda. Maryland 20014, U.S.A., in microfiche and (ready-to read) xerox copy form. ERIC document numbers are: ED 057 084, ED 059 276 and ED 059 277.

1) The European study tradition. This may be considered to have started with the pedagogical fact research of Petersen. The tradition continued, as modified by Winnéfeld, and has influenced the empirical study of teaching in many ways, especially in the German-speaking area (Reiniger 1924 and 1929; Müller-Petersen 1952, Winnefeld 1957; Petersen & Petersen 1965; Röhrs 1968; Kessel 1970; Maier & Pfistner 1971). In German Democratic Republic particularly, the part played by observational study has substantially increased in the last few years (Roth 1969; Grassel 1970).
2) Study tradition of interaction analysis. The famous studies of classroom climate by Anderson and the research group of Lewin, Lippitt and White are classics in the literature of educational psychology (Anderson 1939; Lewin et al. 1939). With the studies of Withall (1949), and especially those of Flanders, it may be said that the school of interaction analysis came to birth (Amidon & Hough 1967; cf. also Flanders 1970). A knowledge of Flanders´ studies and of interaction analysis (FIAC) is vital to the understanding of this report, because the choice of a system of classification (FIAC) involves adherence to a theoretical frame of reference as its basis. Nor is the contribution of Bales (1959) without influence. The interaction process analysis of Bales (IPA) and the IAC system of Flanders are closely similar applications of the observational method. Interaction analysis today has an important field of application in the study of teaching and in teacher training (Flanders 1970; Ober & Bently & Miller 1971).
3) Teacher efficiency studies. These are numerous, and among them it is advisable to be aware of the main results of such designs in which the variables for teaching are based on observation, and some kind of

adjusted gain scores are used as a criterion variable (Rosenshine 1968; Flanders & Simon 1970; Flanders 1970, 376-426; Nuthall 1970; Rosenshine 1971).

4) Methodological questions raised by the observation process (Medley & Mitzel 1963; Weick 1968).

The above classification is, of course, arbitrary and overlapping. In practice there are no such mutually exclusive study traditions and schools of thought. Many studies deal with material from different fields. Chief emphasis in the present report is on interaction analysis and questions of method of observation.

2. Study Aims

2.1. General Aim

Problems concerning the construction of variables describing the instructional process have become strongly evident in recent times. There are several reasons for this. Some researchers regard attempts to elucidate the question of instructional efficiency as premature, because the character of the independent variable (instruction) is too little known. B. O. Smith (1969) expresses the matter as follows:

> "All these considerations support the conclusion that teaching is to be studied in its own right if we would understand it and thereby gain control over it."

De Landsheere (1971) presents another viewpoint which supports a methodology based on taxonomic systems:

> "One of the main factors explaining the general failure of research trying to relate teacher behaviour to pupil achievement is the crudeness of the independent variables used."

Apart from the degree of specificity of the variables, attention should be paid to this problem: variables relating to instruction are often assembled in such a way that they indicate unconnected elements in the classroom communication. Instruction is a sequence of activities advancing in time, a process whose connection with the changing behaviour of its participants is cumulative. Consequently, the variables should be determined on the basis of the connection between the elements appearing in the process, that is, on the context. Attempts in this direction have been made. The Bellack cycle, the B. O. Smith teaching cycle, Flanders´ critical teaching behaviour and Nuthall´s verbal move sequence may serve as examples.

The general aim of the present study is to examine the factor-analytical method of sequence analysis, and to produce variables that measure the appearance of sequential tendencies. We shall also examine the process from the starting point of transition probabilities between the elements. These methodological examinations are confined to the FIAC system.

2.2. Specific Aims

The specific aims fall within three main areas:

1) The reliability problem of measures of classroom behaviour (Komulainen 1970b). The reliability of the coding forms an inescapable methodological question in observational research. In the training and research work of observers certain standard solutions have been thought to be sufficient. In the case of the FIAC system this is Scott´s II. Our purpose is to examine the practical utility of this type of method.
2) Within the framework of lessons, sequences of interaction may occur which characterize only the lessons of a certain type. We shall analyze these sequences by the technique of inverse factor analysis (Koskenniemi & Komulainen 1969).
3) Within the framework of lessons, sequences of interaction appear whose basic form remains the same, but whose relative frequency varies from lesson to lesson. Factor analysis will be applied to identify such sequences if possible, and to form quantities indicating their tendency to appear (Komulainen 1971a). Sequences are also analyzed by examining probabilities of transitions from one state to another (Komulainen 1971b). We thus attempt to define more precisely the sequence of events arising from successive states within the process.

2.3. The Aims of This Report

The first part of this report summarizes the contents of earlier reports. The aim is to present the main features of reliability examination and the factor-analytical approach for the investigation of behavioural sequences. In order to create a more penetrating sythesis, various special questions are examined which have received less attention in earlier reports. A further aim is to use the devices offered by Markov chains and by stochastic information theory as a means of elucidating the degree of differentation of behavioural sequences. It is hoped thereby to obtain a more precise and analytical picture of the preliminary results based on transition probabilities (Komulainen 1971b).

2.4. Study Material

The material was video-taped in the laboratory class of the Institute of Education, Univ. of Helsinki, in the autumn term of 1967. It consisted of 25 lessons covering five subjects of the regular third grade curriculum. All lessons were recorded with the same class. Questions of validity are of central importance in the material of this type. They have been discussed elswhere (Komulainen 1970a, 72-79). At the time of writing, the study is continuing in accordance with both the plans introduced in Chapter 6.

The taxonomic instrument was a modified FIAC system (App. 1).

Earlier reports have discussed only the class instruction lessons coded by FIAC, which have been mentioned above. The present report uses for comparative purposes the material gathered by Holopainen (1971, 45-48 and 1972, 4-5) for his study of group work, and 96 regular class instruction lessons from school terms 1967-69, both coded with Bales´ IPA. Comparative materials are used only in Section 5.5.

3. Reliability

The nominal scale of codings makes it difficult to apply normal methods of reliability assessment to measurements obtained by interaction analysis. The techniques for assessing errors of measurement are thus more developed than those for measuring errors of classification (Reiss 1971, 21). The definition of reliability as a ratio of true to total variance is not applicable to such a situation (Valkonen 1971, 60).

In Report No 2,(Komulainen 1970b) the reliability of codings was assessed as follows: in addition to Scott's II coefficient based on marginal distributions (Scott 1955), agreement coefficients for categories were calculated by the author's method. The normal code/3 sec. procedure was reduced to a simple yes/no for each category. It is then possible to calculate an agreement coefficient for each category. It also ensures that the decision of each coder is based on the same time unit. The background for this coefficient is introduced in Report No. 2, pages 13-15. Formulae with symbols from set theory are given on pages 16-17. Using 0/1 codes (0 = category not present in the time unit; 1 = category present in the time unit), formulae can be simplified as follows:

Agreement for the category between coders A and B is obtained from

$$(1) \qquad A = \frac{\Sigma AB}{\frac{\Sigma A}{2} + \frac{\Sigma B}{2}}$$

Agreement due to chance is calculated from the starting point of the statistical independence hypothesis. The multiplication rule of the classic probability calculation is then applied. The chance agreement can be computed from

(2) $$A_r = p_A \cdot p_B$$

using relative frequencies or

(3) $$A_r = \frac{\Sigma A \cdot \Sigma B}{N^2}$$

Table 1 shows the calculation procedure by means of a simple example.

Table 1. Calculation of the Agreement Indices A and A_r.

		Coder A			Coder B			A.B	
		Categories			Categories				
Unit	1	2	3	1	2	3	1	2	3
1	1	1	0	1	0	0	1	0	0
2	0	1	0	0	1	0	0	1	0
3	1	1	0	1	1	0	1	1	0
4	1	0	1	1	0	1	1	0	1
5	0	1	1	1	1	1	0	1	1
6	0	0	1	0	1	0	0	0	0
7	1	0	0	1	0	0	1	0	0
8	0	1	0	0	1	1	0	1	0
9	1	1	1	1	1	1	1	1	1
10	0	0	1	0	0	1	0	0	1
N=10	Σ 5	6	5	6	6	5	5	5	4
	A						.91	.83	.80
	A_r						.30	.36	.25

In Report No. 2, A coefficients were used as such, because A_r coefficients remained relatively low (range .00 - .14; Komulainen 1970b, 19). It is possible for agreement coefficients to be so consructed as to allow for the fact that part of the agreement (A) was caused by chance (A_r). The corrected A coefficient could be calculated from them in the manner of Scott´s II.

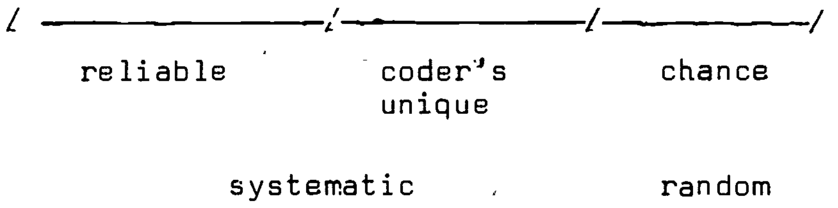
$$\text{(4)} \qquad \text{Corrected } A_c = \frac{A - A_r}{1 - A_r}$$

In the case of frequent categories (6 and 9) this correction would have slightly lowered the coefficients. This is negligible, however, so that the correction was considered unnecessary.

Scott's II coefficient calculated from marginal distributions is almost the only index used to indicate the reliability of FIAC. II can be calculated quickly and easily: simple nomograms can be drawn up for its graphic estimation. This is necessary during the training of coders to ensure a swift feed-back. The author´s view, based on a comparison, is that minimum proficiency Scott´s II > .85 is a relatively conservative requirement. If broader category systems are used its attainment may be difficult. Comparison between these indices shows that the use of Scott´s II is justified, although it is not based on cross-tabulation from common units. The danger of mutually compensating errors (or identical marginal distributions despite a divergence of unit by unit codings) did not appear serious in the light of the results obtained by me earlier.

The reliability of observation will remain a persistent methodological problem, because the value of results depends crucially on the accurate use of the metalanguage in the coding process. Care should be taken not to align the reliability problem of category systems with the normal measurement on the quantitative scale, where reliability is defined as the ratio of true to observed variance. Functioning with ipsative nominal scales involves factors which complicate the classic treatment of measurement errors. The error does not then enlarge the variance, as with quantitative variables, but produces a futile or "worse" variance (cf. Valkonen 1971, 61). A high degree of agreement in classification is easy to attain by using few categories. The measurement of concepts by means of such a classification remains crude and deficient in validity. As the validity problem is often very complex, reliability has been the means of demonstrating the utility of the whole system of classification. The classic theory of measurement errors regards reliability as a necessary but insufficient precondition of validity. In connection with categorization, the number of classes and subdivisions in the category system can also be regarded as a prequisite of validity. A set of four to six categories is the probable minimum in this respect.

In connection with measurements based on classification, lack of reliability does not mean that the majority of classifications occur by chance. The coder's individual and unique manner of interpreting the situation and using the metalanguage of the coding system is an additional factor causing disagreement: it may remain constant intraindividually yet vary from one coder to another.



There is reason to take seriously the warning of Weick, who points out that the observer forms an incalculable factor in any observational system (1968, 360). Emphasis on the unique quality of the coder's contribution leads to uncertainty over the extent to which the same concepts correspond to each other in different studies (Rosenshine 1970, 120).

