A Random Process Model of Cognitive Deficit in Schizophrenia

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Abstract

It is argued that in schizophrenic patients the process of selecting responses to incoming stimuli becomes increasingly random the more disturbed the patient is. This is seen as a disordered overextension of normal behavioral flexibility and variability. A model is proposed which considers the range of human behavior to be the result of perceptions of incoming stimuli compared to related analogs retrieved from memory. In the schizophrenic individual, the range of memory elements likely to be elicited by an input becomes abnormally large so that in the severely disturbed patient, behavior approaches randomness. The model is discussed in light of current thinking about schizophrenia, and data are presented in support of the new approach.

Since Kraepelin, thought disorder has been considered the most prominent symptom of schizophrenia. The specific nature of this disorder has yet to be clarified, as schizophrenia is characterized by a marked heterogeneity of symptoms in single patients and groups of patients (Chapman and Chapman 1973, 1975). One approach to reducing this heterogeneity has been to seek to show a particular differential deficit which can be separated from the generalized deficit in schizophrenia and which can be contrasted with normal thought; indeed, the concept of thought disorder itself implies a discrete entity (Bourne et al. 1977; Harrow and Quinlan 1977).

This perspective is based on the assumption that the disorder involves a specific cognitive dysfunction; that is, information processing in the schizophrenic individual is thought to be biased in a particular, abnormal way. In this view, when schizophrenics and normals are compared in information processing, the responses of the schizophrenics should be seen to deviate from normal in a well-defined way. Based on this traditional approach, a theory of thought disorder in schizophrenia would generate a specific prediction of the types of errors a group of schizophrenics will make on a given task; or in an empirical study, the pattern of errors would be scrutinized for some indication of a particular type of error from which one can infer a specific deficit that distinguishes schizophrenics from normals. Thus, the implicit assumption that schizophrenia can be characterized by a specific abnormality of processing, or by a family of such abnormalities, has led to a search for consistency in the behavior of schizophrenic subjects.

This state of affairs is to be contrasted with the frequent observations of clinicians and the anecdotal reports of researchers that much of the cognitive behavior of schizophrenics appears disconnected, unsystematic, indeed random (e.g., Gil lis and Blevens 1978). Nevertheless, in an effort to make sense out of apparent chaos, clinicians and researchers have frequently disregarded this random material for the purpose of serious analysis, noting its presence only in passing. Random data are frequently ignored because it is assumed that randomness cannot reflect a specific deficit in schizophrenia. For example, Chapman and Chapman (1973) note at numerous
points in their book on studies of schizophrenia that unsystematic responses or patients who were behaving unsystematically vis-a-vis the tasks were disregarded in the data analysis. This attitude toward such responses is entirely understandable since behavior of this type, at one level, would appear to be refractory to analysis.

It is our explicit contention in this article that such random, unsystematic behavior is precisely that which may be the most revealing in informing the clinician or investigator about the nature of cognition in schizophrenia. We will argue that the cognitive deficit in schizophrenia produces a response pattern which approaches randomness in the highly disturbed, and further, that this is a disordered extension of normal function. We propose that the approach to randomness reflects the basic nature of disordered thought in schizophrenia, and we suggest a model to account for it. The explanatory concepts to be outlined are intended to apply specifically to thought disorder and to its manifestations in non-paranoid schizophrenia.

The Model

We will examine hypotheses about the nature of the cognitive deficit in schizophrenia that follow from a model which considers the range of human behavior to be the result of a basic neuropsychological process, i.e., the comparison of perception with an analog from memory (Sengel and Shurley 1979). According to this model, human behavior is assumed to be based primarily upon the comparison of current sensory input with a similar past input and executing the past behavior associated with the previous input stored in memory.

Thus, given an immediate input, the system seeks a similar past input and its associated behavior and tends to execute the previous behavior pattern. In effect, the brain scans its memory banks for an appropriate analog to current input and bases its behavior on the comparison.

In figure 1 the perceptual signal, P, is the result of immediate input. The element $E^{-1}$ on the memory path indicates that input is delayed for some period of time for storage consolidation. The memory reference signal, $R$, relates, then, to a similar past input and its associated behavior pattern—an analog based on a past situation. Two signals are depicted to portray comparison. In the comparator, the memory reference signal is compared with the perceptual signal, and behavior output is based on that comparison. Behavioral feedback enables the system to evaluate outcomes. Outside forces are events over which the individual system has little or no control such as social change. The system would tend to respond to current input with a replication of relevant past behavior.

