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How Do Normal Subjects Learn a Simple Adaptative Task: How and Why Do Paranoid Schizophrenic Patients Fail?*

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Summary. The authors studied the behavior of normal subjects and paranoid schizophrenic patients in a simple problem-solving situation. The schizophrenics were divided into two sample groups, one of individuals under treatment and the other of individuals not under treatment.

The learning process involved in this problem-solving situation is very similar to an instrumental conditioning, and can be understood by means of the following assumptions: (1) the subjects use decision functions in reacting to the stimuli, although they may be not fully aware of this; (2) learning is the result of successive transformations of these decisions in the course of time; (3) the changes have specific probabilities and are related to (a) those responses which are made to the latest stimuli, and (b) a differential probability for decision functions which were effective, or only interrupted painful reinforcement, or were completely ineffective.

In schizophrenics further factors of importance were (1) an 'inertia' factor and (2) the rigidly continued use of unsuccessful or only partially successful decision criteria.

The authors used a systems theory based on Galois field theory and a calculus of operators specifying three groups of subjects. A computer program based on these hypotheses was tested in a simulation experiment.

The statistical evaluation of the results showed a congruence between the theoretical approach and the experimental data.

Key words: Paranoid schizophrenia – Cognitive processes – Problem-solving – Cybernetic model – Computer simulation – Generation of time sequences.

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Zusammenfassung. Die Verfasser untersuchten das Verhalten in einer einfachen Problemlösungssituation bei Normalen und bei paranoid Schizophrenen. Die Schizophrenen wurden in zwei Gruppen eingeteilt, eine unter Behandlung und eine zweite ohne Behandlung.

Der Lernprozeß dieser Problemlösungssituation ähnelt einer instrumentalen Konditionierung und kann verstanden werden mit folgenden Voraussetzungen: 1. Die Probanden benutzen Entscheidungsfunktionen für ihre Reaktionen auf Reize, obwohl sie ihnen nicht völlig bewußt sind; 2. das Lernen ist ein Produkt von aufeinanderfolgenden Transformationen dieser Entscheidungsfunktionen im Verlauf der Zeit; 3. diese Veränderungen haben spezifische Wahrscheinlichkeiten und betreffen a) jene Antworten, die bei den letzten Reizen vorkommen, und somit b) eine differentiale Wahrscheinlichkeit für Entscheidungsfunktionen, die effektiv waren, oder nur schmerzhafte Verstärkungen unterbrechen, oder völlig ineffektiv waren.

Weitere Faktoren bei Schizophrenen waren 1. ein "Inertia"-Faktor, 2. die starre Fortsetzung von erfolglos oder nur teilweise erfolgreichen Entscheidungsgesetzen.

Die Verfasser verwenden einen Algorithmus, der auf einer Operator-Algebra und der Theorie der Galois-Felder basiert zur Bestimmung von drei Probanden-Gruppen. Ein entsprechendes Computer-Programm wurde in einem Simulations-Experiment getestet.

Die statistische Bewertung der Experimente ergab eine Kongruenz zwischen den experimentellen Daten und der theoretischen Betrachtungsweise.

Schlüsselwörter: Paranoide Schizophrenie – Kognitive Prozesse – Problemlösung – Kybernetisches Modell – Computersimulation – Zeitfolgeentstehung.

Introduction

This study is an attempt to understand a particular type of behavior of human subjects, not by means of an 'extensional' approach which would aim to specify couples of 'stimuli' and 'responses,' but rather in terms of *decision functions* and probabilistic *transformations* of such decision functions in time.

We tried an approach which allowed us, within a certain set of assumptions, to predict the behavior of the subject. For that purpose we started our investigation using a theoretical analysis we had made previously with Jose Mira, of the concepts of 'intention' and '*signification.*' As a first step we tried to clarify the operational definition of the concept of 'intention of nerve nets.'

Such nets can be considered as devices which process information about the environment received by means of 'receptors,' and use such information together with the present state of the net to produce, on the one hand, a mapping of the state of the environment in terms of the next internal state of the net, and on the other hand, the next output of the net. Thus, the formulation of the concepts of signification and intention is simple.

Let us term the state of the net at instants t and $t+1$ S_t and S_{t+1} respectively. Similarly, the state of the output at instants t and $t+1$ will be termed Y_t and Y_{t+1}, and the state of the input at instant t will be termed χ_t.

The behavior of such a system will be prescribed by the relationships:
$S_{t+1} = TS_t + U\chi_t$
$Y_{t+1} = AS_t + B\chi_t$
where T and U as well as A and B are transformation matrices.

If, as we said, the system processes information about the environment received as an input, together with a mapping of the environment in the form of an internal state of the net, the concept of *signification* will correspond to the pair of matrices T and U, and the concept of *intention* to the pair of matrices A and B. These two pairs of transformations *implement the decision rules acting on the vectors* S_t and χ_t, producing S_{t+1} and Y_{t+1} respectively.

In this context, a *learning process will be represented by an operator L which acts on T and U and transforms them into decision functions T′ and U′*, taking into account past experience, and *an operator L′ which acts on A and B and transforms them into decision functions A′ and B′*.

This approach is based on a particular branch of systems theory in which operations are specified with the following algebraic structures: *a basic Galois field structure,* (the field of scalars), *a vector space,* which includes all possible vectors χ_i, S_j, Y_k, and an algebra of operators A, B, T, U, . . .

It was hoped that with the help of these postulates: (1) empirical data and concepts of psychologic and psychiatric theory could be used as a basis for formulating theoretical concepts; and (2) it might be possible to find a rigorous formulation which could be used in the still more difficult domain of 'social relationships' [11].

Piaget's *INRC* group of transformations is a particular case of the transformations L or L' of matrices T, U, A, B. This is not very surprising, because T, U, A, and B, together with S and χ, define logical functions, and operators L and L' define their transformations, as with the transformations *INRC* of Piaget, but with the distinction that Piaget has used purely extensional logic.

In an experimental situation of problem-solving, analogous to an instrumental conditioning, we did not use single stimuli, but classes of stimuli. Each stimulus involved simultaneously more than one variable.

The data we obtained showed that subjects could rapidly learn the defensive strategy which allowed them to avoid painful stimuli, and also that most of them were able to define verbally the *Boolean function specified by those visual stimuli which would be followed by punishment if the subject did not press the appropriate key.*

These results led us to a reinterpretation of a much simpler situation, to the statistical characterization of the responses, to its computer simulation, and finally to the establishment of its generative mathematical function in the form of a time equation. In this case the situation was also one of problem-solving, of a quasi-instrumental conditioning type, but the stimuli were of only two types—a yellow flash of light which would never be followed by an electric shock on the wrist, and red flashes of light which would be followed by an electric shock if the subject did not press a certain key of the three keys on the table in front of him. Flashes of light illuminated a translucent screen placed in front of subjects.

One of the three keys looked very different from the other two, to simplify the task of the subjects and the analysis of data.

Set was established by means of three instructions given after the subjects were seated in front of the screen.

Each experiment was interrupted if the subject was able to avoid electric shock five times in succession, or if more than 75 stimuli of each kind, yellow and red, had already occurred.