4. Exploring the Sequences through Factor Analytic Techniques

4.1. Summary of Methodology

The transition matrix was examined by factor analysis in order to ascertain which transition clusters (sequences) are to be found. Both inverse and normal factor analysis were used. Because the units are only one in number (the same system with measurements in time $t_1 \dots t_{25}$), they are called O and P techniques (Table 2).

Table 2. Factor Analytic Techniques (Cattell 1952, 109)

Data plane	Technique	Factor regarded as constant	Correlated and factorized	Nature of factors
V - P	R	S	Variables	Trait factors
	Q		Units	Type factors
V - P	P	U	Variables	State factors
	O		Situations	Situation factors
P - S	T	V	Situations	Situation factors
	S		Units	Type factors

V = variable

P = unit (person etc)

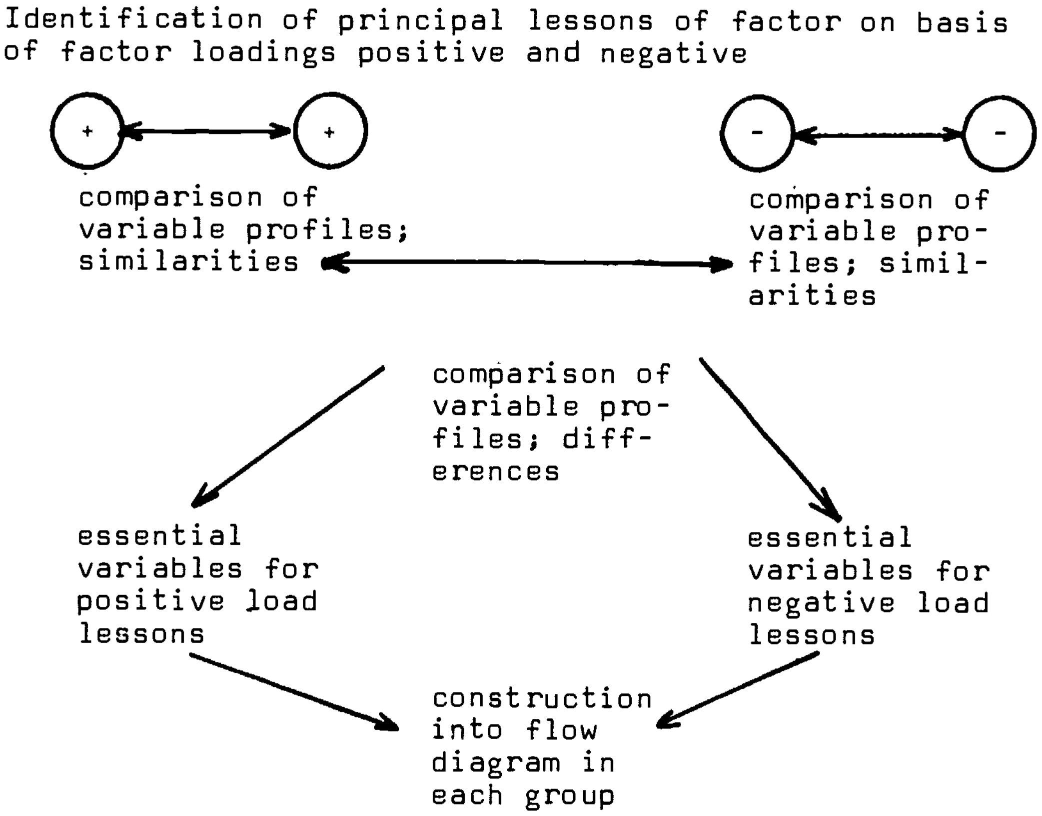
S = situation ($t_1 \dots$)

<u>O technique</u>. The same system (group, organism, individual etc.) is examined by making repeated measurements of the same variables in different situations which are then correlated. In

the present study, the interaction matrices from the identical class of students but produced by different situations were correlated with each other. The sequences were constructed as follows:

1) The two lessons with the strongest positive factor loading were sought; also the two with the strongest negative loading. A strong bipolarity was expected in view of the the ipsative nature of the data matrix.
2) Variables were identified which were parallel (as standard deviations from the arithmetic mean) in the positive load lessons and, correspondingly, in the negative load lessons, but which separated the lessons of different sign from each other (Figure 1). This was best performed by drawing the standardized variableprofiles of all four lessons on the same graphic illustration and making comparisons with it.
3) From the variables discovered (e.g. 9-1, 1-3, 3-3, 3-6) sequences were constructed to illustrate separately the process of the lesson type for each pole of the factor (Koskenniemi & Komukainen 1969, 18-28).

Figure 1. Interpretation Procedure for the O Technique

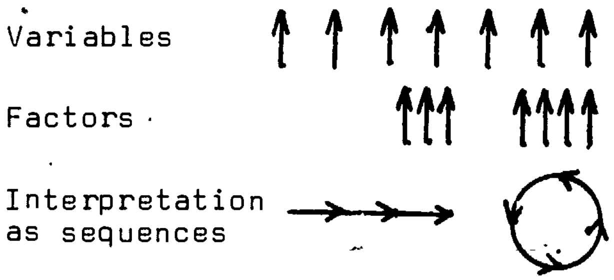


The O technique interpretation could presumably be improved and freed from subjective errors by calculating factor scores for the variables and using them in the interpretation. Another method would be to correlate factor loadings of the lessons with other variables. The emerging correlation matrix would identify the essential variables for each type (Baumann 1971, 174). It is probable that the instability of interpretation within the context of inverse factor analysis could be substantially reduced by applying these different methods.

P technique. In the same system, repeated measurements are made from a number of variables in different situations. The variables are intercorrelated, and factor analysis with varimax rotation is performed (Komulainen 1971a). The interaction sequences were elucidated as follows:

1) High-positive and high-negative load variables for the factors were sought and arranged in their own groups.
2) Chains formed by transitions were constructed for each factor pole and their features presented as flow diagrams (Komulainen 1971a, 16-25).

Figure 2. Interpretation Procedure for the P technique



4.2. Some methodological problems

For each lesson, a normal interaction matrix was formed, whose cells were used as variables. Because the interaction accumulates heavily in certain areas of the matrix, 50 out of the total 169 possible cells were selected for treatment (Komulainen 1971a, 12-14).

Figure 3. Variables selected from interaction matrices

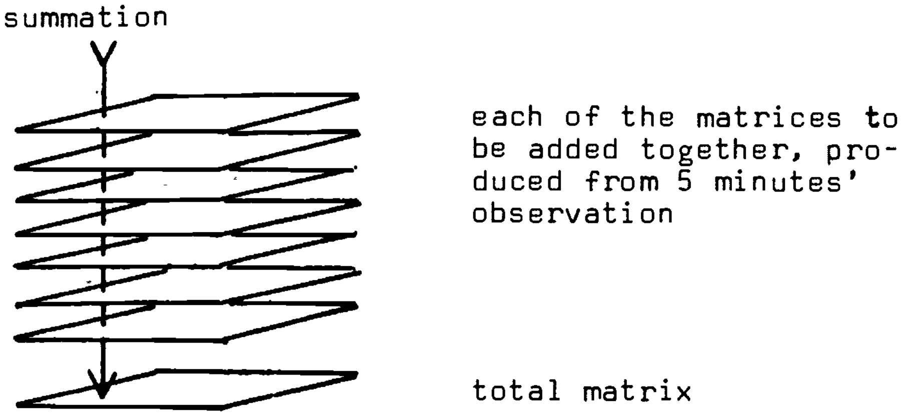
	1	2	3	4	5	6	7	8	9	10	11	12	13
1			5	7	13	16	25		35				
2						17							
3			6			18							
4				8					36			45	
5					14				37				
6				9	15	19	26	31	38	42		46	
7				10		20	27	32	39			47	
8						21	28	33				48	
9	1	3		11		22	29		40			49	
10	2	4				23				43			
11													
12				12		24	30	34	41	44		50	
13													

The selected variables contain some 85 % of transitions of the matrix. Certain problems are raised when cells of the millage matrix are used as variables in factor analysis.

N/p ratio. In the present study the number of observations is very small compared with the number of variables. The invariance of the factor structure from one sample to another thus becomes a problem. Dawley & Maxwell (1971, 63) note that it is a safe rule to require $N - p > 50$. Pawlik (1971, 276) for his part writes that, on the evidence of methodological experience, factor loadings vary far more than correlation coefficients from one sample to another, so that a factor analysis with $N < 60$ should not be performed. Cattell mentions a 4-to-1 rule of thumb as the minimum

(1952, 345), although he notes that the most difficult problem of the P technique in particular is to ensure an adequate amount of repeated measurements. When using the P technique Cattell himself has been obliged to compromise with regard to this minimum (e.g. Cattell et al. 1947). With extremely small N/p ratios we are brought back to the fact that the rank of the data matrix is less than or equal to the smaller side of the data matrix. The rank is equal to the number of factors that can be delineated. Rummel (1970, 220) expresses the view that when the interest is only in describing data variability, factor analysis will yield such a description regardless of the fact that variables exceed cases in number. In the present study, however, observations used in the P technique may be regarded as aggregates obtained by adding.

Figure 4. Total Matrix Calculated as Sum of Parts



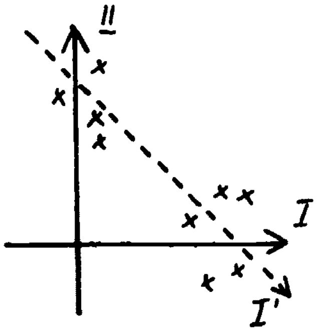
The total millage matrix may be described as a sum matrix formed from the parts of a lesson. Selection of the total matrix as a unit of observation is based on the following arguments, among others:

1) Distributions of variables from total matrices were nearer to a symmetrical, unimodal form than distributions from partial matrices, where positive skewness - especially in variables on the diagonal (steady state cells) - might grow diturbingly strong.
2) Partial matrices would remain too scanty in the observation material. If 500-600 acts of a lesson are divided into, say, six parts and a 13 x 13 matrix is formedfromeach, it is clear that such a matrix is highly unstable (expected mean frequency 0.6 transition/cell).
3) If intercorrelations between variables calculated over total matrices are high among certain contingencies, it may be presumed that the transitions in question have occurred during the lesson so close to each other in time that they may be regarded as belonging to the same behavioural sequence. The similarity of factor structures calculated for matrices of different length (5 min., 10 min., etc.) will give empirical support to the hypothesis.

Correlations calculated for the aggregate, i.e. total matrix, are in general higher than those calculated from parts of the aggregate. In such a case the increase in the intercorrelations is due to the disappearance of a part of the random variation in the values of smaller units around the regression line (Valkonen 1971, 51).

Ipsativism of measurements and form of distributions. Doubly standardized data have been labelled ipsative in contrast to normative (Cattell 1966a, 115-116). Dubois calls such matrices closed systems, and points out that such system may cause diffuculties of interpretation in factor analysis (1957). Those matrices may also be considered ipsative whose row sums add to a constant from one observation to another. Horst mentions that the influence of such centering on the rank of the matrix is of considerable importance (Horst 1965, 294). He also developes methods of deriving the factors for one scaling of the data matrix from the factors of a different scaling (Horst 1965, 295-314). Baumann notes that the form of the primary set of data is decisive for the emerging factor structure. From the centred matrices emerge fewer but strongly bipolar factors (Baumann 1971, 178).

