A SYNTACTIC APPROACH TO THE ANALYSIS OF NONVERBAL BEHAVIOUR *E*

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1.INTRODUCTION

In the field of nonverbal communication, it is convenient to discriminate between what are known as the structural and the external variable approaches. This was pointed out in a review article by Duncan (1969). Generally, the structural approach involves examination of the relationships amongst the observable behavioural levels and elements, whereas the external variable approach is based on a general statistical description of a situation. This paper is concerned with application of the structural approach. This approach to social interaction has recently been given increased attention in the fields of ethology and social psychology. Accordingly, various rule-following models have been proposed for the description of social interaction (Scheflen, 1967; Cicourel, 1974). The application of such an approach to nonverbal behaviour was also proposed by Birdwhistell (1970) in his linguistic analogy. Although this proved cumbersome to many, the concept of a syntax of behaviour has remained of interest and has been examined by a number of authors.

Almost inevitably, empirical studies of behaviour rely on the acquisition and analysis of observational data sequences. The general problem of behavioural sequence analysis was reviewed by Slater (1973), who discussed the more conservative approaches involving descriptive statistics and Markov chain analysis and commented on their limitations. In principle, Markov chain analysis must be considered a structural approach. However, recently more advantage has been found in structural models of a more complex nature. Dawkins (1976) discussed a number of approaches, emphasising the importance of the concepts of hierarchical organisation and sequential ordering of behaviour, again pointing out the disadvantages of Markov chain analysis. In the field of ethology, various authors have discussed grammatical models, including Westman (1977), who proposed a grammatical model for the animal in its complete environment. Recently, Duncan & Fiske (1977) described a structural approach to social interaction, drawing from the idea of rule-governed sequences of turn-taking.

The concept of rule governed behaviour has been dealt with perhaps most thoroughly in the various fields of linguistics, e.g. in the speech act theory of Searle(1969) and, of course, in the earlier work of Chomsky (1963) by rules of syntax.

The approach outlined in this paper draws from the two basic concepts of rule-governing and hierarchical organisation of behaviour. It therefore involves implications about the regularity of behavioural sequences and their rules of syntax. That is to say, beyond a taxonomy of behavioural units yielding statistical descriptors of frequency, duration, etc., the question is raised as to whether observed behavioural sequences can be described by structural rules. It is maintained here that social interaction may be conceived of as involving, on the one hand, such factors as situational conditions and the participants' understanding of the role imposed on, or adopted by them in the situation; and, on the other, by internal states such as arousal level and mental capacity of the participants. The influence of these factors is then understood to determine the framework of rules according to which the behaviour in the situation is governed. Following the assumption of hierarchical organisation the effect of the situation should be reflected to some extent at all levels of social behaviour.

RESTRICTIONS OF MARKOV TYPE MODELS

Despite their widespread use in the analysis of sequential data, there exist a number of restrictions to the application of Markov type models. These may be divided into those of a technical-statistical nature and those of a theoretical or principle nature. Considering the statistical restrictions, the application of a Markov model requires that the data be stationary, or homogeneous across time. This condition is generally overlooked, rarely checked and very often difficult to verify where many factors affect the observed behaviour.

Furthermore, the amount of data required for the verification of higher order dependencies increases geometrically so that it becomes questionable as to whether this can be realised. These conditions are compounded in such a way that the one often excludes the possibility of fulfilling the other. There do exist approaches to these problems, which involve, basically, segmenting the data into two or more parts and then testing for shifts. However, they involve substantially more effort and appear to be seldom applied to empirical data. In his review, Slater (1973) cites only two cases where rough tests were made. 2) These methods have been formulated recently by Castellan (1979). In those cases where stationarity cannot be verified, or reasonably assumed, the Markov analysis cannot be taken very far. (It is very likely that the nonstationary nature of the data itself is relevant!)

A further technical difficulty, which was also found in our own analysis, arises when expected probabilities are to be calculated. It is not always possible to formulate adequately a formal model, particularly in those cases where conditional probabilities are taken into consideration.