Our hypothesis was that each manipulation of the keys corresponded to some decision by the subject. When the next decision was taken the subject would react not only to the visual stimulus but also to some aspects of his memory of the decision he had made to the previous stimuli and of the success of that decision. He could then transform his immediately preceding decision into a new one and act on it. The formalization detailed above will in this context be adequate to describe and predict events, if we take into account the probabilistic laws of such transformations of the decision functions one into another. It should be noted that in our analysis we made state variables coincide with output variables.

Material and Methods

Fifteen normal subjects were submitted to the experimental investigation described above. The normal subjects were university students or graduates, a few with a minimum of 9 years of higher education. They collaborated in the test as volunteers and were submitted to a battery of tests which included the Wechsler-Bellevue Intelligence Test, T.A.T., and M.M.P.I. All of them were interviewed. In our sample only one of the normal controls had a slight deviation in one of the scales of M.M.P.I., without clinical counterpart. This subject had never sought medical help.

In accordance with the hypothesis that cognitive disturbances might uncover crucial aspects of cognitive processes difficult to observe in normal subjects, we also studied 15 paranoid schizophrenic patients under therapy, and 10 paranoid schizophrenics who had not been under therapy for at least 48 h before the beginning of the test. Paranoid schizophrenia was diagnosed using strict clinical criteria involving the presence of primary delusions, and in most of the cases symptoms of 'first rank' as described by K. Schneider. In none of the patients had the disease reached a chronic stage. All of them have now left our psychiatric clinic and many are working in different jobs or even studying.

A control subgroup of patients was formed with a mean IQ value higher than the mean IQ value in the group of normal subjects.

Results were analyzed using Student's *t*-test when the sample did not deviate significantly from normal distribution in skewness and kurtosis tests. When it did deviate, nonparametric Mann-Whitney's *u*-test was used.

Only those subjects who made at least one active attempt to solve the problem by pressing a key were retained for comparison. Values were taken in the form of a ratio between the number of occurrences of each event and the total number of trials of each subject.

One of the three keys looked very different from the other two and was not relevant for avoidance of punishment. That key was pressed by schizophrenic patients in only 4.73% of the total number of decisions. Normal subjects pressed it in 13.9% of their total number of decision functions.

For the sake of simplicity the pressing of that key and the pressing of the other key which also did not allow avoidance of punishment were grouped together.

Given the experimental design and rules of encoding, pressing the key which would allow avoidance (or interruption) of punishment was denoted by D, and not pressing it by $\bar{D}$, pressing either of the keys which would not affect punishment was denoted by E and not pressing them by $\bar{E}$; occurrence of punishment was denoted by R, avoidance of punishment by $\bar{R}$. The six possible combinations of response and reinforcement were:

$\bar{D}\bar{E}R$ or 001—to be understood as: "decision to press no key, followed by pain."

$\bar{D}ER$ or 011: "decision to press only an 'E' key, followed by pain."

DER or 111: "decision to press both the 'D' and an 'E' key, followed by *interruption* of pain."

$D\bar{E}R$ or 101: "decision to press the 'D' key, but not an 'E' key, followed by *interruption* of pain."

$D\bar{E}\bar{R}$ or 100: "decision to press the 'D' key, but not an 'E' key, resulting in *avoidance* of pain."

$DE\bar{R}$ or 110: "decision to press both the 'D' and an 'E' key, resulting in *avoidance* of pain."

Note that $D\bar{E}R$ and $D\bar{E}\bar{R}$ (and DER and $DE\bar{R}$) differ in that in the first case the 'D' key is pressed more than 5 s after, and in the second case less than 5 s after, the beginning of visual stimuli. This type of encoding was chosen because pressing two different keys is a possible action which is at a "Hamming distance" of 1 from pressing only one of those keys. On the other hand, pressing the same key before and after 5 s from the beginning of the visual stimulus are incompatible movements. If they were encoded using two places, one for D before and the other for D after, this would produce a Hamming distance of 2 between two successive responses and it seems more reasonable, from the behavioral viewpoint, to say that there is a single difference between two responses such as $D\bar{E}\bar{R}$ and $D\bar{E}R$.

We made the following assumptions:

(1) Each act was considered as depending on a decision on action which implied a prediction concerning reinforcement.

(2) Each decision on action was considered as depending on a transformation which always took into account the two preceding decisions. Iterative repetitions were considered as depending on an arbitrary weighing introduced by means of a decision factor which takes into account the length already attained by the iterative sequence.

(3) Each decision of action was defined not as a state, but rather as a Boolean function of the variables D, E, and R. Concerning past events, the value of R describes reinforcement; concerning the next function, it specifies the timing of the decision.

Each decision function f_j was considered as obtained from the preceding function f_i by means of an operator T_i such that $T_i\, f_i = f_j$.

(4) Transformations of decision functions were in general nondeterministic, in the sense that in a given instance:

$T_i\, f_i = f_j$ and later transforms to

$T_i\, f_i = f_j \neq f_k$

(5) To each possible transformation is assigned a probability of occurrence.

We also developed an alternative approach which aimed to make the indetermination vanish by means of intervening variables. Results will be reported elsewhere.

The set of hypotheses and assumptions described is a development of the theory of neural nets initiated by McCulloch and Pitts [1] and takes into account the viewpoints introduced by Simões da Fonseca and McCulloch [9] and Simões da Fonseca et al. [10].

The complexity of the relational structure needed to produce samples with the same 'fine grain' structures as 'real individuals,' gives an indication of how much value may be attributed to theories which attempt to derive the abnormal behavior of schizophrenic patients from a single factor, be it 'selective attention' [2, 3], 'motivation' [5], 'loss of purposiveness' [6], or 'delusional perception' [7].

The situation we have chosen and the method of interpretation we used allows us to treat the behavior of subjects as a consequence of *an intention to control a situation of interaction with the environment*, concomitantly with the process of understanding the *signification* of the stimuli of the environment (as well as of the *intention which lies behind the production–or else the occurrence–of those stimuli in the environment).*

It is in this frame of reference that our experimental set-up meets the theoretical approach in terms of signification and intention, with learning treated as dependent on transformations of decision functions, in the context of the algebraic operational theory of discrete systems.

Results and Discussion

1. Responsiveness to Reinforcement: Single Transformations

By single transformations we mean transformations T between two successive decision functions, such that $T{\cdot}f_i=f_j$, where f_i and f_j are successive decision functions.

We analyzed the probabilities for single transformations involving no change, one change, or two changes in the decision function, and we compared the mean probabilities from each subject group when the stimulus would be followed by reinforcement and when it would not be followed by reinforcement. The results for single transformations involving no change and one change in the decision function are shown in Tables 1 and 2. In the case of single transformations involving two changes, there were no significant differences whether the stimulus would or would not be followed by reinforcement, in any of the subject groups.