Figure 5. Emergence of Bipolar Factors from Centred Matrices



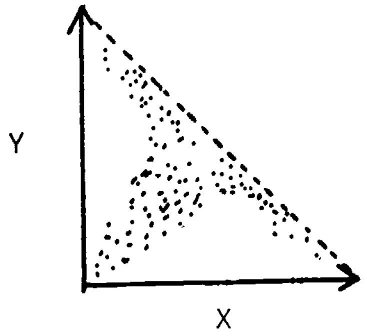
The variables of the present study can be regarded as ipsative. The 50 cells selected from the interaction matrix contain on the average 85 % of all transitions. No variable therefore can be presented as a perfect linear combination of other variables, but within certain limits the row sums of the data matrix reach a constant. The ipsative nature of the variables, combined with the fact that for some observations the entire row sum may consist of an exceptionally high value of one variable, raises a problem that is difficult to control in calculating the intercorrelation matrix. Let us assume a situation where, within a certain range, a moderate positive correlation prevails between two variables, but when one or other obtain a high value the ipsativism load inevitably produces a low value in the other member of such an XY pair.

The situation might appear as in Figure 6. The effect of such exceptional XY pairs is so powerful through squaring that a few divergent pairs may change a moderate positive correlation into a negative one. An effort can be made to control the situation by such methods as the following:

1) Distributional transformations, by which the tail section of each distribution is cut short (e.g. log X).
2) Treatment of the values in tail sections as missing data, in which case values of the variables greater than the cut-off point are ignored when calculating correlations.
3) Rejection of observations which contain values forming the extreme tail section of the variables.

Experiments with fictive examples have led me to propose Method No. 2 for further studies. Distributional transformations produce quite unexpected results in the cases where a divergent variable value is far from the remaining, relatively homogeneous group of scores. Method No. 3 reduces the number of observations which is often too small already. Method No. 2 is likely to give the best appromaximation of the "true" correlation between variables. Side effects harmful to the emergent correlation matrix will probably be quite insignificant.

Figure 6. Influence of Ipsativism as a Scatter Diagram of Correlation between two Variables



Some results obtained through transformation analysis.

Transformation analysis enables us to summarize in what manner splitting the total interaction matrix into parts (see pp. 17-18), and using the parts as observation units, will affect the emergent factor structure. What is the correspondence of factors, and what variables change most from one analysis to another?

Four factorizations were made:

1) Total matrix as an observation unit whose results were reported earlier (Komulainen 1971a);
2) 15' matrix as an observation unit;
3) 10' matrix as an observation unit;
4) 5' matrix as an observation unit;

In each case unities were placed in the diagonal spaces of the correlation matrix as h^2 estimates. Principal axis solutions of six factors were rotated to the varimax criterion. These solutions were compared with each other by means of symmetrical transformation analysis. It may be mentioned as a general observation that the expected phenomenon - average growth of correlations moving toward the total matrix - was clearly apparent. This is seen from the average communalities of different analyses.

Table 3. Average Communalities in Different Analyses

	Analysis 1	2	3	4
Mean	.69	.56	.51	.43
SD	.12	.15	.14	.16
Number of variables	50	50	50	50

It is often asked whether the space activated by factors can be regarded as having the same structure in different cases, or whether the delineation of variables in factor space is

the same in different cases. Symmetrical transformation analysis is a technique presented by Mustonen (1966), which enables to obtain information on similarity of factor structures and abnormal transformation of variables. The advantage of symmetrical transformation analysis over other analogous techniques (cf. Rummel 1970, 463 et seq.; Ahmavaara 1954; Ahmavaara & Nordenstreng 1970) is that the residual co-variances of variables are the same whatever the direction of scrutiny. Orthogonal rotations preceding symmetrical transformation analysis do not affect the examination of transformation of variables. It is generally most advisable to make a transformation analysis after the final orthogonal rotations. Factor correspondences (cosines of angles between axes) appear then directly from the transformation matrix, which in an ideal case is unit matrix I.
Configurational invariance remains relatively high between the analyses (Tables 4-9). Factors I and VI are the most unstable in this respect. An examination of transformation matrices L_{ij} reveals that these factors have a tendency to become mixed with each other. Difficulties in interpretation (Komulainen 1971a, 16-25 and 27-30) and this result indicate that the number of rotated factors may have been too large or that the situation is not favourable for an orthogonal solution.

We shall next examine with which variables structural deviations are clearest of all. This is done by examining how the corresponding variables of factorized solutions behave when placed in pairs in the same space. The cosines of the angle between the vectors are used as descriptive quantities for structural deviations (Table 10, columns 6-11). In Appendix 2 the squared distances between vectors are also shown among different solutions. This is not a highly revealing measure, because a systematic shortening of the vectors was already noted when starting from the calculated total matrix solution.

Table 4. Correspondences of Factor I between Different Solutions (teacher indirect-direct influence)

	1	2	3	4
1		.92	.96	.69
2			.91	.86
3				.65

Table 5. Correspondences of Factor II between Different Solutions (reactive pupil activity)

	1	2	3	4
1		.85	.91	.85
2			.83	.67
3				.96

Table 6. Correspondences of Factor III between Different Solutions (vicious circle)

	1	2	3	4
1		.97	.89	.86
2			.96	.95
3				.98

Table 7. Correspondences of Factor IV between Different Solutions (no clear interpretation)

	1	2	3	4
1		.99	.88	.80
2			.84	.76
3				.95

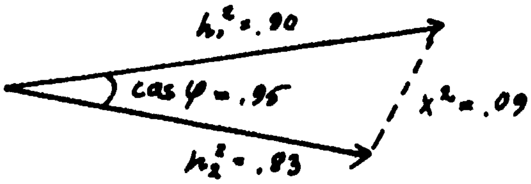
Table 8. Correspondences of Factor V between Different Solutions (question-answer)

	1	2	3	4
1		.91	.89	.77
2			.98	.85
3				.86

Table 9. Correspondences of Factor VI between Different Solutions (spontaneous pupil activity)

	1	2	3	4
1		.92	.93	.59
2			.74	.59
3				.56

Figure 7. Example of Stuctural Deviation of Variables



Structural deviations are centred on variables whose frequency is already low in the total matrix (most clearly for the variable No. 38). Factor structures remain highly invariant between solutions. Structural deviations revealed by variables may be mostly explained through the ceiling effect exerted by the changing form of the distributions (cf.Guilford 1965, 336-338; cf. also Cattell 1952, 322). The skewness of distributions and, consequently, the ceiling effect increases in strength with the shortening of the period from which the matrices for observation units are formed. The differences grow almost systematically and are in the total/5' comparison at their maximum. Results show, however, that information is not substantially contaminated if partial matrices are aggregated into a total matrix. For purposes of practical observation a total matrix may well be used as a starting point for interpretation.

Table 10. Communalities of Solutions and Structural Deviations by Variables between Solutions

Explanations of columns:

(1) = number of variable
(2) = communality of variable in analysis 1 (total)
(3) = " " " " " 2 (15')
(4) = " " " " " 3 (10')
(5) = " " " " " 4 (5')
(6) = structural deviation of variable between analyses 1 & 2
(7) = " " " " " " 1 & 3
(8) = " " " " " " 1 & 4
(9) = " " " " " " 2 & 3
(10) = " " " " " " 2 & 4
(11) = " " " " " " 3 & 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	.90	.83	.80	.73	.95	.95	.89	.95	.97	.96
2	.71	.53	.45	.32	.93	.95	.83	.90	.86	.73
3	.63	.55	.43	.24	.90	.91	.85	.98	.78	.76
4	.64	.30	.30	.26	.94	.78	.57	.92	.80	.93
5	.85	.87	.79	.70	.97	.97	.97	.98	.95	.96
6	.86	.80	.73	.61	.97	.98	.96	.97	.96	.97
7	.69	.55	.60	.55	.84	.90	.72	.93	.95	.91
8	.52	.35	.36	.29	.86	.74	.67	.95	.88	.88
9	.75	.56	.61	.54	.96	.92	.95	.98	.98	.99
10	.63	.38	.34	.19	.95	.92	.75	.95	.75	.86
11	.59	.62	.28	.33	.99	.74	.47	.71	.44	.92
12	.85	.78	.63	.47	.99	.99	.96	.97	.93	.99
13	.58	.35	.46	.34	.76	.82	.67	.87	.91	.95
14	.57	.47	.45	.41	.94	.88	.75	.90	.80	.96
15	.69	.62	.61	.48	.98	.96	.86	.99	.89	.88
16	.49	.40	.47	.37	.75	.71	.69	.96	.84	.87
17	.59	.46	.25	.17	.98	.93	.93	.98	.96	.91
18	.82	.79	.70	.63	.98	1.00	.98	.98	.95	.99
19	.86	.76	.62	.58	.98	.93	.85	.96	.93	.93
20	.59	.41	.32	.39	.95	.93	.72	.90	.74	.88
21	.64	.44	.45	.32	.90	.87	.83	.97	.94	.96
22	.35	.29	.21	.09	.83	.79	.74	.87	.91	.98
23	.68	.53	.45	.37	.95	.92	.76	.99	.86	.67
24	.70	.70	.48	.29	.75	.82	.74	.93	.85	.95
25	.60	.48	.33	.25	.98	.86	.79	.78	.82	.78
26	.86	.60	.46	.49	.95	.82	.88	.92	.91	.85
27	.78	.65	.69	.59	.94	.92	.86	.90	.87	.98
28	.63	.52	.45	.29	.99	.84	.88	.88	.91	.96
29	.86	.73	.69	.45	.98	.98	.99	.95	.96	.96
30	.60	.56	.55	.36	.78	.92	.94	.67	.72	.98
31	.61	.53	.62	.41	.95	.99	.96	.94	.96	.97
32	.64	.35	.30	.30	.96	.95	.91	.90	.83	.92
33	.50	.39	.49	.52	.95	.89	.89	.97	.96	.99
34	.74	.53	.59	.60	.91	.85	.85	.94	.81	.84
35	.67	.40	.33	.14	.97	.92	.76	.83	.78	.54

Table 10. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
36	.83	.77	.48	.55	.98	.91	.88	.88	.83	.98
37	.73	.55	.53	.53	.98	.97	.88	.96	.83	.94
38	.53	.37	.36	.11	.87	.96	.30	.91	.28	.19
39	.90	.68	.64	.60	.95	.99	.99	.97	.98	.99
40	.71	.68	.57	.57	.99	.98	.96	.98	.97	.98
41	.67	.66	.55	.53	.94	.92	.91	.91	.83	.97
42	.42	.43	.51	.56	.95	.89	.56	.94	.69	.74
43	.79	.58	.46	.39	.98	.91	.90	.89	.93	.93
44	.72	.52	.46	.38	.99	.96	.90	.93	.87	.94
45	.85	.78	.60	.55	.94	.86	.76	.97	.87	.94
46	.75	.64	.60	.43	.94	.88	.81	.97	.88	.95
47	.76	.65	.69	.48	.93	.88	.91	.88	.98	.93
48	.76	.61	.63	.65	.98	.92	.91	.95	.88	.90
49	.66	.47	.36	.32	.87	.83	.73	.54	.60	.85
50	.71	.71	.72	.64	.96	.92	.96	.93	.98	.97