We are not suggesting that behavioral output is invariant since normal behavior has a wide range of variation. Rather, the analogs from memory are drawn upon with considerable flexibility. Behavior will vary about a steady state if the analogs selected by the brain are functionally equivalent, i.e., provide a basis for similar behaviors from one occasion to the next (cf. Rashkis and Yanovski 1973). The model assumes that memory retrieval is a statistical or probabilistic process; it is this process that underlies individual flexibility in analog formation. The model is consistent with John’s (1972; Thatcher and John 1977) statistical theory of memory:

The evidence . . . shows unequivocally that the evoked potential recorded from a given brain region during differential generalization is composed of two independent processes, an exogenous process which reflects the physical reality of sensory in-

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Figure 1. Structure of the neuropsychological process of comparing input with an analog from memory

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put, and an endogenous process which represents release of a specific memory. [Thatcher and John 1977, p. 246]

It is this probabilistic nature of memory retrieval which leads to individual behavioral flexibility or variability.

While figure 1 depicts a single input for ease of portrayal, the brain is subject to multimodal input. Memory elements consisting of molecular units and neuronal networks are associated with each input channel (Hyden 1969; Thatcher and John 1977). These elements are electrogenic and respond to the repetition of similar stimuli which have electric field changes similar to those produced by the original event (Hyden 1969; Pribram 1969; Schmitt 1967). In this sense, the brain compares inputs with memory for the retrieval of specific memory elements. Memory elements based on similar inputs may have response ranges which overlap; thus, the repetition of the same or similar stimuli may not evoke the recall of the same element each time but ones similar enough to be functionally equivalent or provide a basis for similar behavior. For example, any unit of the cortex responds with a statistically repeatable pattern to many presentations of a particular stimulus but with variability in response to individual presentations, and the response of a given neuron to a specific stimulus is not invariant (John 1972). Moreover, since a single neuron cannot contain enough information to account for the discriminative abilities of behavior (Eccles 1953; John 1972; Lashley 1969), the memory retrieval mechanism must combine recalled elements into a whole (Pribram 1969; Spinelli 1970). An analog from memory “... must be the product of complex transactions between neuronal ensembles. ... It must also associate [the transactions] into a functional representational unit...” (Thatcher and John 1977, p. 244). In analog formation:

The essential features of the proposed mechanisms are that [memory] readout may be accomplished probabilistically, that different cells may control the same behavior on different occasions, and that any given cell may contribute to the storage of multiple experiences and to the performance of a variety of learned responses. [Thatcher and John 1977, p. 190]

Given the probabilistic nature of memory retrieval, recalled elements stimulated by multimodal inputs may be combined in a new synthesis or analog, as defined here, which triggers a new behavioral response. This variability of analog formation and of the behaviors produced is seen as an integral feature of normal behavior.

**Memory Retrieval and Creativity**

The probabilistic nature of memory retrieval in this model is seen as the basis of creativity. In Koestler's (1964) interpretation, creativity is based on “bisociation,” the joining of previously distinct matrices of thought or behavior. It consists of recognizing an analogy where none was seen before and, from the perspective of the model presented here, is the product of a new synthesis of recalled memory elements. Thus, it is argued that the variability of memory retrieval increases from normal behavior to creativity to schizophrenia. When faced with the repetition of similar stimuli, the normal individual will usually select the same or similar analog from memory on which to base his behavior. In effect, the memory reference signal in figure 1 has a probability coefficient averaging approximately 1, expressing the idea of functional equivalence. Similar stimuli evoke the recall of an analog with a small amount of variance on the average. The creative individual, however, generates more low probability responses than the normal individual. For this creative person, then, the evocation of a response by a stimulus can lead to the combining of previously unrelated memory elements more frequently than for the normal individual. An analog never seen before or a new synthesis of stored elements would result. It is not necessarily the case that all such novel analogs are meaningful, but the process can be seen as providing a basis for creative insight. This process can also be considered to underlie the capacity for disordered thinking in schizophrenia. In the case of schizophrenia, however, the novel analogs generated to an input are rarely meaningful or appropriate in a given context, and thus lack an important feature of what we ordinarily call creative thought.