Normals. From Tables 1 and 2 it can be seen that, for normal subjects, where the stimuli are *not* followed by reinforcement, the mean probability of transformations involving no change in the decision function is significantly higher, and that for one change significantly lower. In other words, the drive for change

Table 1. Reinforcement and single transformations involving no change

Subject group	n	Not followed by reinforcement		Followed by reinforcement		T	U	P
		Mean	Variance	Mean	Variance			
Normals	15	0.6443	0.0581	0.4519	0.0637	2.14		<0.05
Schizophrenics under treatment	11	0.7883	0.0397	0.7466	0.0561	0.45		>0.05
Schizophrenics not under treatment	7	0.7391	0.0443	0.6349	0.0377	1.41	32	>0.05

Table 2. Reinforcement and single transformations involving one change

Subject group	n	Not followed by reinforcement		Followed by reinforcement		T	P
		Mean	Variance	Mean	Variance		
Normals	15	0.2105	0.0319	0.4367	0.0634	2.84	<0.02
Schizophrenics under treatment	11	0.1638	0.0247	0.1962	0.0360	0.44	>0.05
Schizophrenics not under treatment	7	0.1810	0.0262	0.2345	0.0340	0.58	>0.05

in the normal subjects was significantly stronger when the visual stimulus was linked to a possible painful reinforcement than when it was not. Conversely, their level of 'rigidity', as indicated by the proportion of identity transformation (i.e., transformations involving no change), was lower when the stimuli could be followed by reinforcement.

Schizophrenics. With the three schizophrenic groups, however, the corresponding differences were not significant. (Results for schizophrenics under and not under treatment are shown in Tables 1 and 2). In other words, the schizophrenic patients did not make a significant distinction, at the level of decision functions, between visual stimuli followed and not followed by reinforcement. I.e., they would include, from the viewpoint here considered, *two different classes of stimuli in a single class.* This may be interpreted as corresponding to an overinclusiveness of the concept they used to classify stimuli. This phenomenon is analogous to the overinclusiveness of concepts described by Cameron at a clinical level, or to the loss of the limits of concepts described by Carl Schneider [6].

It should be noted, however, that although such distinctions were not used at a pragmatic level, they were maintained at the level of verbal communication.

2. Responsiveness to Reinforcement: Two Successive Transformations

By two transformations applied one immediately after the other, we mean two transformations Ti and Tj defined by the relationships $T_i f_i = f_j$; $T_j f_j = f_k$; $T_j (T_i f_i) = f_k$; in which f_i, f_j and f_k are three successive decision functions.

We analyzed the mean occurrence probabilities for three different cases:
"Identity", I; $T_j(T_i f_i) = f_k$ with $f_i = f_j = f_k$
"Return", R; $T_j(T_i f_i) = f_k$ with $f_i = f_k$ and $f \neq f_i$
"No Return", $\sim R$; $T_j(T_i f_i) = f_k$ with $f_i \neq f_k$

Normals. From Tables 3 and 4 it can be seen that, similarly to what happened in the case of one single transformation which we considered before, for normal subjects, where the stimuli were *not* followed by reinforcement, the mean probability of double transformations $T_j \cdot T_i$ involving no change in the decision

Table 3. Reinforcement and two successive transformations involving no change (I)

Subject group	n	Not followed by reinforcement		Followed by reinforcement		T	P
		Mean	Variance	Mean	Variance		
Normals	15	0.4975	0.1039	0.2603	0.0806	2.14	<0.05
Schizophrenics under treatment	11	0.7201	0.0763	0.6542	0.0843	0.55	>0.05
Schizophrenics not under treatment	7	0.6432	0.0874	0.4895	0.1061	1.26	>0.05

Table 4. Reinforcement and two successive changes of the decision function ($\sim R$)

Subject group	n	Not followed by reinforcement		Followed by reinforcement		T	P
		Mean	Variance	Mean	Variance		
Normals	15	0.0491	0.0042	0.5729	0.0635	2.81	<0.01
Schizophrenics under treatment	11	0.2201	0.0384	0.2680	0.0556	0.52	>0.05
Schizophrenics not under treatment	7	0.2737	0.0514	0.4234	0.0944	1.24	>0.05

functions ($f_i = f_j = f_k$) was significantly higher and in the case of $\sim R$ (involving $T_j \cdot T_i$ such that $f_i \neq f_k$), significantly lower than in the case in which stimuli were followed by reinforcement.

The interpretation of this result may be identical to that we proposed for the case of one single transformation between two successive decision functions f_i and f_j.

Schizophrenics. Both in the group of Schizophrenics which were under therapy and in the group of Schizophrenics which were not under therapy it was not found any significant difference either in case "T" or in case "$\sim R$" (No Return).

Again this may be interpreted as meaning that from the viewpoint of decision functions, schizophrenics would not make the distinction between stimuli followed by reinforcement and stimuli not followed by reinforcement.

Note that two successive transformations is the minimal number of transformations to try a new hypothesis about a given decision function and to maintain it, if adequate, or to change it, or else to persist in it, if it is inadequate, even after receiving feedback about the error commited.

This variable was chosen within the initial hypothesis we formulated about those factors which would intervene in the learning process under study. Computer simulation showed that this expansion in the depth of context, taking into account the relationship of a preceeding transformation on a subsequent one, improved the fit between the time equation for transformations of decision functions, and experimental results.

3. Inter-Group Differences of Rigidity or of Drive to Change in the Case of Stimuli Followed by Reinforcement

As indicator variable for "rigidity" we used single transformations between two successive decision functions implying no change—(H.D.-Hamming Distance), H.D. $(f_i, f_j) = O$.

As indicator variables for "Drive to Change" we used single transformations implying one or two differences between two successive decision functions.

Table 5. Comparison of subject groups: single transformations involving no change

Subject group	*n*	Mean	Variance	Comparison with normals	
				T	*P*
Normals	15	0.4519	0.0637		
Schizophrenics under treatment	11	0.7466	0.0561	3.02	<0.01
Schizophrenics not under treatment	7	0.6349	0.0377	1.84	<0.05
Schizophrenics with IQ higher than normals	6	0.7075	0.0601	2.11	<0.05

Table 6. Comparison of subject groups: single transformations involving one change

Subject group	*n*	Mean	Variance	Comparison with normals	
				T	*P*
Normals	15	0.4367	0.0634		
Schizophrenics under treatment	11	0.1962	0.0360	2.66	<0.05
Schizophrenics not under treatment	7	0.2345	0.0340	2.16	<0.05
Schizophrenics with IQ higher than normals	6	0.1909	0.0263	2.16	<0.05

We analyzed the difference between the mean occurrence probability of "Rigidity" and "Drive to Change" in the group of normals and in the groups of schizophrenics under therapy, schizophrenics not under therapy, and schizophrenics with mean IQ greater than in the group of normal subjects.

Rigidity. The mean probability value for single transformations implying no change of the decision function in the case of stimuli followed by reinforcement was significantly smaller in the group of normal subjects than in any of the three groups of schizophrenics we mentioned.

Drive to Change. The mean probability value of single transformations implying one change of the decision function, was significantly greater in the group of normal subjects than in any of the three groups of schizophrenics we mentioned.

In the case of single transformations implying two changes there was no significant difference.

These results mean that normal subjects were more active in trying to solve the problem and had a lower degree of rigidity and a higher drive to change.