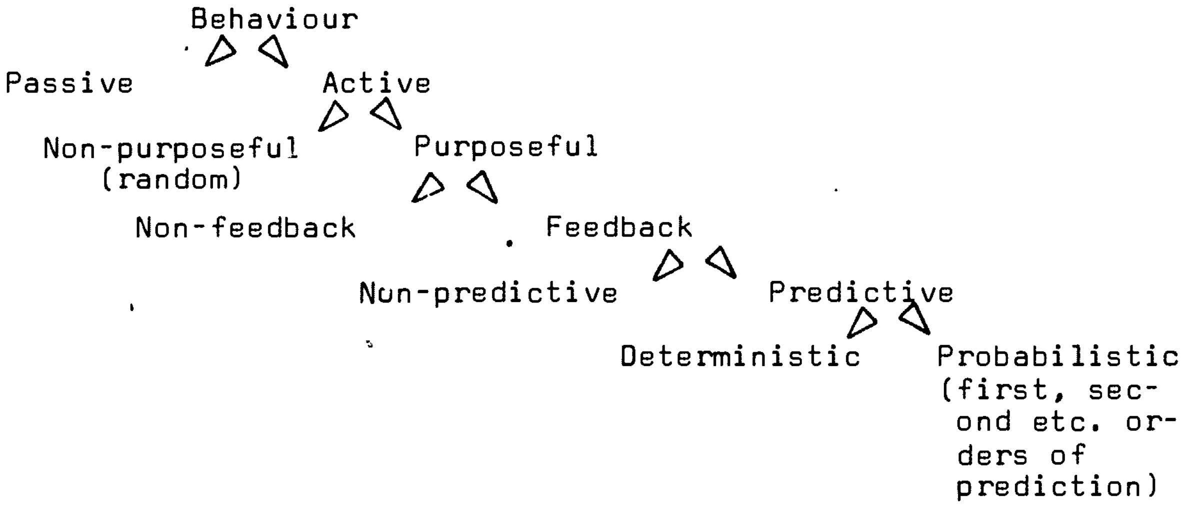
Structural deviations observed in the variables, however, cause doubts as to whether factor scores can be used as indices of the frequencies of sequence occurrence. In the first plase, regression coefficients used in the estimation of factor scores are susceptible to sampling fluctuation. Factor scores as they arise, therefore, are based for each sample on a unique set of regression coefficients. Comparisons between samples become difficult. In the second place, it must be seriously doubted wheter it is at all possible to interpret factors as sequences as explicitly as the writer has done. (Komulainen 1971a, 16-25). Although the interaction matrix may reveal accumulation into certain cells, chains of greater length are hardly to be anticipated. It follows from this that the model sequences presented in the material scarcely at all, still less are they to be repeatedly indentified. A difficult methodological problem arises when chains are sufficiently similar in form to be regarded as belonging to the same type (cf. Hutt & Hutt 1970, 177-178; Cherry 1966, Ch.7). It is evident that indices calculated from interpretation areas of the matrix have a content which is similar and more concrete but fully adequate for practical application.

5. Sochastics of Classroom Communication

5.1. General

If the notion of hierarchic structure held by Rosenblueth et al. (1943) is slightly modified, it can be easily recognized that interaction in the classroom has features which classify it as active, purposeful, feedback-oriented, predictive and probabilistic in the range of behaviour.

Figure 8. Range of Behaviour (modified from Rosenblueth et al., 1943, 223)



Because there are intentive, goal-oriented features in the classroom interaction which are clearly predictable in a probabilistic sense, it is quite natural to examine interaction in a manner based on the notion of probability. Communication theory and Finite Markov chains are the two main areas on which the following investigation is based. Information theory and Markov chains are not separate sectors. Indices evolved as part of communication theory are specifically used to illustrate the characteristics of each particular chain.

The stochastic assumption implies that variability is itself conceptually included in the model and not merely added as an extrinsic error term to an equation whose primary structure has already been determined (Jaeckel 1971, 242). The stochastic assumption has long been linked to the concept of instruction (e.g. Winnefeld 1957, 30-44; Grassel 1970, 8-18).

5.2. Finite Markov Chains

In an earlier connection I have presented a background for the use of Markov chains (Komulainen 1971b, 1-8). Mere definitions of the concepts in use are given here. They follow mainly the practice suggested by Kemeny & Snell (1960).

A finite Markov chain is a stochastic process which moves through a finite number of states, and for which the probability of entering a certain state depends only on the last state occupied (cf. later expanded process).

An ergotic set of states is a set in which every state can be reached from every other state, and which cannot be left once it is entered.

An ergotic state is an element of an ergotic set.

A cyclic chain is an ergotic chain in which each state can only be entered at certain periodic intervals.

A regular chain is an ergotic chain that is not cyclic.

The chain of states arising from the classroom interaction in connection with coding is therefore mainly a regular chain. It contain no <u>absorbing states</u> (i.e. states which, once entered, are never left) and is not cyclic.

Formed from a chain is a transition probability matrix, which is a square matrix (of order k x k; k = number of states), and whose row sums add up to unity. Calculable for states from the transition probability matrix are <u>first passage times matrix</u> (FPT) and the corresponding <u>variance</u> (or standard deviation) <u>matrix</u> (SD of FPT). FPT quantities express the average number of steps before entering a certain state for the first time after the initial position. The figures of the SD of FPT, in turn, express variation observed in the number of steps around their corresponding means (Arosalo 1968).

The Markov chain theory can be used for the examination of dependences extending back more than one step. From the original Markov chain we form a new Markov chain. A state in the new chain will be a pair of states in the old chain. Such a new chain is called <u>expanded process</u>. By examining this process we obtain more detailed information, because it is based on conditional probabilities that are determined by two preceding states in the original chain. The <u>order of approximation</u> in the chain under examination has no theoretical upper limit. Because the number of new states in the expanded process grows as a power function, there are practical limits.

By combining the original states we can reduce their number to a smaller one, while still preserving essential features from the original process in a rougher form. With the number of states reduced in this way we pass to the examination of higher approximation orders. Such a chain we call lumped process.

In the present study one long chain with 14 660 successive steps was formed from the whole material, and on its basis the transition probability matrix was calculated. With the original number of states (k=13) an expanded process with 169 states was formed, whose transition probabilities have been presented and examined earlier (Komulainen 1971b, 9-15). From the original system of 13 states a lumped process with 5 states was formed, from which in turn expanded processes were formed which were based on ever higher orders of approximation. Results concerning stochastics of classroom communication are based on this material.

Table 11. Summarized Treatment of Results

Original (k=13)	Number of states	Conditional p	Results	
			FPT & SD of FPT	Indices from information theory
Original	13	$p_x(y)$	yes	yes
Expanded	169	$p_{wx}(y)$	no	yes
Lumped (k=5)				
Lumped	5	$p_x(y)$	no	yes
Expanded	25	$p_{wx}(y)$	no	yes
Expanded	125	$p_{vwx}(y)$	no	yes
Expanded	625	$p_{uvwx}(y)$	no	yes
Expanded	3125	$p_{tuvwx}(y)$	no	yes

5.3. Information Theory and Its Underlying Concepts

The origin of the mathematical theory of communication cannot be linked with any specific investigator. Elements of the theory can be observed in the work of several researchers (Cherry 1968, 41-52). The work of Hartley, Gabor, Wiener, Shannon, Weaver and others led to a relatively integrated system of concepts whose practical utility has been demonstrated in several fields (cf. e.g. Miller 1963). Information theory is a formal - as opposed to substantive - theory. It is not a model of behaviour, even communicative behaviour, but rather a tool that may be used in the construction of such models. Information theory is much more general than the terminology associated with it might suggest. Measures based on probability concept are applicable to many situations where terms like "information transmission" are awkward or quite inappropriate (Frick 1959, 183-184).

A precursor of information theory was probability theory, which started from intellectual schematization of what happens in games of chance, and which has grown into one of the fundamental tools of exact science (Rapoport 1956, 141). Information theory suffers thus from all the conceptual difficulties associated with probability theory (Frick 1959, 183). Information theory is fundamentally a theory of selection. Something is selected from a set of predefined alternatives. To examine the selective process it is essential to be able to examine the set. Scrutiny of the characteristics of a Markov chain is based on transition probabilities between states in the set. With the indices of information theory it is attempted to describe the chain formation tendency of classroom communication classified by the 13 categories FIAC system. These indices have very clear connections with the statistical measures regularly used (cf. e.g. Hays 1963, 610-612; Ackoff 1958, 218; Miller 1963, 125). Information and redundancy are central concepts in these indices.

Information. For Shannon, the amount of information contained in a message is the amount of freedom of choice involved in the selection of the message. A unit of choice is defined as the selection of one out of two equally available symbols. Thus, in selecting one of two equiprobable symbols, one choice-unit is involved and the resulting one-symbol message contains one unit of information (Ackoff 1958, 214). The term "information" occurs in the theory of communication in a particular way. It is not synonymous with "meaning". Only the amount of information is measured - the amount does not specify the content, value, truthfulness, exclusiveness, history or purpose of the information (Miller 1963, 123). Cherry criticises the concept of information in the context of the mathematical theory of information as follows:

> "The measure for H (the amount of information) from Wiener and Shannon is applicable to the signs themselves, and does not concern their 'meaning'. In a sense it is a pity that the mathematical concepts stemming from Hartley have been called 'information' at all. The formula for H is really a measure of one facet only of the concept of information; it is the statistical rarity or 'surprise value' of a source of message-signs" (Cherry 1966, 51).

Bit. The amount of information depends upon the fraction of the alternatives that are eliminated by the message. Every time the number of alternatives is reduced to half, one unit of information is gained. This unit is called one 'bit' of information. The amount of information in a message that reduces k to k/x is $\log_2 x$ bits. To give a classic example, a child needs four bits of information in order to select with certainty from sixteen equally probable boxes the one which contains a sweet ($\log_2 16=4$ or $-\log_2(1/16)=4$, if for each box $p=1/16$). Such a situation of equal probabilities represents <u>maximal uncertainty</u> (H_{max}).

<u>Average amount of information (or uncertainty)</u>. Since we wish to deal with sources rather than particular messages, we need a measure to represent how much information a source generates. If different messages contain different amounts of information, then it is reasonable to speak of the average amount of information per message we can expect to get from the source. This expected value is denoted:

$$(5) \qquad H = -\sum_{i=1}^{k} p_i(\log_2 p_i)$$

Its interpretation is the average minimum number of yes-no answers required to describe the selection of the signals from the predefined set (Cherry 1966, 178-182; Miller 1963, 124).

<u>Redundancy</u>. Events may have sequential connections in the sense that knowledge of a preceding result reduces the uncertainty of predicting a following result. The chain then contains a redundancy whose amount is expressible with the indices of information theory. Quantitatively speaking, the redundancy of a source is assessable only in relation to the known set of probabilities. Thus we can quote the redundancy of a source on a monogram or digram basis etc. The redundancy of a source may be quoted:

(6) $$R = \frac{H_{max} - H}{H_{max}}$$

where H = average amount of information of 1, 2 etc. orders of approximation

and H_{max} = average amount of information of zero order of approximation

This index receives the value 1 when the chain contains no information (there is no freedom of choice, or the probability of selecting any one of a set of signs is 1.o) or the information is fully predictable. If the chain's degree of organization is completely random, the index receives the value 0. If the course of action is coherent in the sense that future conduct depends upon past conduct, we say that the behaviour is predictable or, to some degree, stereotyped. In such cases the redundancy can be used to measure the degree of organization in the behaviour sequences (Frick 1959, 185; Miller 1963, 128). There is a simple yet very important theorem concerning statistical constraints and redundancy, expressed by Cherry as follows:

> "If all the various transition probabilities $p_i(j)$ are equal, then the individual signs become statistically independent and equally probable. In such a case there are absolutely no preferred guesses as to what signs will be given out by the source; redundancy is provided by the existence of unequal transition probabilities... But notice that the converse does not hold: it is easy to arrange that all signs should be equiprobable, yet have unequal transition probabilities" (Cherry 1966, 184).