The Markov model is also limited in that such mechanisms as recursion, self-embedding and right to left dependencies(dependencies of present events on future events) cannot be adequately covered. Such mechanisms are of interest when plans of behaviour, anticipation, etc. are to be taken into consideration.

The second type of restriction, which is ultimately of more importance concerns the theoretical considerations associated with the application of the model rather than the model itself.

Firstly, the Markov model and transition frequency analyses take into consideration only the observed behaviour without requiring information or examination of the underlying mechanisms. Although these approaches do not exclude such questions, the danger arises that the analyst may forget the true complexity of the examined phenomena and adopt the simplicity of the model as an adequate description.

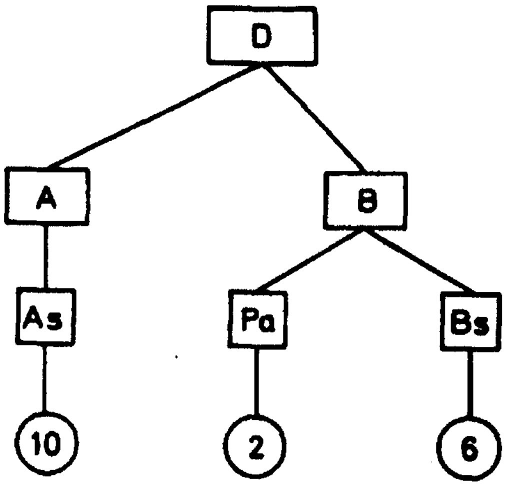
There is little question that observational data can often be found to exhibit Markov properties, in the general sense that sequential dependencies can be determined. Of importance, however, is that the Markov model does not allow one to go far enough regarding the complexity of the structures underlying the observational data.

As mentioned earlier the structural approach to psychological and ethological phenomena, whereby the concepts of rule following and hierarchical organisation play major roles, demands a more suitable model for the empirical data.

GRAMMATICAL MODEL

Within the context of social behaviour, the significance of sequential coordination of speech and gaze behaviour has been variously recognised (Kendon, 1967; Argyle & Cook, 1976).

The data analysed by the present authors were obtained from continuous binary coding of speech and gaze during dyadic interaction. This yields four channels of binary data, which are stored together with the points in time at which events occur on each channel. The four binary channels deliver a behavioural repertoire for the dyad containing sixteen mutually exclusive states or elements. The sequences of these elements represent the data which have been analysed by the proposed method. The main purpose of the structural, or syntactic approach is to describe the process of interaction and the relationships amongst the observed behavioural aspects. A simple tree derivation is shown in Figure 1 for a string of three behavioural states, or elements. The relationships between the hierarchically ordered terminal and nonterminal elements are defined by the accompanying rewrite rules.



D → A B

A → As
B → Pa Bs

As → 10
Pa → 2
Bs → 6

Figure 1: A simple tree derivation for a string of three terminal elements.

Thus, a dialogue exchange (nonterminal: D) can be rewritten as consisting of the floortime, or turn, of participant A (nonterminal: A) and the turn of participant B (nonterminal: B).
Similarly, the turns of each participant can be rewritten as required, as consisting of those states during which the participant actually speaks (As, Bs) and as pauses (Pa). These states can then, in turn, be rewritten as terminal elements (for the example shown: 10,2,6).

In terms of Chomsky's hierarchy of grammars, the first order Markov chain is equivalent to a Type 3 grammar. In light of the limitations of this model which have been described, it was decided to use the more flexible Type 2 grammar as a basic model. As a formal model, a probabilistic grammar based on a Chomsky Type 2, or phrase structure grammar has been explored. Thus, for each analysed episode, the interaction is described by means of : a repertoire, or terminal vocabulary of behavioural states, a structural description in the form of a set of rewrite rules, and a set of probabilities, associated with the frequencies of occurrence of each of the rewrite rules.