Notice that in case decisions $\bar{D}\bar{E}R$ were excluded, the difference vanished concerning transformations implying no change and was maintained concerning transformations implying one change between two successive decision functions.

4. Inter-Group Differences in Two Successive Transformations in the Case of Stimuli Followed by Reinforcement

We selected as indicator variables for the comparison between the group of normal subjects and the group of schizophrenic patients under therapy, not under therapy and with mean IQ greater than in the group of normal subjects, respectively, those variables already mentioned in section 2, namely:

I — "Identity"
$\sim R$ — "No Return"

In the case of two successive transformations T_i and T_j; $T_j\,(T_i\,f_i) = f_k$, leading from f_i to f_j and from f_j to f_k respectively, the mean value of the probability of Identity (I) transformations was significantly smaller, and that of "No Return" ($\sim R$) transformations was significantly greater, in the group of normal subjects than in the group of schizophrenics under therapy and in the group of schizophrenics with mean IQ greater than in the group of normal subjects.

In the group of schizophrenics not under therapy the same was true concerning I transformations, but not as far as $\sim R$ transformations were concerned.

"I" transformations included $\bar{\text{D}}\text{E}\bar{\text{R}}$ decisions functions.

The two variables "I" and $\sim R$ we mentioned are indicators of the way individuals of the different groups explore the possibilities of action and then

Table 7. Comparison of subject groups: two successive transformations involving no change (I)

Subject group	n	Mean	Variance	Comparison with normals		
				T	U	P
Normals	15	0.2603	0.0806			
Schizophrenics under treatment	11	0.6542	0.0843	3.46		<0.01
Schizophrenics not under treatment	7	0.4895	0.1061		87	<0.01
Schizophrenics with IQ higher than normals	6	0.5709	0.1131	2.15	75	<0.05

Table 8. Comparison of subject groups: two successive changes of the decision function ($\sim R$)

Subject group	n	Mean	Variance	Comparison with normals	
				T	P
Normals	15	0.5729	0.0635		
Schizophrenics under treatment	11	0.2608	0.0556	3.13	<0.01
Schizophrenics not under treatment	7	0.4234	0.0944	1.21	>0.05
Schizophrenics with IQ higher than normals	6	0.3098	0.0695	2.14	<0.05

return to adequate or inadequate decisions, or become immobilized in adequate or inadequate decisions.

Schizophrenic patients either do not explore possibilities or they become immobilized in inadequate responses, as is indicated by the high probability of ("001") $\bar{D}\bar{E}R$.

They also may become immobilized over inadequate response (011) $\bar{D}ER$, (111) DER (101) $D\bar{E}R$. In their attempts of adaptation they follow a "drift" which does not bring them back to the adequate responses, (110) $DE\bar{R}$ or (100) $D\bar{E}\bar{R}$, as is expressed by the fact that they use those decision functions a number of times which is not significantly different from normals and yet do not learn to solve the problem as often as normal subjects do.

Schizophrenics try the adequate responses but do not remain there: they suffer a "cognitive drift" which brings them away from adequate responses, although they know which are the adequate responses.

It should be noted nevertheless, that most of the probability mass on "I" is due to (001) $\bar{D}\bar{E}R$ decision functions, because, if we make the comparison taking away $\bar{D}\bar{E}R$ the difference vanishes. This means as it did in the case of one single transformation, either lack of motivation, or else active inhibition of the drive to explore hypotheses. As a consequence the chance of solving the problem are reduced—*t* value was than 1.59 and 0.53 in the comparison between normal subjects and the group of schizophrenics patients under therapy and schizophrenics patients not under therapy respectively. In the comparison between mean values in the group of normal subjects and schizophrenics under therapy, concerning respectively $DE\bar{R}$ and $D\bar{E}\bar{R}$ the difference was not significant—*t* value, was 0.62 and 1.34 respectively in the same comparison, but now made between the group of normal subjects and schizophrenics without therapy.

Initial "Inertia"

In what concerns initiative to begin exploration, which is measured by the length of initial (001) $\bar{D}\bar{E}R$—no movement—the mean of the percentual value was greater in the group of schizophrenics patients under therapy and those with a mean IQ greater than in the group of normal subjects. In these groups it was also greater but not significantly different—which corresponds to the high dispersion of the samples.

Table 9. Interruption of efforts to adapt

Subject group	*n*	Mean	Variance	Comparison with normals		
				T	*U*	*P*
Normals	15	0.0689	0.0140			
Schizophrenics under treatment	11	0.2522	0.0550	3.34	131.5	<0.01
Schizophrenics not under treatment	7	0.4128	0.1190	3.52		<0.01
Schizophrenics with IQ higher than normals	6	0.2649	0.0897	3.52		<0.01

Table 10. Exploration of combinatorial possibilities

Subject group	n	Mean	Variance	Comparison with normal	
				T	P
Normals	15	0.3273	0.0398		
Schizophrenics under treatment	11	0.0744	0.0017	4.12	<0.001
Schizophrenics not under treatment	7	0.1228	0.0212	2.42	<0.02
Schizophrenics with IQ higher than normals	6	0.1324	0.0244	2.13	<0.05

Interruption of Efforts to Adapt

Interruption of efforts to adapt, after the beginning of active search to solve the problem, was significantly greater in all three groups of schizophrenic patients than in the group of normal subjects.

This variable may be correlated either with the "loss of dominating set" described by Shakow [6] or else with a tendency to retreat when suffering is involved in adaptative efforts (Rodnick and Garmezy [5]).

Schizophrenic patients, as it may be seen in the structure of the program required to simulate them, either make short lived attempts or they make them with a much longer duration than normals do.

Exploration of Combinatorial Possibilities

The mean value of the combinatorial possibilities attempted by the different groups of schizophrenics is not significantly different from that of normals, if we separate that combinatorial exploration from the length of the sample. The mean value of the probability of exploration of new "Minterms" relatively to the length of the sample was significantly greater in the group of normals than in the group of schizophrenic patients.

Probabilistic Algorithm

The indicators above show that there are significant differences between normal controls and schizophrenic patients in the way they try to solve the problem of avoiding suffering in our experimental situation.

When we started the interpretation of our results, our hypotheses concerning the generative law which would specifiy the probabilistic transformations of decision functions involved the following factors:

1. An initial factor of inertia, operative until some behavioral attempt to solve the problem was made.

2. A second factor of inertia, corresponding to the temporary abandonment of such efforts of adaptation.

3. A factor which implied maintaining the correct behaviour ($D\bar{E}\bar{R} \cup DE\bar{R}$) when three or more of such adequate decision functions had been used in uninterrupted sequence.