Order of approximation. A zero order approximation to the stochastic structure assumes that all events (signs) are equiprobable and independent of each other (=H_{max}). A first order approximation is obtained by assuming that successive signs are independent but have unequal probabilities (measured on an adequate sample of classroom interaction). In second order approximation the conditional probabilities of the digram structure $p_x(y)$ are known. In higher order approximations we further specify the conditional probabilities $p_{wx}(y)$ etc.

Average amount of information in different orders of approximation.

Order of approximation	Formula
0	$H_{max} = -\log_2(1/k)$
1	$H(x) = -\sum p_i(\log_2 p_i)$
2	$H_x(y) = -\sum\sum p_{j\ j}(\log_2 p_i(j))$
3 etc.	Similarly the information rate (or uncertainty) may be calculated for chains having trigram structure; etc.

Relative reduction in uncertainty. The relative reduction in the average amount of information which Hays suggested (1963, 612) has also been calculated. In this the object of comparison is not the maximal state of uncertainty (H_{max}), but the preceding H value from its approximation. Then, for instance, the relative reduction in uncertainty in y given x is:

$$R_x(y) = \frac{H(y) - H_x(y)}{H(y)} \tag{7}$$

When examining the chains we must stop at the point, compatible with the amount of data available, where uncertainty (average amount of information) is no longer being significantly reduced. Unfortunately, there are no statistical significance tests for the verification of this change. We shall return later to the fundamental phrase "compatible with the amount of data available".

5.4. First Passage Time Matrix (FPT) of the Original Process with 13 States

When we examine average step figures in the FPT matrix we observe clear differences between the columns, whereas the within-column variance is small. The between-columns variance is due to the relative frequencies of the states concerned. The more repetitive a state is, the fewer the number of steps by which it is reached: the state from which a start is made hardly affects the matter. As to the within-columns variance, attention is drawn to the natural (and trivial) occurrence that the average number of steps from state x to state y decreases as the corresponding $p_x(y)$ increases. Correlation coefficients calculated between columns (FPT matrix and $p_x(y)$ matrix) vary between -.80 and -1.00, the median being -.95. From the dispersions corresponding to average values of the FPT matrix (Table 15) it is seen that when moving to the same state (1-1, 2-2 etc.) average steps vary less than when moving to other states. Dispersions also have a strong connection with the corresponding relative frequencies by categories. It is apparent from the calculated matrices of the Markov chain that they give no significant information on the structure of classroom communication. From the FIAC matrix they give trivial and redundant information which is easy to read from $p(y)$ and $p_x(y)$ values or even straight from transition frequency matrix. These descriptive quantities have been used with great success, however, to illustrate such matters as social rise (or decline) between generations, or to predict interprovincial migration in a certain district (Nowak 1964; Bartholomew 1967; Rikkinen 1971). The usefulness of the FPT matrix and the SD of FPT matrix for analysis of typical classroom communication with instruments similar to FIAC is greatly reduced by the fact that transitions in the observation chain are not separate, independent of each other, but the y of a preceding pair is always the x of a following pair. This produces an internal dependence which is clearly harmful to the expressiveness of the descriptive quatities of the Markov chain.

Table 12. Transition Frequency Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	22	7	226	133	39	173	65	28	58	60	6	61	5
2	1	40	0	31	3	51	24	2	38	18	3	21	o
3	2	0	303	37	10	113	5	7	15	40	7	29	0
4	7	1	0	137	2	34	39	26	357	23	8	288	1
5	2	1	0	2	79	5	6	2	77	4	0	57	0
6	9	15	1	226	56	2615	123	65	54	192	24	193	12
7	2	1	2	51	9	73	390	36	134	70	11	210	77
8	1	3	1	24	5	62	52	256	39	36	13	136	36
9	617	82	18	95	12	47	86	23	1296	16	8	112	12
10	198	66	16	19	1	169	60	30	6	241	3	56	3
11	11	10	0	5	0	17	8	29	5	2	26	31	4
12	11	6	1	146	18	207	155	120	341	151	36	1321	5
13	0	0	0	17	1	19	53	40	4	18	3	0	387

Table 13. Transition Probability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	.02	.01	.26	.15	.04	.20	.07	.03	.07	.07	.01	.07	.01
2	.00	.17	.00	.13	.01	.22	.10	.01	.16	.08	.01	.09	.00
3	.00	.00	.53	.07	.02	.20	.01	.01	.03	.07	.01	.05	.00
4	.01	.00	.00	.15	.00	.04	.04	.03	.39	.02	.01	.31	.00
5	.01	.00	.00	.01	.34	.02	.03	.01	.33	.02	.00	.24	.00
6	.00	.00	.00	.06	.02	.73	.03	.02	.02	.05	.01	.05	.00
7	.00	.00	.00	.05	.01	.07	.37	.03	.13	.07	.01	.20	.07
8	.00	.00	.00	.04	.01	.09	.07	.39	.06	.05	.02	.20	.05
9	.25	.03	.01	.04	.00	.02	.04	.01	.53	.00	.00	.05	.00
10	.23	.08	.02	.02	.00	.19	.07	.03	.01	.28	.00	.07	.00
11	.07	.07	.00	.03	.00	.11	.05	.20	.03	.01	.18	.21	.03
12	.00	.00	.00	.06	.01	.08	.06	.05	.14	.06	.01	.52	.00
13	.00	.00	.00	.03	.00	.04	.10	.07	.01	.03	.01	.00	.71

Table 14. First Passage Times Matrix (FPT)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	17	76	40	16	89	10	21	36	11	22	120	11	98
2	16	63	53	16	92	10	19	36	10	22	119	10	97
3	18	77	26	17	91	9	23	37	13	21	119	11	99
4	14	76	52	16	93	12	21	35	7	23	120	8	97
5	14	76	52	19	62	13	21	37	7	24	121	9	98
6	18	77	56	17	91	4	21	36	13	22	120	11	97
7	16	77	54	18	93	12	14	34	11	22	119	9	87
8	17	77	55	18	94	12	19	22	12	22	117	9	88
9	9	73	47	17	92	12	21	37	6	24	121	11	97
10	13	70	50	18	93	9	20	35	13	17	120	11	96
11	16	71	54	18	94	11	20	28	12	23	99	9	92
12	16	76	54	18	93	12	20	34	10	22	118	6	96
13	20	79	57	20	96	14	17	29	14	23	120	13	27

Table 15. Standard Deviations of the First Passage Times (SD of FPT)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	22	106	63	22	127	14	28	49	15	30	168	14	135
2	21	97	73	23	129	14	27	50	14	30	168	14	135
3	23	107	51	23	128	13	30	50	16	30	168	14	136
4	19	106	72	22	130	16	28	49	11	31	168	12	135
5	19	106	72	25	106	16	29	50	11	32	169	12	136
6	23	107	75	24	129	8	29	50	16	30	169	14	135
7	21	107	74	24	130	16	23	48	14	30	168	13	128
8	22	107	74	24	130	15	27	38	15	30	167	12	129
9	15	104	69	23	129	15	29	50	10	32	169	14	135
10	19	102	71	24	130	13	28	49	16	26	169	14	135
11	21	103	74	24	131	15	28	43	15	31	153	12	132
12	21	106	74	24	130	15	28	48	14	30	167	10	135
13	24	109	76	25	132	17	25	44	17	30	169	17	70

If dispersions in the SD of FPT matrix are examined, the ratio of figures to corresonding averages in the FPT matrix clearly shows that the distributions of the first passage times are positively skewed. This leads - intuitively, it is true - to two alternatives. Either (1) the information on behaviour obtained in natural situations is highly unstable (or the sampling error is considerable), or (2) parts of the chain can not be regarded as arising from the same population. The former hypthesis is supported by Cattell's observation (1966b, 393-396) that situation variables generally have a far greater variance than test variables. Similarly, Winnefeld (1957, 30-32) emphasizes the openness, instability and tendency to disturbance of the pedagogic field. But what view would such a hypothesis disclose to the researcher? Thereafter one could study just as well the chain generated by the source of random numbers. Far more convincing is the notion that, above the microlevel of instruction, higher level constraints or frame factors can be found which provide us with a source of explanation for the disparity of chain components. Guiding factors of this kind have been found, for instance, first, in the composition of a group of pupils and the theme dealt with (Lundgren 1972); second, in the process of clarifying objectives (Flanders 1970, Ch. 10) and in the cognitive treatment level of the subject matter (Taba et al. 1964). Cattell also notes that it is useless to examine endogenous processes alone, because processes are environmental tied in most cases.

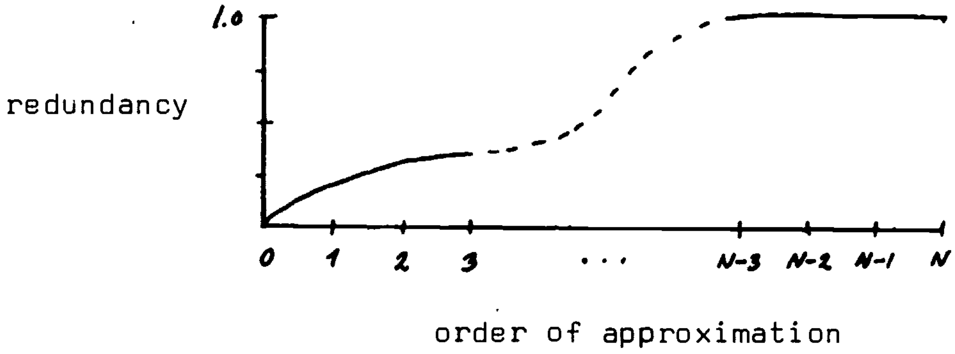
> "Thus nest-building in spring can be defined only in term both of the behaviour of the bird and of the unfolding of spring" Cattell 1966b, 394).

Jackson (1962) and Koskenniemi (1972a) are among those who strongly emphasize external factors of a directly observed situation, especially the preparation and planning process which precedes instruction. In this respect the purpose of constructing theories of instruction is to integrate the existing store of information, which is already considerable. Mere enumeration and grouping of the factors affecting the teaching-learning situation are not sufficent: theoretization must also be capable of specifying the intervening mechanisms which enable us to explain and understand the connections between frame factors and the micro-level of instruction. It is clear that instruction is in practice a more spontaneous, less rational and therefore more unstable, process than the so-called preactive phase of instruction. If it is thought indispensable to remain in natural situations with greater external validity, the only possibility of reducing the part played by random error is greatly to increase the number of units studied.

5.5. Information Rate (average amount of information or uncertainty) and Redundancy Measures of the Original Process

As with the FIAC instrument, variables have been formed in different ways from the observation devices used. In small-group studies (e.g. Bales 1950; Mishler & Waxler 1968) variables have generally been formed from category profiles (i.e. first order approximation). In analysis of classroom communication, not only the category profile bu also a number of sum and ratio variables are almost always calculated: to form these the number of transitions must be known (second order of approximation). A factor of interest is the extent to which uncertainty decreases from one level of approximation to the following. Redundancy can be used as an index of the degree to which the later phases in a chain are predictable from its earlier ones. In addition to the redundancy column the 'relative reduction in redundancy' column should be studied in the tables presented. Because the ratio of chain length to number of categories (k) decreases continuously as we advance to expanded processes of higher approximation orders, and because redundancy grows as a result of this trivial circumstance, a clear turning point in the redundancy curve is often recognizable in the relative reduction column. Later redundancy again grows strongly when the limit of statistical uniqueness is reached: there is only one chain of the length of that examined, so that all transition probabilities are 1.0.