The hypothesis that the breadth of association characteristic of schizophrenia may be related to creative behavior has been proposed by others, as well (e.g., Arieti 1955; Dykes and McGhie 1976; Kris 1952; Kubie 1958; Rashkis and Yanovski 1973). While the formal similarity between creativity and some aspects of schizophrenic thought has often been observed, the process underlying the similarity has yet to be conclusively demonstrated (cf., Dykes and McGhie 1976). The model presented here provides a mechanism of memory retrieval by which creativity and some aspects of schizophrenic...
cognition can be seen to have a common basis.

Predictions From the Model

We argue that in schizophrenia the system generates new combinations of memory elements or analogs so frequently that unpredictable behavior is the result. In terms of figure 1, for the schizophrenic the probability coefficient of the memory reference signal would vary significantly from a value of 1.0. Several testable hypotheses follow from this concept of schizophrenia. For example, the model implies that schizophrenic thinking is an extension of the process underlying normal behavior, i.e., it has greater variance. As depicted in figure 2, this concept entails a view of schizophrenia as an extension of or on a continuum with normal thinking as opposed to a typological view of schizophrenia as a distinct entity (see also Claridge 1972; Dykes and McGhie 1976; Harrow and Quinlan 1977; McConaghy and Clancy 1968). For a given stimulus, the normal individual has a certain range of potential responses. In this model, an increasingly schizophrenic person will show a decreased probability of performing the correct response and an increased probability of performing a range of incorrect responses. As the severity of disordered thought increases, the variability also increases. Division of this continuum into categories that reflect degree of disturbance is arbitrary. Nevertheless, the figure illustrates the conceptualization of schizophrenia entailed by the model. At the limits of this continuum, new combinations of memory elements are so frequently generated that behavior is unpredictable; hence, any analog selected approaches equiprobability and therefore randomness. Thus, we hypothesize that the degree of approximation of randomness in overt responses will be a direct function of the severity of the thought disorder. If this is true, highly disturbed schizophrenics should not show inflexibility in cognitive performance, but rather their overt responses should approach randomness. This will remain true even with feedback, as that input will also trigger the almost random combination of memory elements. The less disturbed, however, should move toward the correct response or the selection of an appropriate analog with feedback.

A Test of the Model

To demonstrate the validity of the model presented above, two sets of data from this laboratory were examined. The first set of data are from Fishkin and Williams (1976) who tested the ability of schizophrenics to use hypotheses logically in solving a conceptual problem. The second set of data are from a detailed examination of the patterns of errors and correction procedures of schizophrenic subjects on a paper-and-pencil test of cognitive deficit (Fishkin et al. 1979). Each set of results is based on a different test of schizophrenics' cognitive abilities, but both have one factor in common, that the overall form, or pattern of results, is that which would be expected if the information processing ability of schizophrenics approaches randomness as the level of disturbance increases.
One must keep in mind as these data are being discussed that the subjects in both studies were cooperative, relatively intact, and capable of being tested for a moderately prolonged time period. As a result, it is reasonable to expect that during periods of decompensation, these subjects would have demonstrated more extreme degrees of the types of cognitive deficit discussed below. Moreover, although the performance of the subjects on the tasks shows a strong influence of a random process, the performance is of necessity somewhat organized or the tasks could not have been completed. Furthermore, the model predicts what form the data from a given population of subjects would take if the degree of randomness is a direct function of the severity of the thought disorder, but it does not make strictly quantitative predictions.

**Pishkin and Williams’ Results.**

Pishkin and Williams (1976) compared schizophrenics and hospitalized nonpsychiatric controls on a concept identification task. The subjects were required to categorize colored geometric patterns by trial and error as being members or nonmembers of the concept by finding the relevant dimension (e.g., color) and then learning the category assignment of each of the two values (e.g., red and blue) on that dimension. The subject signaled his guess as to the category assignment by pressing a button labeled either “Member” or “Nonmember” of the concept. Before each category guess, the subject indicated which dimension(s) he was considering by pressing one or more of six keys corresponding to the physical dimensions (color, form, size, number, horizontal/vertical position, and orientation).