4. A weighing factor corresponding to (a) one change, two and three changes transformations taking into consideration to which of the three classes NE specify below:

$\{\bar{D}\bar{E}R \cup \bar{D}ER\}$, $\{DER \cup D\bar{E}R\}$, $\{D\bar{E}\bar{R} \cup DE\bar{R}\}$, corresponded respectively, any two successive functions in the sequence of decisions of the subject and (b) a

Table 11. Characteristic equation of transformation in time of decision functions of normal subjects (as studied in the present test and sample)

$$F_j(t+1) \equiv a_0 F_i(t) \prod_{t=0}^{t} \left(F_i(t) \equiv \bar{D}\bar{E}R\right) \oplus$$

$$\oplus\, a_1 F_i(t) \prod_{t-k}^{t} \left(F_i(t) \equiv \bar{D}\bar{E}R\right) \left(\sum_{t=0}^{t} \left(F_i(t) \not\equiv \bar{D}\bar{E}R\right)\right) \oplus$$

$$\oplus\, a_2 F_i(t) \prod_{t-3}^{t} \left(F_i(t) \equiv D\bar{E}\bar{R} \cup DE\bar{R}\right) \oplus$$

$$\oplus\, a_3 F_i(t) \prod_{t-2}^{t} \left(F_i(t) \equiv D\bar{E}\bar{R} \cup DE\bar{R}\right) \oplus$$

$$\oplus\, a_4 F_i(t) \prod_{t-4}^{t} \left(F_i(t) \equiv D\bar{E}R \cup DER\right) \oplus$$

$$\oplus\, a_5 F_i(t) \prod_{t-3}^{t} \left(F_i(t) \equiv D\bar{E}R \cup DER\right) \oplus$$

$$\oplus\, a_6 F_i(t) \prod_{t-2}^{t} \left(F_i(t) \equiv D\bar{E}R \cup DER\right) \oplus$$

$$\oplus\, a_7 F_i(t) \cdot \left(F_i(t-1) \equiv \bar{D}ER\right) \oplus$$

$$\oplus \sum_{m=1}^{m=3} \sum_{n=1}^{n=3} a_{m,n} T_{i,j} \cdot F_i(t) \cdot a_k\left((A_i F_j) / \left(F(t-1) \cap F(t)\right)\right)$$

Explanation of symbols (Tables 11 and 12)
With further conditions:
1) If $a_j = 1$ then $a_i = 0$ for any $i > j$
2) each coefficient a_i assums value 1 or 0 with characteristic probabilities p_i and $q_i = 1 - p_i$
3) $a_{m,n} \equiv f(F(t-1))$ $a_n \equiv f(F(t-1) \cap F(t))$
$\cap$ logical product (equivalent to product modulo 2)
$\prod_{i=1}^{n}$ product modulo 2 over i
$\oplus$ stands for adition "modulo 2"
$\sum_{i=1}^{n}$ "adition modulo 2" over i
$\cup$ "inclusive or" ($f(x,y) = xy \oplus x \oplus y$)
$\sum_{i}^{n}$ "inclusive or" over i

"prediction factor", according to which the results of the preceding procedure of transformation were rejected or accepted, before being tried, as if a judgement was made about their possible adequacy with a specified probability for both cases.

This generative law was approximately correct in characterizing the behavior of our subjects—whether normal controls, paranoid schizophrenics under therapy, or paranoid schizophrenics not under therapy—as a computer simulation showed.

For a better fitting of experimental data we had nevertheless to introduce (1) a factor of inertia with decremental probability in time, of maintaining decision functions belonging to the class {DER ∪ $\overline{\text{DER}}$}, (2) a factor of inertia, expressing a

Table 12. Part 1

```
0:FXD 21.73495137→C⊢
1:22→A;ENT R44,R45;PRT R 44,R45⊢
2:DSP A;DSP;DSP⊢
3:ENT RA;PRT RA;IF (A+1 →A)≮42;JMP - 1⊢
4:R27 →R46;R28→R47;R29→R48;0→A⊢
5:0→RA;IF (A+1→A)≮19;JMP 0⊢
6:0→R49→R50;8PC 6;ENT "8T",R0;IF R 0=0;JMP 0⊢
7:GSB 74⊢
8:(R36 >X)+(R36≮X) (R37>X) 11+(R37≮X)(R38>X)111→R4;IF R4=0;JMP 2⊢
9:(R38≮X)(R39>X) 10 1+(R39≮X) (R40>X) 110+(R40≮X) 100→R 4⊢
10:1+R1→R1;IF R1>75;0→R1;JMP - 6⊢
11:(R4=11)+(R4=111)+(R4=101)→R12;R1 2+(R4=1)→R3;R12+R11→R11⊢
12:0→R17→R18→R19→R4 3;R8→R9;R7→R8;R6→R7;R5→R6;R4→R5→R2⊢
13:FXD0;DSP R2;DSP;DSP;DSP;PRT R2;IF R2=1;1→R16⊢
14:((R5=100)+(R5=11 0))((R6=100)+(R6=110))((R7=100)+(R7=110))→R0⊢
15:IF R0((R8=100)+(R8=110))((R9=100)+(R9=110));JMP-11⊢
16:IF R4=1;GSB 74⊢
17:IF (R2=1) ((R16=0) (X≮R41)+(R16=1)(X≮R42));1→R4;JMP - 7⊢
18:IF R3=1;JMP 58⊢
19:IF R3=0 ;JMP 59⊢
20:(R11>4)(R49>4) ((R0=1)78+(R0=1) ((R8=110)+(R8=100))15)→R43⊢
21:(R5=101)+(R5=111)→R14;R14+R49→R49;R5=11 →R15;GSB 74⊢
22:IF (X≤R43)(R0+R0((R8=100)+(R8=11 0)));JMP - 12⊢
23:IF (R14=1)+ (R15=1);JMP 62⊢
24:0→R17→R18 → R19;GSB 74⊢
25:IF (R20<X)(R21>X );1→R18;JMP 21⊢
26:IF R21≤X;1→R19;JMP 31⊢
27:IF R 20>X;1→R17⊢
28:IF R2≠111;JMP 3⊢
29:GSB 74⊢
```