Figure 9. Connection of Redundancy with Degree of Approximation in Study of Finite Material (N=number of elements or steps in the chain)



For comparison the same indices were calculated for two other sets of material which were taped with the same class. Holopainen (1971; 1972) analyzed with Bales' IPA 13 group work lessons videotaped during the academic year 1968-69. Indices illustrating the group work process were calculated on the basis of Holopainen's results (1971, 117), converting them to $\log_2$ system and expressing them in bit units. With the same class in 1967-69 96 lessons of regular class instruction were videotaped. The Lessons were coded with Bales' IPA. All the 25 lessons of this work coded with the FIAC system were included in these 96 lessons. The sets of material mentioned make some kind of a frame of reference for comparisons of predictability. It should be noted, however, that H_{max} in the 96 lessons material is not $\log_2 13$ (with 13 category IPA) but $\log_2 26$, because teacher and pupils are kept separately as actor and target in the interaction matrix. Bales' 13 category modification by Holopainen (1972, 6) was employed in both sets of material. The meanings of the columns in the following tables are:

(1) order of approximation
(2) number of states (k) in the process
(3) expected N/k; N= number of successive elements or steps in the cain
(4) average amount of information or uncertainty (bits)
(5) redundancy
(6) relative reduction in redundancy

Table 16. Redundancy in the Group Work Material of Holopainen (1971).

(1)	(2)	(3)	(4)	(5)	(6)
0	13	646.2	3.70	.00	.00
1	13	646.2	3.17	.14	.14
2	169	49.7	3.12	.16	.02
3	2197	3.8	2.90	.22	.07
4	28561	.3	2.18	.41	.25
		N=8400			

Table 17. Redundancy in the 96 Class Instruction Lessons Material

(1)	(2)	(3)	(4)	(5)	(6)
0	26	1426.0	4.70	.00	.00
1	26	1426.0	3.84	.18	.18
2	676	54.9	2.78	.41	.28

N=37080

Table 18. Redundancy of the Original FIAC Chain

(1)	(2)	(3)	(4)	(5)	(6)
0	13	1127.7	3.70	.00	.00
1	13	1127.7	3.19	.14	.14
2	169	86.8	2.17	.41	.32
3	2197	6.7	2.05	.44	.05

N=14660

The main results expressed in Tables 16 - 18 are as follows. Redundancy in the chain illustrating group work does not increase after first order of approximation. The sharp rise in fourth order of approximation occurs because a limit has been reached in the N/k ratio in whose proximity conclusions cannot be drawn for such a short chain (8 400 acts vs. 28 561 different combinations of four states). Any observed combination far exceeds the probability of its expected chance occurrence. In class instruction lessons the difference between first and second order of approximation is considerable: in both cases the redundancy rises, for the second order to a value of .41. According to Table 18, the redundancy no longer grows after this. For Table 17 material, unfortunately, no trigram structure was available so that comparison for these parts is lacking. Results show that the interaction matrix contains information which should be taken into account in determining variables. This observation supports the decision, made at an earlier stage, to use millage matrix cells as variables. Work directed by a teacher is clearly more organized (stereotyped) in its sequences than group work. Interaction roles in the former are quite distinctly separated, and the impulses of pupils to direct the process must be restricted to some extent. When Bales' IPA is applied to examination of the task-oriented small group, it appears that the interaction profile contains all the information obtainable from analysis. It is quite conceivable that the age (grade) of pupils and their habituation to small group work are connected with the arrangement of interaction structure.

In addition to the above, corresponding descriptive quantities for state chains beginning with 1, 2, ... 12 and 13 were calculated from the original material (FIAC). It should be noted that when measures of chains formed in this manner are examined, redundancy may fall in the higher orders of approximation; this is shown in column 6 as a negative quantity of the relative reduction of uncertainty. If the total chain is examined, this is seen impossible. With higher approximation orders redundancy may remain unchanged or grow, but it cannot diminish. How then does such a phenomenon occur when we examine such parts of the chain that are specified by the initiating state? As an example, let us take state chains which begin with 4.

$i=4;$	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}
	.01	.00	.00	.15	.00	.04	.04	.03	.39	.02	.01	.31	.00

Table 19. Redundancy of the Original 13-state Chain Specified According to the Initiating State (i)

(1)	(2)	(3)	(4)	(5)	(6)
i=1					
0	13	67.9	3.70	.00	.00
1	13	67.9	3.08	.17	.17
2	169	5.2	2.07	.44	.33
i=2					
0	13	17.8	3.70	.00	.00
1	13	17.8	2.93	.21	.21
2	169	1.4	2.27	.39	.22
i=3					
0	13	43.7	3.70	.00	.00
1	13	43.7	2.18	.41	.41
2	169	3.4	1.91	.48	.12
i=4					
0	13	71.0	3.70	.00	.00
1	13	71.0	2.26	.39	.39
2	169	5.5	2.40	.35	-.06
i=5					
0	13	18.1	3.70	.00	.00
1	13	18.1	2.11	.43	.43
2	169	1.4	1.22	.67	.42
i=6					
0	13	275.8	3.70	.00	.00
1	13	275.8	1.63	.56	.56
2	169	21.2	1.66	.55	-.02
i=7					
0	13	82.0	3.70	.00	.00
1	13	82.0	2.71	.27	.27
2	169	6.3	2.26	.39	.17

Table 19.
(continued)

(1)	(2)	(3)	(4)	(5)	(6)
i=8					
0	13	51.1	3.70	.00	.00
1	13	51.1	2.70	.27	.27
2	169	3.9	2.39	.36	.12
i=9					
0	13	186.5	3.70	.00	.00
1	13	186.5	2.09	.44	.44
2	169	14.3	2.04	.45	.02
i=10					
0	13	67.0	3.70	.00	.00
1	13	67.0	2.78	.25	.25
2	169	5.2	2.53	.32	.09
i=11					
0	13	11.4	3.70	.00	.00
1	13	11.4	3.06	.17	.17
2	169	.9	2.18	.41	.29
i=12					
0	13	193.7	3.70	.00	.00
1	13	193.7	2.33	.37	.37
3	169	14.9	2.03	.45	.13
i=13					
0	13	41.7	3.70	.00	.00
1	13	41.7	1.55	.58	.58
2	169	3.2	1.68	.55	-.08

(meanings of columns on page 43)

We observe that 4-4 and 4-12 are the transitions which make the first order distribution of state chains beginning with 4 as above illustrated. In fact it would be more correct to speak of second approximation order, because i = 4 is a condition for the relative frequencies of the following states although it is a constant. Intuitively it is clear that such a high predictability may decrease if the components of the chain are examined separately (specification made according to the initiating state). On the other hand, the average amount of uncertainty in the whole chain cannot grow in comparison with the previous approximation. Such a decrease in redundancy occurs particularly in the case of chains beginning with i in which the state frequency profile after i is especially uneven. Some p_j may then be approaching unity, and the redundancy does likewise. In the distribution of the following states, however, no p_k need necessarily come close to 1.

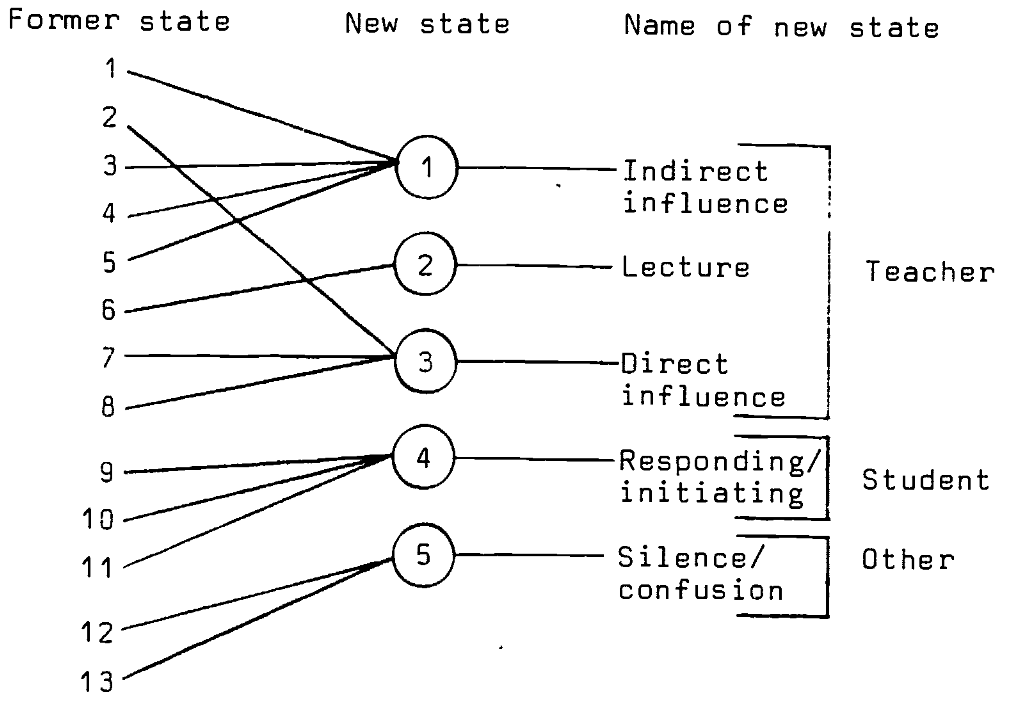
Activity is most predictable after the starting states 5 (broad question) and 6 (lecture). The predictability of the former may be due to the chain 5-5-12-12, because a broad question is often longer than normal and leads to a pause for reflection before the pupil speaks. The latter owes its predictability directly to the 6-6-6-6 nature of the "gives information" category. $p_6(6) = .73$ reflects this characteristic. Least predictable is behaviour after 10 (spontaneous relevant student talk). Such an input of the pupil - because of its content and other factors assessed by the teacher - contains many further possibilities. Such spontaneous stimulus demans that the teacher decide quickly how to react. The situation produced by quick decisions obviously leads to great variations in what follows. In activity after 4 (narrow question) the small extent of predictability is surprising. One would expect drill-type exercises, for instance, to be particularly stereotyped. The fact is, however, that questions in accordance with category 4 are highly varied - 80 % of questions asked belong to this category. The discriminating power of the FIAC version in use with regard to the cognitive level of a question is far too modest. Stereotyped drill obviously covers only a small part of category 4.

Regarded as a whole, chains examined componentially give the same picture of the situation as does the whole material. Redundancy grows, to be sure, as we move to second order approximations, but a vital turning point in the reduction of uncertainty is reached within the distribution of categories after the specified initial state.

5.6. Redundancy in the Lumped Process

The examination of expanded process presupposes that either the material has a notably great number of transitions (e.g. 100 000 - 300 000), or a clustering of original states to new states has to be done.

For the present material the latter method, the lumped process, was chosen. Former states were combined to form new states as follows:



From the new chain formed from combined states it was possible to examine even 5-gram structure. The expected mean frequency was still 4.7 per combination, which then number 3,125.