In this way, before each choice, the experimenter could document the aspects of the stimuli the subject was considering in solving the problem. This method provided insight into the logic and consistency with which subjects used information from one trial to the next. For example, if a subject was entertaining the hypothesis that “all red stimuli belong to the concept” and so classified a red stimulus but was then informed that his guess was wrong, he could change the composition of his hypothesis to another dimension or test the opposite hypothesis (i.e., that “red objects do not belong to the concept”). In such a fashion, a number of aspects of the problem-solving behavior of the subjects could be determined.

In this task a perfect information processor could be expected always to maintain a hypothesis after a previously correct response, and to change his hypothesis after an error on the previous trial (a win-stay, lose-shift strategy). A random processor would equally often keep or reject a hypothesis after correct responses and do the same after errors. The model of schizophrenic thought disorder proposed here states that the schizophrenics ought to approach the random end of the continuum defined by these two extremes. Thus, their behavior would not be expected to be perfectly random, but it should be less organized than the behavior of the normals. In addition, if some measure of severity of schizophrenia were available for these data, the model would predict that the more severely ill schizophrenics would fall closer to the random extreme of the continuum.

The data presented by Pishkin and Williams showed the predicted pattern. Schizophrenics more often changed hypotheses after correct responses than normals ($t(98) = 2.05$, $p < .05$) and also changed more often following an error ($t(18) = 2.23$, $p < .05$). The normals, instead of changing their whole hypothesis after an error, tended to add a dimension on the next trial ($t(98) = 2.37$, $p < .05$), thus making small, systematic, exploratory hypothesis changes. This modification of the win-stay, lose-shift strategy allowed the normals to be sure of including potentially missed information on the next trial after an error and of retaining any accurate hypotheses following a correct response. The schizophrenics changed the composition of their hypotheses regardless of the outcome of the previous trial. In the authors’ words, “In this respect, it appeared that schizophrenics were randomly choosing dimensions among the stimuli presented to them” (Pishkin and Williams 1976, p. 387). The most parsimonious explanation for these findings is that the schizophrenics were being unsystematic in choosing the next behavior in sequence based on the input (feedback) derived from the previous trial.

**Results From the Whitaker Index of Schizophrenic Thinking (WIST).**

The WIST is a paper-and-pencil test of cognitive disorder which measures the degree of unwitting illogicality and idiosyncrasy of thought. Fishkin et al. (1979) reported a detailed analysis of performance on the WIST of three groups of diagnosed schizophrenics. Subjects who took the WIST were divided into three groups according to the degree of thought disorder shown on the test. The low group showed performance essentially within the normal range (WIST Index ≤ 15, $n = 12$). The medium group showed moderately disordered thought (Index 16 to 30, $n = 12$), while the high group showed...
more severe thought disorder (Index 31 or greater, n = 12). The purpose of the analysis was to determine the manner in which the severely disturbed schizophrenics made errors on the test.

The WIST consists of three subtests (Similarities, Word Pairs, and New Inventions) for a total of 25 multiple choice items. The subject completes the test at his own pace while being timed to the nearest minute by the tester who scores the test and then reviews the test with the subject, pointing out errors and allowing the subject to retake each originally incorrect item until he has chosen the correct response. Each item has five choices: the correct choice, a loose associate, a personal reference choice, a clang associate, and a nonsense associate (in ascending order of illogicality). The four incorrect choices receive error weights 1 through 4, respectively. The WIST Index is the total of time in minutes for the first attempt on the test, plus the summed error weights for all items over the initial and correction trials. The test has the advantage of allowing an analysis of severity of illogicality, as well as providing a glimpse of how well a subject can correct his performance on an item after being shown it is incorrect.

According to the original design of the WIST, a normal subject with an eighth grade education would be expected to make no errors on the test. The more severely disturbed schizophrenic subjects, as defined by their scores on the WIST, could be expected to have achieved high scores in several different ways. First, their responses could be logically accurate, but time taken to complete the test could have been excessive, thus inflating their Index totals. Second, they could have made severe errors on the first attempt to take the test because the specific question content triggered particular psychodynamic aspects of their symptomatology causing a rigid focusing on answers fitting this pattern (e.g., a subject could choose a disproportionate number of clang associates). However, upon being told which items were incorrect, the severely disturbed subjects could have corrected their errors rapidly by immediately choosing the correct response. The third possibility is that these subjects achieved high scores because they were unsystematically choosing answers on a significant number of items the first time through the test and then during the correction procedure continued to choose responses at random. Therefore, it is important to note that a high WIST Index, which would cause a subject to be diagnosed as severely thought disordered, could be achieved in several ways, only one of which would be based on random performance.