Table 12. Part 2

```
30:(X≤R22)11+(R>22) (X≤R 23)101+(X>R 23) 110 →R4⊢
31:IF R2≠101;JMP 3⊢
32:GSB 74⊢
33:(X≤R 22)+(X>R22) (X≤R23) 111+ (X>R23 )100→R4⊢
34:IF R2≠1;JMP 3⊢
35:GSB 74⊢
36:(X≤R22)11+(X>R 22) (X≤R23)101+(X>R 23)100→R4⊢
37:IF R2≠ 11;JMP 3⊢
38:GSB 74⊢
39:(X≤R 22)+(X>R22) (X≤R23)111+(X>R23) 110→R4⊢
40:IF R2≠100;JMP 3⊢
41:GSB 74⊢
42:(X≤R22)+(X>R22) (X≤R23)101+(X>R23)110→R4⊢
43:IF R 2≠110;JMP 14⊢
44: GSB 74⊢
45:(X≤R22 )11+ (X> R22 )(X≤R23))111+ (X>R 23)100→R4;JMP 12⊢
46:GSB 74⊢
47:IF R2=111;(X≤R24 )+(X>R24)100 →R4⊢
48:IF R2=101;(X≤R 24)11+(X>R24)110 →R4⊢
49:IF (R2=11→R0) (X≤R25);100→R4⊢
50:IF R0(X>R 25);101 → R4⊢
51:IF (R2 =1 →R0)(X≤R 25);110→R4⊢
52:IF R0(X>R25);111→R4⊢
53:IF(R2=100→R0))(X≤R26);111→R4⊢
54:IF R0(X>R26);11→R4⊢
55:IF (R2=110→R0) (X≤R26);101→R4⊢
56:IF R0(X>R26);1→R 4⊢
57:GSB 74⊢
58:IF (R4=1) (R4=R5)(R5=R6);JMP - 34⊢
59:IF (R4 =11)(R4=R5)(R5=R6)(X>R45);JMP-49⊢
60:IF ((R4=100)+(R4=110))(R4=R5)(R5=R6);JMP- 50⊢
61:IF (R4=1) (R4=R5) (R5≠R6) (X>R44);JMP - 37 ⊢
62:IF (R4=11);(R4=R5)(R≠ R6) (X>R45);JMP - 52⊢
63:IF ((R4=100)+ (R4=110)) (R4=R5)(R5 ≠R6);JMP-53 ⊢
64:IF ((R4=1)+(R4=11))(R4≠R5) (R5=R6 ) (X≤R46);JMP - 54⊢
65:IF ((R4=101)+(R4=111)) (R4≠R5) (R5=R6) (X≤R47);JMP-55⊢
66:IF ((R4=100)+ (R4=110)) (R4≠R5) (R5=R6) (X≤R48);JMP - 56⊢
```

Table 12. Part 3

```
67:IF(R4=11) (R4≠ R5) (R5≠R6) (R4=R6) ( X≤R 30);JMP - 57⊢
68:IF ((R4=101)+(R4=111)) (R4 ≠R5) (R5≠ R6) (R4=R6) (X≤R3 1 );JMP-58⊢
69:IF ((R4=100)+(R4=110)) (R4≠R5) (R5≠R6) (R4=R6) (X≤R32);JMP -59⊢
70:IF ((R4=1)+ (R4=11)) (R4≠R5) (R5≠R6) (R4≠ R6 ) (X≤R33);JMP - 60⊢
71:IF ((R4=101)+(R4=111))(R4≠R5)(R5≠R6) (R4≠R6) ( X≤R34);JMP - 61⊢
72:IF ((R4=100)+(R4=110)) (R4≠R5) (R5 ≠R6)(R4≠R6) (X≤R35);JMP - 62⊢
73:JMP 9 ⊢
74:29C→X;X - INT X → X →C;INT (1E4X)/100→X⊢
75:RET ⊢
76:IF ( R4=1) + (R4=11);58→R20;85→R21;50 → R 46;100→R47;50→R48;JMP - 52⊢
77:IF (R4=111)+(R4=101);60→R20;80→R21;40→R46;80 →R47 ;40→R48;JMP - 57⊢
78:IF (R1≤9) (R11≤6); 53 → R20;65 →R21;100 →R46;100→R47;10→R48;JMP -58⊢
79:IF R11>6;GSB 74⊢
80:IF X≤95;15→R20;22→R21;50→R46;50 → R47;100 →R48;JMP -60⊢
81:IF X>95;53 →R20;65 → R21;100→R46;100→R47;50→R46;JMP-61⊢
82:IF R17=1;JMP-54⊢
83:IF R18=1;JMP-37⊢
84:IF R19=1;JMP-74⊢
85:IF R5= 11;JMP4⊢
86:IF R5≠R7;59→R10 ⊢
87:IF (R6=R7) (R8 ≠ R9);60 →R10 ⊢
88:IF (R6=R7)(R7=R8)(R8=R9);10→R10⊢
89:IF R5=11;35→R10;GSB 74⊢
90:IF X≤R 10;JMP-80 ⊢
91:IF(X>R10) (R14=1);70→R20;200→R21;JMP -67⊢
92:IF R15=1;68→R20;200→R21;JMP - 68⊢
93:END ⊢R50
```

Initial values introduced in the simulation of normal subjects.

R_{44}=100;R_{45}=0;R_{22}=22;R_{23}=68;R_{24}=62;R_{25}=46;R_{26}=43;R_{27}=40;

R_{28}=100;R_{29}=30;R_{30}=100;R_{31}=100;R_{32}=30;R_{33}=20;R_{34}=20;R_{35}=20;

R_{36}=53;R_{37}=60;R_{38}=73;R_{39}=100;R_{40}=300;R_{41}=75;R_{42}=5.

Table 13. Normal subjects

	Real subjects computer simulated				
	Mean	Variance	Mean	Variance	t
P1	0.3480	0.0420	0.3230	0.0323	0.42 $P>0.05$
P2	0.1373	0.0421	0.1573	0.0161	0.40 $P>0.05$
P3	0.1760	0.0320	0.1240	0.0126	1.13 $P>0.05$
P4	0.5729	0.0635	0.6230	0.0405	0.72 $P>0.05$
P5	0.4519	0.0637	0.4290	0.0338	0.35 $P>0.05$
P6	0.4367	0.0634	0.3923	0.0178	0.78 $P>0.05$
P7	0.1493	0.0204	0.1910	0.0153	0.98 $P>0.05$
P8	0.1313	0.0546	0.1160	0.0438	0.22 $P>0.05$
P9	0.0260	0.0034	0.0173	0.0011	0.64 $P>0.05$
P10	0.1064	0.0275	0.0453	0.0093	1.57 $P>0.05$
P11	0.6155	0.0743	0.6310	0.0783	0.18 $P>0.05$
P12	0.2791	0.0719	0.3330	0.0847	0.60 $P>0.05$
P13	0.3000	0.0731	0.3707	0.0713	0.83 $P>0.05$
P14	0.4847	0.1301	0.4348	0.0803	0.51 $P>0.05$
P15	0.2160	0.1036	0.1945	0.0434	0.27 $P>0.05$
P16	0.7827	0.0670	0.7467	0.0389	0.52 $P>0.05$
P17	0.1417	0.0381	0.2160	0.0361	1.23 $P>0.05$
P18	0.0769	0.0101	0.0380	0.0058	1.45 $P>0.05$

Explanation of symbols (Tables 13—15)

P1 Ratio between the number of different decision functions which were attempted and the total number of decision functions

P2 Probability of single transformation implying no modification (excluding $\bar{D}\bar{E}R$) $f_i = f_{i+1} = f_{i+2}$

P3 Probability of two successive transformations implying the return to the initial decision function $f_i = f_{i+2} \neq f_{i+1}$

P4 Probability of two successive transformations implying that $f_i \neq f_{i+2}$

P5 Probability of single transformation implying no change (distance between f_i and f_{i+1} equal to zero)

P6 Probability of single transformation implying one change (distance between f_i and f_{i+1} equal to one)

P7 Probability of single transformation implying two changes (distance between f_i and f_{i+1} equal to two)

P8 Ratio between the length of initial inertia and the total number of decision functions

P9 Probability of $\bar{D}\bar{E}R$, after the first decision which was different from $\bar{D}\bar{E}R$

P10 Probability of one single transformation in which f_i belongs to the class $\{\bar{D}R\}$ and implying no change