A probabilistic grammar was selected as a model following the assumption that the observed strings of behavioural states represent ′noisy images′ of ordered structures. Accordingly, the behavioural sequences are generated on a grammatical level and the inevitable deviation which is present in the observational data can be described on the probabilistic level (Grenander, 1969).

The grammars are constructed in practice according to the following criteria:

1. The behavioural repertoire is defined by the 16 possible combinations of the binary coded speech and gaze of the two participants. These mutually exclusive behavioural states are taken as the terminal syntactic elements.
2. It is assumed that the observed strings of syntactic elements can be described by the rewrite rules of a suitable grammar. The observed strings thus represent the basic units of analysis.

With social interaction, it has been found more suitable to define the unit of analysis as an exchange between participants, in contrast to the unit of analysis with grammars of natural languages, which is the speech act or sentence.

3. For each of the rewrite rules of the grammar a probability can be estimated. After establishing the tree derivations for all of the observed strings in the episode, the necessary rules and their probabilities can be determined. The frequencies of occurrence of the observed strings during the episode thus yield the total frequencies with which each rewrite rule is required. These frequencies can be used, in turn, to estimate the probability of each rewrite rule. The procedure used in practice is maximum likelihood estimation.

A probabilistic grammar (Levelt,1974: 34-55) can be constructed for each analysed episode according to these criteria. Such a grammar includes a terminal vocabulary (Vt) corresponding to the observed behavioural repertoire, a nonterminal vocabulary (Vn) consisting of structural units of higher order, and a set of rewrite rules (P), to which a probability measure (p) is allocated.

DISCUSSION

In the present study, the application of such concepts as rule governing of behaviour and hierarchical organisation of behaviour has been proposed for the description of the process of social interaction. In this sense, the observed levels of behaviour are assumed to be hierarchically closely linked. A similar description has been proposed by Harre & Secord (1972) in the act/action/movement model for social behaviour. Pursuing this argument, it should be possible to derive a set of rules to describe the structural relationships which are ultimately reflected in the observed stream of behaviour.
It would appear that, according to the statistical and theoretical restrictions discussed, the Markov type model is inadequate but for description of the simplest behavioural situations. Generally, the possible structural relationships and hierarchical organisation of behavioural sequences can only poorly be considered with this model.

On the other hand, the proposed model emphasises the importance of syntactic rules and the description of underlying structural relationships.
The probabilistic grammar delivers quantitative measures of the syntactic properties of the situation and therefore provides a basis for statistical testing of structural differences in social interaction. One shortcoming is perhaps that the grammars deal only with the sequential features of the observed behaviour and neglect state durations. This can be overcome either by taking a fixed sample rate during observation and thus introducing null transitions, or by allocating to each behavioural state the statistical descriptors relating to its distribution function. These descriptors could then be incorporated into the grammar as attributes of the respective terminal element.
The approach outlined corresponds to the research strategy recently proposed by Duncan & Fiske (1978), where it is argued that both structural and statistical aspects of the interaction process ought to be taken into consideration. The features of the probabilistic grammar, namely, the behavioural repertoire, the structural description, and the probability measure enable the determination of structural changes in the interaction process, both for situational and role dependencies. On the basis of these features, various measures can be obtained. For example, a quantitative comparison can be made between interaction samples by determining the changes in rule probabilities. Further, the symmetry of interaction, as it is manifested in the observed behaviour, may be calculated from the probabilities of complementary rewrite rules

within one sample. This may be understood as an expression of the dominance relationships between the participants.

However, the most important feature of the grammatical model is the possibility of extending its various features, for example, by including additional rewrite rules, appending the vocabularies, or allocating attributes to the terminal elements. This permits flexibility in matching the model to the phenomena in question.

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NOTES

1. The work reported here was supported by the Deutsche Forschungsgemeinschaft, Antrag El 67/1.

2. The same problem is encountered in spectral analysis of physiological signals where both measurement resolution and short sample time are required. The main author has examined practical solutions to this dilemna and used similar tests for EEG analysis (Clarke, 1975).

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