According to the theory presented here, very slightly disturbed schizophrenics would be expected to make few errors and to make errors of the less severe types (loose associate and personal reference). Perhaps most importantly, such sub-

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**Figure 3. Proportion of errors of each type for each severity group**

The high (31 and greater) group subjects make relatively fewer nonsensical errors and more severe errors than the low and medium groups, approximating the random curve.

jects should be expected to correct an error as soon as it has been pointed out to them in the correction procedure. More severely disturbed schizophrenics would be expected to make more errors and to make all types of errors in approximately equal number. Moreover, their responses should continue to approach randomness after an error has been pointed out to them in the correction procedure. The proposed model therefore predicts that subjects scoring relatively more poorly on the test should do so in a particular way, and the degree of randomness should be a direct function of the severity of the thought disorder.

To determine how the severely disturbed subjects attained their high WIST scores, Fishkin et al. (1979) compared the three severity groups to assess the style of responding and method of error correction used. First, the time to complete the test only partially accounted for the difference in Index between the low and high groups (7.67 versus 14.83 minutes, respectively; or a factor of 2). The difference in summed, weighted error scores was far greater (3.08 versus 39.67, respectively; or a factor of over 12). Thus, time alone was not a large determinant of a high WIST Index for the severely disturbed subjects.

Second, the way in which the subjects in each group went about making their errors was quite revealing. A randomly performing subject would be expected to choose each type of incorrect answer choice equally frequently, while a more effective processor of information would show a relatively higher proportion of less severe errors. Figure 3 shows that this was precisely the case. The abscissa shows the types of errors in order of severity; the ordinate shows the proportion of errors. The data are shown for the three severity groups with a hypothetical line for a perfectly random processor shown for comparison. The most severely disturbed group strongly tended to make each type of error with equal probability, closely approximating randomness. The goodness-of-fit test comparing the random distribution and the obtained probability distribution of errors for the highly disturbed subjects showed a significant association to the random pattern ($\chi^2 (3) = .126, p < .01$).

A second set of curves was plotted, against a theoretical random processor, which showed the probability of a group's being correct or making a less severe error on correction trials, given an error on the first attempt. In figure 4, the abscissa shows the successive responses on correction trials (2 through 5), and the ordinate shows the probabilities. A reference curve was plotted showing the random probability of a correct response or a less severe error on each attempt. The obtained data showed that the less severely disturbed subjects rapidly found the correct response during correction trials or at least tended to make less severe errors. The high WIST group, beyond the first correction trial (response number 2), closely approximated the

![Figure 4. Probability of Improving on each correction trial on the WIST for three severity groups given an error on the preceding trial](https://academic.oup.com/schizophreniabulletin/article-abstract/6/3/526/1908429/1908429)

The most severe group of schizophrenics approaches random in its ability to be correct or make a less severe error on attempted correction trials.

random curve. Again, this evidence is in accordance with a model that postulates an approach to random response selection as the severity of thought disorder increases.

The third analysis performed on these data compared the groups in the probability of choosing the correct response on each attempt to complete the items. In figure 5, the abscissa shows the five attempts possible on any given item, and the ordinate shows the probabilities. The low and medium groups show a strong tendency to be correct on a given trial and to increase the probability on successive attempts. The data for the severely disturbed group, on the other hand, fall intermediate to the curves from the less disturbed groups and the random curve. Furthermore, the severely thought disordered subjects show little or no increase in their likelihood of finding the correct choice over several attempts.

The clear implication of these findings is that the performance of the severely disturbed subjects on the WIST approximates the performance produced by a random processor. In all cases the more severely disturbed subjects show performance which approaches randomness. This finding is all the more significant in view of the fact that the WIST itself was designed so that the questions contained emotion-laden items and so that each type of error was capable of triggering psychodynamically rooted pathological responses. Thus, the random performance of the high group occurred in the face of a test designed to elicit systematic types of error.

In this section, we have reviewed two sets of somewhat disparate data and have shown that the performance of groups of schizophrenic subjects is consistent with a model that predicts an approach to random selection of response alternatives as the severity of the cognitive disorder increases. These data are inconsistent with the hypothesis of an inflexible system of responses to various inputs.