P11 Probability of one single transformation in which f_i belongs to the class $\{\bar{D}R\}$ and implying one single change

P12 Probability of one single transformations in which f_i belongs to the class $\{\bar{D}R\}$ and implying two changes

P13 Probability of one single transformation in which f_i belongs to the class $\{DR\}$ and implying no change

P14 Probability of one single transformation of a decision function f_i which belongs to the class $\{DR\}$ and implying one change

P15 Probability of one single transformation of a decision function f_i which belongs to the class $\{DR\}$ and implying two changes

P16 Probability of one single transformation of a decision function f_i which belongs to the class $\{D\bar{R}\}$ and implying no change

P17 Probability of one single transformation of a decision function f_i which belongs to the class $\{D\bar{R}\}$ and implying one change

P18 Probability of one single transformation of a decision function f_i which belongs to the class $\{D\bar{R}\}$ and implying two changes

Table 14. Schizophrenic under therapy

	Real subjects computer simulated				
	Mean	Variance	Mean	Variance	t
P1	0.0791	0.0019	0.0897	0.0020	0.68 $P>0.05$
P2	0.1336	0.0398	0.0852	0.0279	0.79 $P>0.05$
P3	0.0736	0.0039	0.0355	0.0015	2.40 $P<0.05$
P4	0.2680	0.0556	0.3421	0.0369	1.03 $P>0.05$
P5	0.7466	0.0561	0.7182	0.0268	0.43 $P>0.05$
P6	0.1962	0.0360	0.1961	0.0165	0.00 $P>0.05$
P7	0.0736	0.0081	0.0852	0.0036	0.49 $P>0.05$
P8	0.3682	0.1039	0.4430	0.0850	0.72 $P>0.05$
P9	0.1945	0.0525	0.1482	0.0171	0.83 $P>0.05$
P10	0.1800	0.1186	0.1867	0.0728	0.07 $P>0.05$
P11	0.6173	0.1166	0.6215	0.0667	0.04 $P>0.05$
P12	0.2036	0.0601	0.1900	0.0240	0.22 $P>0.05$
P13	0.2344	0.0810	0.1963	0.0431	0.86 $P>0.05$
P14	0.4522	0.1717	0.4335	0.0661	0.18 $P>0.05$
P15	0.3133	0.1641	0.3659	0.0693	0.50 $P>0.05$
P16	0.5967	0.1246	0.6739	0.0941	0.70 $P>0.05$
P17	0.3033	0.1065	0.2296	0.0754	0.74 $P>0.05$
P18	0.1011	0.0182	0.0961	0.0461	0.07 $P>0.05$

tendency to repeat decision function $\bar{D}$ER. Those corrective factors were enough to produce a satisfactory fit between simulation results and the empirical sample for normal controls.

For both groups of paranoid schizophrenics, in order to obtain a good fit we had to admit that there were still three groups: (a) one in which maintaining the decision functions of class $\{DER \cup \bar{D}\bar{E}R\}$ had a higher probability, (b) one in which the tendency to stick to decision $\bar{D}$ER was higher, (c) one which combined trends (a) and (b).

The expressions in Table 11 correspond to the generative laws of normal subjects. The generative law of the behavior of paranoid schizophrenics implies only a different probabilistic weighing of those factors.

It should be added that successive factors are to be understood as *intervening* in the transformation process *only if every one of the preceding factors has been excluded from that specific transformation.* The true probabilities of the total process do not result from simple combination of successive probabilities, but from a time walk along successive probability distributions.

For the first term we would have p_1 and $1-p_1$; for the second term we would have $(1-p_1)$. p_2; for term i, we would have $(1-p_1)$ $(1-p_2)\ldots(1-p_{i-1})p_i$.

To control the adequacy of our generative law we ran a simulation in a programmable calculator Hewlett—Packard 9820-A, with 427 registers and a mathematical functions 'plug in.'

Table 15. Schizophrenic without therapy

	Real subjects		computer simulated		
	Mean	Variance	Mean	Variance	t
P1	0.1271	0.0211	0.0800	0.0014	1.17 $P>0.05$
P2	0.0914	0.0214	0.1514	0.0341	0.75 $P>0.05$
P3	0.1157	0.0066	0.0629	0.0039	1.65 $P>0.05$
P4	0.4234	0.0944	0.4107	0.0506	0.13 $P>0.05$
P5	0.6349	0.0377	0.6579	0.0500	0.25 $P>0.05$
P6	0.2345	0.0340	0.2000	0.0245	0.51 $P>0.05$
P7	0.1629	0.0148	0.1423	0.0072	0.45 $P>0.05$
P8	0.0971	0.0144	0.1614	0.0712	0.60 $P>0.05$
P9	0.3443	0.1260	0.2650	0.0652	0.59 $P>0.05$
P10	0.1971	0.0426	0.2779	0.0815	0.66 $P>0.05$
P11	0.5729	0.0952	0.4736	0.0585	0.81 $P>0.05$
P12	0.2314	0.0401	0.2500	0.0381	0.20 $P>0.05$
P13	0.2786	0.0699	0.3507	0.0756	0.57 $P>0.05$
P14	0.4157	0.1368	0.3471	0.0990	0.44 $P>0.05$
P15	0.3057	0.0235	0.3021	0.0584	0.04 $P>0.05$
P16	0.4175	0.1686	0.3656	0.0710	0.35 $P>0.05$
P17	0.1500	0.0367	0.1389	0.0311	0.24 $P>0.05$
P18	0.4325	0.1736	0.4956	0.0935	0.40 $P>0.05$

Our program and initial values for normal subjects are given in Table 2.

Results of the comparison between samples obtained by simulation and samples of real subjects are given in Tables 13, 14 and 15.

Discussion of Results of the Simulation

The good fit between characteristics of those samples obtained by simulation and those of real subjects confirmed the adequacy of the above time equation. The time equation specifies the dynamics of the transformation of each decision function into the following one, for the groups of subjects we mentioned. We have also specified the coefficients of the time equation which characterized each of these groups.

Differences between the data we introduced to obtain the fit between simulated samples and real samples, were greater than those which characterized each sample when it was generated (or observed, in the case of real subjects). This is expressed, for example, in the probability of initial maintenance of $\overline{\text{DER}}$ (initial inertia) and return to or maintenance of inactivity after having been active—what is specified by the thresholds in registers R41 and R42.

The program includes instructions to introduce data (lines 0 to 3). According to these instructions, lines 4 to 10 prepare each simulation which will last 75 trials at most for each subject simulated.

The first state in the beginning of the simulation of the problem solving process of a given 'subject' is determined in lines 8 and 9. A push-down store with a five-state capacity, is represented by the instruction in line 12. Decision instructions concerning initial inertia as well as interruption of efforts to solve the problem are represented in line 17.

A decision factor concerning conditions for persisting on adequate responses which avoid punishment $(\bar{D}ER \cup DE\bar{R})$ are represented in line 21.

A factor concerning maintenance of decision functions which interrupt punishment corresponding to class $(DER \cup DE\bar{R})$ as well as a factor concerning remaining in the completely inadequate decision function $\bar{D}ER$ are represented in lines 23, 85 and following lines.