Table 20. Transition Frequency Matrix of the Lumped Process

	1	2	3	4	5
1	1001	325	187	655	441
2	292	2615	203	270	205
3	130	186	804	362	480
4	992	233	394	1603	221
5	194	226	374	553	1713

Table 21. Transition Probability Matrix of the Lumped Process

	1	2	3	4	5
1	.38	.12	.07	.25	.17
2	.08	.73	.06	.08	.06
3	.07	.09	.41	.18	.24
4	.29	.07	.11	.47	.06
5	.06	.07	.12	.18	.56

Table 20 shows that the logical clustering of the original states has been successful, because the relative frequencies of the new states in the lumped process are very homogeneous (p_1 = .18, p_2 = .25, p_3 = .13, p_4 = .24 and p_5 = .21). The monogram distribution produces no notable redundancy, but the reduction of uncertainty remains dependent on conditional transition probabilities. From the five-state chain obtained expanded chains were formed as far as 5-gram structure.

It is observed from the digram transition probability matrix that the so-called steady-state cells on the diagonal contain very high probabilities. When a substantial proportion of the variations are homogenized in the clustering, the stereotyped nature of class instruction is emphasized more than before. Some law of continuity controls instruction directed by a teacher. Thus predictability from the dyads is strongly emphasized in comparison with the profile. Predictability has been examined in the same manner as in the original 13-state process. Here too the chain was dispersed into the chain groups following each state, in which the same examinations were made.

Table 22. Redundancy of the Lumped 5-state Chain in Total and Specified According to the Initiating State (j)

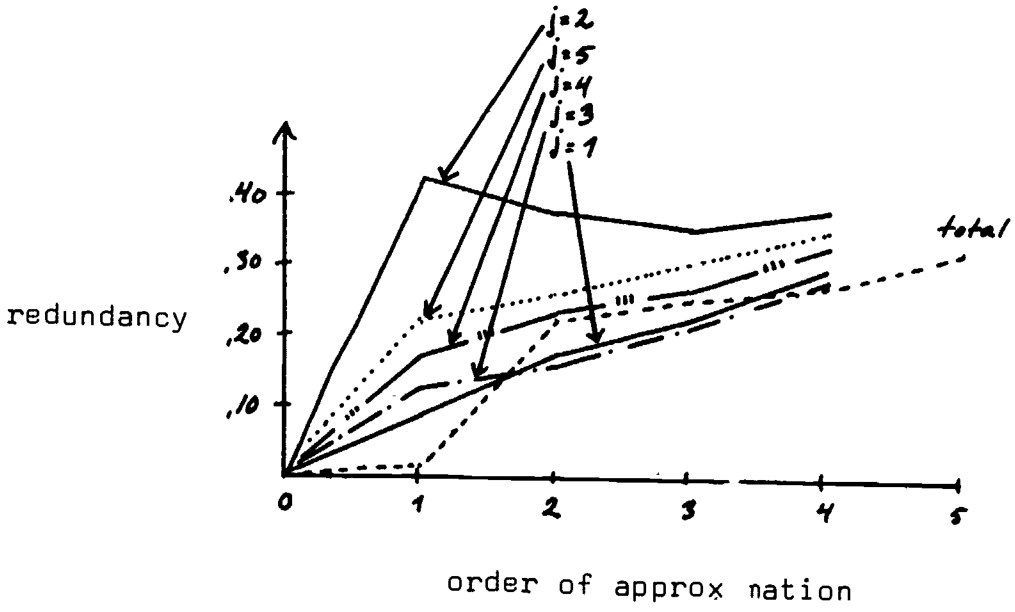
(1)	(2)	(3)	(4)	(5)	(6)
Total					
0	5	2932.0	2.32	.00	.00
1	5	2932.0	2.29	.01	.01
2	25	589.4	1.82	.22	.21
3	125	117.3	1.72	.26	.05
4	625	24.5	1.66	.28	.03
5	3125	4.7	1.54	.34	.08
j=1					
0	5	521.8	2.32	.00	.00
1	5	521.8	2.11	.09	.09
2	25	104.4	1.89	.19	.14
3	125	20.9	1.79	.23	.05
4	625	4.2	1.63	.30	.09
j=2					
0	5	717.0	2.32	.00	.00
1	5	717.0	1.38	.41	.41
2	25	143.4	1.44	.38	-.04
3	125	28.7	1.49	.36	-.04
4	625	5.7	1.41	.39	.05
j=3					
0	5	392.4	2.32	.00	.00
1	5	392.4	2.06	.12	.12
2	25	78.5	1.93	.17	.06
3	125	15.7	1.83	.21	.05
4	625	3.1	1.66	.29	.09
j=4					
0	5	688.6	2.32	.00	.00
1	5	688.6	1.91	.18	.18
2	25	137.7	1.79	.23	.06
3	125	27.5	1.69	.27	.06
4	625	5.5	1.57	.33	.07

Table 22.
(continued)

(1)	(2)	(3)	(4)	(5)	(6)
j=5					
0	5	612.2	2.32	.00	.00
1	5	612.2	1.82	.22	.22
2	25	122.4	1.69	.27	.07
3	125	24.5	1.62	.30	.04
4	625	4.9	1.50	.35	.07

(meanings of columns on page 43)

Figure 10. Relationship between Redundancy and Order of Approximation



Examination of the lumped process convincingly reveals that no important reduction of uncertainty occurs from digram to trigram structure in the material. Total uncertainty based on recognition of dyads is 1.82 bit/code. Recognition of 5-gram structure reduces this to 1.54 bit/code, but this is a phase in which the amount of material produces a spurious decline in the average amount of information. Structures of different orders of approximation from the lumped process, specified according to the starting state j of the chain (j ranging from 1 to 5), are examined in Table 22 and, with regard to the growth of redundancy, in Figure 10. The redundancy in the chains beginning from state 2 behaves exceptionally. Negative signs will be observed in the column "relative reduction in uncertainty" of the Table (Table 22; j = 2). The reason for this has been given in Section 5.5., pp. 45-48. Examining the chains which begin from state 2 (lecture), we notice that the distribution of the following states is dominated by a tendency to stay in the steady state (p_2 = .73), provided, that is, that the mon gram structure is studied with 2 as the starting state. Lecturing and giving information are, by their nature, activities which require a certain temporal continuity. The probability of leaving this state grows, however, when the number of successive 2-states increases. This is why redundancy in a case like this decreases in higher orders of approximation.

Regarded as a whole, the general impression received from the lumped process is very similar to that given by the original 13-state chain. Uncertainty is not substantially reduced if we move to higher approximation orders from the digram structure. Predictability of the course of instruction is relativelu poor, and lasts only for a average of 5-7 seconds. It should be remembered that when comparing the bit figures of column 4 in Tables 16, 17, 18, 19 and 22 the relative nature of the concept is to be taken into account. The bit figures are naturally smaller in the lumped process, because the selection is between 5 states instead of 13.

6. Discussion

6.1. On Sequential Analysis of Behaviour

Knowledge of the elements of behaviour is obtained by observation. The elements must be specified in advance by means of a taxonomy. The basis of classification may be either logical or empirical, often also a combination of both. In most cases taxonomies are deduced from theoretically derived concepts. These concepts and constructs are then operationally defined through the classification system and those indices which can be derived from it. A good example of the connection between theory and taxonomy is the IAC system of Flanders. Measurement by a taxonomy of this kind is never "objective": events are seen in the framework of a particular taxonomic solution (cf. Koort 1972). Within different taxonomies the determination of variables has been based on frequency of occurrence, duration, intensity etc. The fact that behaviour is structured makes it easier for us to predict what behavioural elements will occur in a specified environment. These elements are not in a random sequence. Some occur more frequently in temporal juxtaposition with each other than with others. Any sequence of events between which conditional probabilities exist may be called a stochastic process. The most common stochastic processes are Markov chains. In the first place four models have been used to deal with statistical dependencies between behavioural events.

The X^2 model. Many ethologists (cf. Hutt & Hutt 1970, 171) but also small-group investigators (e.g. Steinzor 1949) have tabulated observations of behaviour in the form of a contingency table. They employ the technique of calculating the expected value for each cell, using the hypothesis of statistical independence. The expected value for each cell is obtained from the ratio:

$$\frac{\text{row total} \times \text{column total}}{\text{grand total}}$$

Any "major discrepancy" between expected and observed value will give indications of affinity between the acts. Applying the simple X^2 we can define in statistical terms what we mean by a "major discrepancy". Thus this type of analysis forms a valuable initial step in studying the dependencies amongst sequences of behaviour.

The factor analytic model. This is the model employed in various parts of this study. Wiepkema (1961) was one of the first to demonstrate the possibilities of factor analysis in this field. Later Coats, Gess, Soar and the present writer have all independently applied factor analysis to study of the interaction matrix (cf. Flanders 1970, 412-413). The model gives a highly promising opportunity to form the variables of a lesson. Further study must be directed to the examination of the validity of the variables.

The informational model. The previous models make use of the digram structure of behaviour. The indices of mathematical communication theory enable us to examine the connections of longer state chains. The model holds a central position in the present study. Such exhaustive analyses were made because in the works of researchers using FIAC or similar category systems there is some indication of models based on transition probabilities, Markov chains in particular. It seem probable, however, that such models do not open new possibilities for the formation of variables.

The phrase structure grammar model. It has been questioned whether Markov processes are the most appropriate model for the comprehensive description of behaviour. It has been suggested that models derived from psycholinguistics might be particularly worthy of study. For instance, Miller et al. (1960) have stressed the role of plans directing the behaviour. Elsewhere Miller (1962) gives a graphic example of the determination of syntactic structure. The article by Miller (1962) together with a short monograph by Chomsky (1957; cf. also Chomsky 1964) provide an adequate introduction to the subject. According to available information only Marshall (1965) in reanalysis of the material of Fabricius & Jansson (1963) has used generative grammar for the formal analysis of structured behavioural sequences. A phrase structure grammar is then composed which is capable both of generating the requisite behaviour patterns and of representing the hierarchical organization of these patterns. The strength of this model lies in its ability to deal with a considerably greater behavioural repertoire and much longer sequences than can be treated by Markovian processes alone. No applications to classroom communication are known. To what extent the determination of variables by this means becomes fruitful, is a matter which remains to be seen.

6.2. Some Critical Points of View

Stationary vs. non-stationary sources. Mathematical communication theory can be applied to situations in which organism adopts a reasonably stable course of action that can be described statistically. Statistical stationariness means that if the observer watches the sequence for a very long time T, the relative frequency estimates p(i) of the various signs he makes will not depend upon the actual moment of starting, i.e.

the statistical properties of a stationary source are invariant under a shift of the time origin. This assumption of stationariness is normally required in statistical communication theory, and is one of its present limitations. This is one of the main obstacles to the application of the theory to human interactive behaviour (Cherry 1966, 179).

Delayed constraints. There remains one interesting question. To what extent does behaviour in the classroom communication network depend upon any particular past event independent of intervening more recent past events?

Crossing constraints. The time order of events is not always their logical or true succession. During the instruction process an interruption occurs (e.g. a spontaneous, irrelevant pupil suggestion), and the interrupted sequence continues perhaps after three or four acts. Similarly, and especially during lessons containing periods of individual guidance, a crossing interaction is noticeable whose time succession does not correspond to the logical or intended succession. In a long chain this may be considered a random phenomenon whose divergences will balance out before long. There are some clearly recognizable situations, however, in which the occurrence of such crossing successions is more frequent than usual.