Conclusions

Two other theories of schizophrenia, although based on Hull-Spence behavior theory rather than memory retrieval, are somewhat similar to the one presented here in their predictions of overt responses in schizophrenia. Mednick (1958) explained thought disorder in schizophrenia as resulting from the arousal of irrelevant remote associates by a heightened drive state that he equated with anxiety. Specifically, heightened drive should produce a flattened gradient of stimulus generalization. The theory is internally inconsistent, however, since according to the Hull-Spence theory, heightened drive should steepen the gradient, thus producing more dominant associations and leading to be-
behavioral rigidity. Moreover, Chapman and Chapman's (1973) review of relevant studies found little support for Mednick's anxiety theory of schizophrenia.

In relation to a hypothesis of overt responses, Broen and Storms' (1966; Broen 1966) theory is most similar to the hypothesis outlined above. Based on principles derived from behavior theory, Broen and Storms (1966) postulated that schizophrenics have a higher drive level than normals or a lower ceiling on response strength or both. Consequently, competing responses would come to have equal strength to the dominant response, and the schizophrenic would then emit inconsistent behaviors given a particular stimulus. This is characterized as response disorganization in which the probabilities of alternate responses are more nearly equal (Broen 1966). As noted by Chapman and Chapman (1973), the major weakness of the theory is that there is no a priori specification of the location of the ceiling on response strength. Its location is inferred from the data it is used to explain; hence, either a steepening or a flattening of the gradient of response strength is compatible with the theory. In general, most drive-level theories suffer from the difficulties inherent in specifying drive level before testing. Instead of drive level being predicted by the theory, it is usually inferred post hoc.

The advantage of the hypothesis of overt responses in schizophrenics presented here, i.e., that degree of randomness is a direct function of the severity of disturbance, is that given an independent assessment of severity of disturbance, it provides an a priori prediction of performance. Although alternative interpretations are not excluded, the pattern of data reported is consistent with the model and indicates directions for further research.

Since the experiments discussed here were not designed to test this theory, the analyses are of necessity post hoc. Furthermore, it would be desirable to obtain a measure of severity of disorder that is independent of the measure of random performance. Experiments in preparation at this laboratory are designed to address these limitations. A first step in extending our work is to demonstrate further that the WIST is a valid measure of severity of schizophrenia in general, and thought disorder in particular. A study now being planned will include blind, independent clinical ratings of severity for comparison with the WIST Index. With such additional validation, the WIST can be used to define level of thought disorder in future experiments. Moreover, schizophrenic subjects will be matched with subjects with a manic disorder to determine if random responsiveness in WIST performance is a specific cognitive dysfunction in schizophrenia or reflects a generalized psychotic deficit. The first experiment planned, then, will seek to replicate the results of Fishkin et al. (1979), and to demonstrate the reliability and validity of the phenomenon. Future work will examine the predictions from the model on other instruments.

While these limitations must be recognized, the model nevertheless leads to some heuristic insights. For example, the concept of analog formation as a combination of recalled memory elements provides a mechanism that accounts for associative substitutions and intrusions, and the coexistence of logically incompatible ideas which characterize schizophrenic thought disorder. A highly variable, probabilistic memory retrieval system would be expected to combine such elements, and almost randomly so, in the highly disturbed. The memory elements alone may be nondeviant, but they are associated or combined into an analog in a way that approaches randomness. Furthermore, the information processing deficit would not be expected to yield specifically defined, consistent, aberrant responses relating to some underlying psychodynamic disorder. Rather we would expect a derangement of normal functioning lacking in specificity. Thus, we contend that the system becomes disordered and ultimately random in the severely disturbed. In information processing terms, the system would tend toward entropy, and therefore the responses generated would approach randomness. The present model is an attempt to schematize the manner in which such a process would occur.

If the approach advocated here to the understanding of schizophrenia is correct, several important implications for future research arise. Most notably, this approach would allow a cross-cultural, indeed an interspecies, study of the disorder unhindered by the cultural and species bias that has made such research difficult in the past. This is so because the model predicts that the form in which behavior occurs will approach randomness in schizophrenia; the content will vary based on the specific conditions of testing. If such elimination of cultural bias were possible, considerable power would be gained in our ability to study the disorder.

References


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