Conditions which specify the dependence of transition probabilities on the class to which belongs the last decision function are represented in lines 18, 19 and 76 to 78.

Lines 24, 25, 26, and 27 lead to a choice of 0 or 1 or 2 changes according with probabilities specified in lines 76 to 78. An hypotheses concerning new decision functions is then produced taking into account the probability of approaching or remaining in each of the three classes we mentioned before (lines 28 to 56).

Such 'hypotheses' are then accepted or rejected according to predictive weights (lines 57 to 73).

Criteria for success in the test are specified in lines 14 and 15.

To produce the fit between samples obtained by simulation and our sample of normal subjects we needed only to use a single program. On the other hand, for both samples of paranoid schizophrenic patients, we had to use sub-samples obtained by means of deleting or introducing factors of persistence of decision functions belonging to $\{DER \cup D\bar{E}R\}$ as well as of decision function $\bar{D}ER$.

One of these programs can be understood as producing "patients" without persistence and "losing the dominating set" and another for producing "patients" rigidly fixated on inadequate decisions and without altering these decisions—a fact which fits in well with the difference between patients which appear as mainly autistic and without initiative and those who are very active but do not alter from their mistaken beliefs as quickly as normals do.

The probabilistic characterization of the transformations which occurred in the sample had descriptive value, separating normal subjects from patients. After implementing the time equation characteristic for each group in the form of computer programs those programs had power to generate the fine grain structure of the "walk" of subjects along their space of decision functions.

The disturbance of schizophrenic patients included several factors, namely (a) initial inertia, (b) a later tendency to inertia alternating with very short attempts to adapt, or else long-lasting sequences of inadequate and rigidly maintained behavior, (c) characteristic distribution of inertia as well as of one or two changes in single transformations, after $\bar{D}R$, DR or D-$\bar{R}$ respectively, (d) different distribution of probabilities of acceptance of a certain state after two previous transitions.

Contrary to what might be suggested by a selective attention theory, many patients insist very rigidly on the same type of attempts, independently of external signals.

Many patients are not discouraged and are completely successful in performing single conceptual operations which are not disturbed by punishments—a fact which is against simple motivational theories. The main difference in these compared with normal controls is not in their ability to perform isolated formal operations, which in general is well preserved, but rather in their use of a *completely different strategy* and structure of transformation of the decision functions when they try to solve the problem.

Disturbances in cognitive processes vary with different subjects in the samples of patients. There are four main types: (a) subjects who do not make any attempt to solve the problem; (b) subjects who are very slow to begin to make attempts and thereafter often interrupt their efforts. In general, these subjects make very short attempts which, although sometimes adequate, are very quickly abandoned; (c) subjects who are very active but rigidly persist in inadequate and long-lasting efforts; (d) subjects with an apparently completely normal structure of responses.

To simulate types (a), (b), and (d) a single set of data and the same program were enough to obtain an adequate fit in most aspects (including the number of subjects which behaved according to the respective type). To simulate type (c), two small modifications had to be introduced in lines 21 and 23. According to these results we suggest that cognitive disturbances in paranoid schizophrenics are mainly of formal operations as described by Piaget. The disturbances disappear when the subject recovers.

It is reasonable to suppose, as the period of normal operations begins at 11 years of age, that that period is the crucial one for cognitive disturbances in paranoid schizophrenia, although affective disorders may lie behind those cognitive disturbances.

Concerning learning theory in general, our program suggests that reinforcement acts differentially—enhancing or inhibiting some crucial areas of decision in different degrees (lines 76 to 78 in the program). Furthermore, learning implies, besides the acquisition of the final correct reaction, a very complex time pattern of sequential decisions, which our program is powerful enough to describe and implement.

It is very probable that this patterning of sequential decisions in time does not depend only on the present experience the subject is having, but also represents a structure acquired in the past.

This structure is transferred to new situations which appear ambiguous, but not when the situation is clear-cut, as other experiments of our group have shown and as is also often confirmed in the literature.

This pattern is in some sense a *mediational generative structure* which generates either peculiar types of behavior or, sometimes, characteristic symptoms. Complex relational structures of cognitive, motivational, perceptive, as well as predictive and valuative types, trigger temporarily the use of this mediational generative structure, which incorporates all these influences under a single dynamic process.

The basic elements of our theory are elementary decisions identified with elements of GF (2), which may take value 1 or 0.

Those elementary decisions are combined in n-tuple vectors: decision functions which represent mutually related simultaneous and disjoint decisions.

These vectorial decision functions have here the ambiguous status of being *representations of past events, new decision functions* which may be accepted or not, and also decision functions which once accepted are transformed into action.

The goal is set by the aim of attaining $\bar{R}$.

The mechanism of attaining the goal is supposed to be a transformation of decision functions by means of which successive possibilities are explored.

The theory supposes that, in general, subjects do not explore possibilities in an optimal way. It is supposed that there is involved *a basic drive to take some initiative* (which is present in every transformation of decision functions), with a certain weight; a second basic drive of getting *out of the situation by not intervening,* and still other basic drives: (1) *a negative one* of persisting in inadequate responses *(2)* a *moderately positive one* expressed in not trying to obtain the maximum of possible aspiration once an intermediate goal has already been attained and *(3)* a *positive one* of trying to obtain maximum success.

Besides these three factors, which take as a factor of reinforcement the 'distance to some reference vectors,' there are further factors of reinforcement: (a) the differentiation between decisions which involve approaching or abandoning each of the three classes, we mentioned before and (b) the acceptability of new hypotheses, which is different and initially smaller with the class ($D\bar{E}\bar{R}$ $DE\bar{R}$) because it involves a time-coupling which may provoke some difficulties in producing adequate reactions toward the system which generates stimuli and reinforcements.

The order of sequencing of attempts is also a crucial factor, transforming the relative probability weight of each of the factors we mentioned. Our identification of clinical variables in experimental data is the following: autism and loss of the set are represented in factors 1 and 2 respectively; adherence to completely inadequate hypotheses—which at this level might be related to what at the clinical level appears as *delusional beliefs,* may be represented by our third factor. Low level of conceptual sharpness is represented by higher probability of abandoning adequate decisions and smaller probability of abandoning inadequate decisions. Overinclusiveness is represented in the group of paranoid schizophrenic subjects by the absence of differences between reactions towards stimuli followed or not followed by reinforcement.

The theory of learning we propose implies *different factors of memory.* Each of them has a *different span as well as an intervention of a set of basic drives,* a predictive factor concerning what decision function is to be tried and a loss of sharp boundaries shown in overinclusiveness and a less effective differentiation between inadequate classes, persisting in the inadequate class of decision *and still in not even posing the hypotheses of* $\{D\bar{E}\bar{R}$ $DE\bar{R}\}$ and still in a difficulty in maintaining the coupling with the time structure of the environment.

Our transformation time equation is an *intentional one* which generates decision rules concerning subjects which belong to the same group.

Those three functional time equations *express the generative intention of members of the group,* at a collective level of characterization when they attempt to avoid punishment in our experimental set-up.

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