Non-Markovian constraints. Chomsky (1957; 1964) has shown that certain types of constraints that occur in human communication cannot be generated by any left-to-right finite state Markov chain. The existence of nested grammatical structures in language implies that the individual's present behaviour is based upon his plan for future behaviour and on his prediction of the behaviour of the other members of the social group (altmann (1965, 519). Observation of redundancy does not tell us what factors cause statistical dependence in the chain. The goal is certainly one of the explanatory frame factors which steer the process of interaction. In its further investigations the Helsinki IPA research group has paid vigorous attention to the goal-oriented nature of instructional situations. By way of preliminary experiments during the autumn term of 1972 a series of instructional periods was held in the school class of the Institute of Education, University of Helsinki; the first phase of this consisted of joint planning within a framework defined by the teacher. Planning is directed both to aims and modes of work (Koskenniemi (1972a).

Generality vs. uniqueness. A comment by Cherry will serve as introduction to the problem:

> "The gathering of monogram and digram statistical data involves an immense amount of labour, and with trigram, quadrigram and so forth this becomes increasingly prohibitive; lest the reader should feel that we are merely quibbling and avoiding a point of principle, that given time, patience, unlimited cash and computing machines we could collect 10-gram or 100-gram word transition probabilities of Shakespeare's writings, the following point should be stressed. The limitation is not mere labour of letter or word counting: it is the fact that there are not enough books. The data gathered would not be statistical; they would be Shakespeare's actual lines and verses, for each sequence would occur only once" (Cherry 1966, 40; underlining by the present author).

The problem is how to examine the classroom communication in our obviously similar present-day conditions. Coded with a 13-category instrument for tally/3 seconds, chain variations of one minute duration may occur to the number of about 1.9×10^{22}. Here too, however, the purpose of measurement is to produce variable values which will indicate essential features of the instructional situation, not to reproduce the original sequence of behavioural events in numerical series.

Variables which are too general have not proved useful, as Landsheere (1971) indicates in his criticism of research on instruction. In my view the factor-analytical approach offers a fruitful starting point for the formation of variables from sequential behaviour: superfluous uniqueness is removed, and, on the other hand, over-simplifying generalization is avoided of the dimensions of classroom communication.

A note on research strategy. In the last few years there has been a spirited debate on the strategy followed in the research on teaching. This was started by Stolurow (1965), and it has led to discussions on active vs. passive or improving vs. descriptive approach. Both trends have their supporters. Ebel (1969) argues that we should gather data which describe the present state of education and then let experience, reson, dialogue and consensus - rather than controlled experimentation - guide us to educational improvement. As Gage and Unruh put it:

> "The long-range assumption of describers is that once important correlates of teacher effectiveness in the present-day classroom have been ascertained, it will be possible to train teachers to be more effective. They take the conventional classroom as given, and seek to improve the behaviour of the teachers in it" (Gage and Unruh 1969, 4).

Jackson (1966), Bellack (1966), Smith and Meux (1970) etc. also start with a "passive" approach. The improvers, taking an "active" approach, attempt rather to master the teaching model, i.e. to develop a new model of instruction that will make explicit the manipulable elements and relationships needed to optimize learning. Experimentation will correct and refine the model (Gage & Unruh 1969, 5). The ideas of active approach supporters are compressed by Travers as follows:

> "Useful knowledge about the conditions that are related to learning is not likely to be derived from the observation of naturally occurring teaching situations. A much more profitable approach is to construct genuine laboratory experiments involving classroom-like situations, but with a much higher degree of control over experimental conditions than was found in some of the older forms of educational experiment that compared method A with method B. Once the study of teaching has developed techniques that approximate those of an experimental science, the difficulties at present associated with the widespread usage of ill-defined terms ceases to exist" (Travers 1971, 39).

The tendency to move from correlative to experimental designs is seen with other researchers who have a more moderate attitude to the subject (e.g. Flanders 1970; Nuthall 1970 and 1972). It should be borne in mind, however, that the approaches presented here are not opposed to each other because they produce different kinds of information. There should be no orthodoxy in this matter. Both should have a place in the field of research on teaching.

6.3. Continuation of Study

I mention here two directions in which I intend to continue research into the instructional process. The necessary material has been collected, but analysis and reporting are not yet completed. For reasons of space the following introduction is merely schematic.

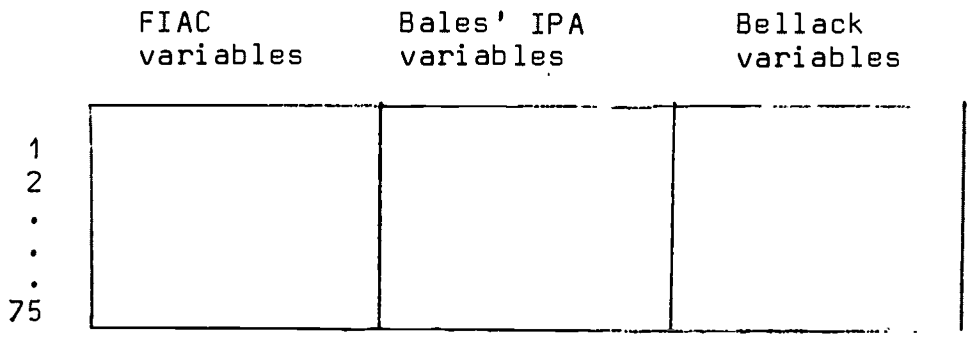
Plan A. At the Institute of Education, University of Helsinki, the classroom behaviour of the same set of pupils was followed up for two academic years (1969-71) during class instruction lessons in different subjects. Analyses were made by a modified 23-category subscripted FIAC system, which can, if required, be reduced to the regular ten categories (Flanders

1966; 1970, 126-152). Independently of the above, the same lessons were analyzed by Bales' IPA (1950) and a slightly modified version of the coding system developed by Bellack and his associates (Bellack et al. 1966; Karma 1972). The aims are:

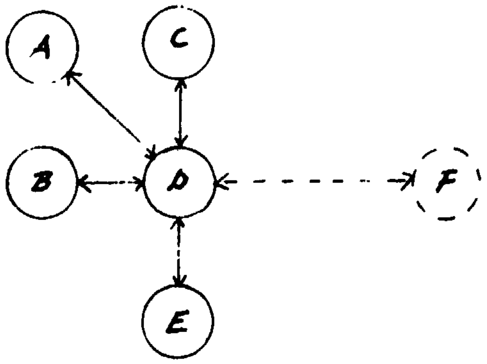
(1) To recapitulate with more extensive material the factor-analytical and information-theoretical examinations which have already been performed.

(2) To perform an examination between taxonomies in order to formulate more precisely the validity of the sequence factors within the context offered by other taxonomies.

The data matrix to be analyzed is the following:



Plan B. In autumn 1971 a new form of entrance examination was set up for the selection of elementary school teacher candidates. In this connection a research team led by Associate Professor Alikoski gathered a considerable body of information on the applicants. Most of this had no effect on the composite entrance requirement score on which selection was based. As a new instrument of selection a so-called teaching episode was used for the first time, replacing the "instruction test" used in earlier years (cf. Koskenniemi et al. 1965, 553-556). The teaching episode was about 10 minutes in length, the pupils were from the fourth grade, and the theme of instruction with necessary material was given to the candidate an hour in advance. Performance was rated in three dimensions by three independent judges. The teaching episode had considerable influence on the variance of selection scores. The present writer arranged stereo voice recordings of all the teaching episodes performed by applicants for the Helsinki Teacher Training College. These were analyzed by the 23-category subscripted FIAC system and the Bellack system. One hundred and sixty persons took part on the entrance examination, and half were allowed to continue their studies in the training institute. The aim now is to follow the studies of those admitted by obtaining similar information on the final phases of their training in the spring term of 1974. This study is correlative, chief attention being directed to connections between process variables (behaviour measured by teaching episode) and other groups of variables. Material has been collected for the first phase. Groups of variables for this study are as follows (cf. Sandven 1967):



(A) Personal data, earlier teaching experience etc.

(B) Ability, attitude and personality variables

(C) Committee's appraisal of teaching episode

(D) Teaching episode: FIAC, Bellack

(E) Candidate's own perception of teaching episode

(F) Possible follow-up in final phase of training

In the further study which is here introduced, and whose details cannot be elaborated for reasons of space, use will be made of the data on formation of variables which were obtained in the present study.

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Appendix 1.

The Classification System Employed

	(1)	(2)	
Teacher talk	1	1	Accepts, praises or encourages
	2	2	Corrective feedback
	3	3	Uses pupil ideas
	4	4a	Asks narrow questions
	5	4b	Asks broad questions
	6	5	Gives information or own opinions
	7	6	Gives directions
	8	7	Criticizes pupil behaviour
Pupil talk	9	8	Answers a question
	10	9a	Relevant spontaneous talk
	11	9b	Irrelevant spontaneous talk
Others	12	10	Silent work, individual work, guidance
	13	Z	Confused situation

(1) Symbols of categories employed in this report

(2) " " " " " previous reports

Appendix 2.

Structural Deviations for Corresponding Variables between Analyses, Indicated as Squared Distances between Vectors

(cf. Section 4.2.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	.09	.09	.19	.09	.06	.06
2	.10	.08	.24	.11	.15	.22
3	.12	.11	.21	.03	.22	.18
4	.12	.25	.43	.05	.11	.04
5	.06	.05	.05	.03	.08	.06
6	.06	.03	.07	.05	.07	.04
7	.20	.14	.35	.08	.06	.10
8	.13	.24	.29	.04	.08	.08
9	.06	.12	.09	.02	.03	.02
10	.08	.12	.30	.04	.17	.09
11	.01	.27	.51	.31	.56	.05
12	.02	.03	.11	.05	.12	.03
13	.24	.20	.32	.11	.06	.05
14	.07	.13	.25	.09	.18	.04
15	.03	.06	.18	.01	.12	.14
16	.23	.28	.28	.04	.12	.11
17	.04	.13	.18	.05	.10	.05
18	.03	.01	.04	.04	.08	.01
19	.03	.12	.24	.06	.11	.08
20	.07	.10	.29	.08	.21	.09
21	.12	.15	.21	.02	.06	.04
22	.11	.13	.18	.07	.09	.04
23	.07	.11	.29	.02	.14	.11
24	.35	.23	.32	.10	.23	.06
25	.03	.16	.24	.19	.16	.14
26	.10	.28	.21	.09	.10	.14
27	.10	.12	.20	.13	.16	.03
28	.02	.19	.17	.12	.11	.05
29	.04	.04	.08	.08	.08	.07
30	.26	.10	.09	.36	.28	.04
31	.06	.01	.06	.07	.04	.06
32	.09	.11	.15	.07	.11	.05
33	.05	.11	.11	.03	.04	.01
34	.14	.21	.21	.07	.22	.20
35	.06	.13	.34	.12	.17	.24
36	.04	.16	.19	.18	.25	.03
37	.04	.06	.16	.04	.18	.06
38	.13	.05	.50	.07	.37	.40
39	.09	.03	.05	.04	.03	.01
40	.01	.04	.06	.03	.04	.02

Appendix 2.
(continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
41	.08	.11	.12	.11	.20	.04
42	.04	.10	.44	.06	.31	.28
43	.04	.15	.20	.12	.09	.07
44	.03	.08	.16	.07	.13	.05
45	.09	.22	.36	.05	.19	.07
46	.09	.16	.27	.04	.15	.06
47	.11	.17	.14	.16	.04	.10
48	.04	.12	.13	.06	.15	.12
49	.16	.21	.31	.39	.33	.10
50	.06	.12	.05	.10	.03	.04

Columns are:
(1) = Number of variable
(2) = Structural deviation of the variable between analyses 1 and 2
(3) = " " " 1 and 3
(4) = " " " 1 and 4
(5) = " " " 2 and 3
(6) = " " " 2 and 4
(7) = " " " 3 and 4

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