reaction time and attention in schizophrenia: a critical evaluation of the data and theories*

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Introduction

> The literature on schizophrenia is a voluminous one, the size of which is in part determined by the multiplicity of the contradictions. There is a marvelous value in this since one can, on an *ad hoc* basis, claim that virtually anything has been demonstrated and be correct. Despite the usefulness of this contradictory literature, as a practical ego support it presents real problems. One research strategy in coping with this state of affairs is to seek out those findings which have been consistently replicated. The reaction time (RT) studies are the closest thing to a north star in schizophrenia research. [Cancro et al. 1971, p. 352]

As reaction time (RT) studies can be considered the "north star" of schizophrenia research, they also appear to be a microcosm of psychological research in this disorder, if not of psychopathology generally. Not only is their number probably larger than those employing any other single experimental task, but the diversity of assumptions and theoretical persuasions that are represented within their boundaries is also immense. A partial listing of the hypothetical constructs invoked to explain schizophrenic RT performance ranges from segmental set, narrowed attention, selective filter deficit, response competition, and protective inhibition to social withdrawal, sensitivity to social censure, defective biological motivation, and impression management. Clearly, these approaches to understanding the nature and causes of this complex and tragic disorder run the gamut from basic structural to learned to motivational preferences among theorists.

The predominant hypotheses in RT research, however, are in the realm of attention, an area that has been central to both clinical and experimental work on schizophrenia for many years. Eugen Bleuler, for example, had noted some disturbances of attention in schizophrenia in his classic work, *Dementia Praecox or the Group of Schizophrenias*, first published in English in 1950 but originally in German in 1911:

> As a partial phenomenon of affectivity, attention is affected with it by deterioration. Insofar as interests are extant—in milder cases this means for the majority of events, in severe cases at least for the emotionally charged activity . . .—attention appears to be normal at least according to our present methods of observation. However, where affect is lacking, there will also be lacking the drive to pursue the external and internal processes, to direct the path of the senses and the thoughts; i.e., active attention will be lacking.
>
> Passive attention is altered in an entirely different manner. On the one hand it is evident that the uninterested or autistically encapsulated patients pay very little attention to the outer world. On the other hand, however, it is remarkable how many of the events which the patients seem to ignore are registered nevertheless. The selectivity which normal attention ordinarily exercises among the sensory impressions can be reduced to zero so that almost everything is recorded that reaches the senses. Thus, the facilitating as well as the inhibiting properties of attention are equally disturbed. [p. 68]

Two aspects are especially notable in Bleuler's comments. First, he subordinates attention to affectivity, especially in the case of so-called "active" attention. This hierarchy of psychological functions resulted in

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attentional disturbances not being included among his well-known four primary symptoms. Further discussion of this ordering of fundamental deficits will occur in the section on motivational factors in attention.

Second, disturbances of "passive" attention are seen as more universal to schizophrenics, and involve what would now be known as deficits in selective attention (e.g., Kahneman 1973). This particular aspect of attention has received the broadest theoretical consideration as the source of deviant RT in schizophrenia. The experience of this phenomenon among schizophrenics has been strikingly recorded in their self-descriptions:

> I can't concentrate. It's diversion of attention that troubles me. . . . The sounds are coming through to me but I feel my mind cannot cope with everything. It's difficult to concentrate on any one sound. It's like trying to do two or three different things at one time. [McGhie and Chapman 1961, p. 104]

Thus, the clinical significance of attentional changes in schizophrenia seems clear. The impact that the construct of attention has had on systematic experimental research and theory on this disorder is, if anything, even more marked. The reviews of McGhie (1970) and Neale and Cromwell (1970) provide a sense of the wide scope of experimental tasks and theories that have been applied in the study of schizophrenic attentional dysfunction. Especially relevant to the topic of the present review is a major problem observed by Neale and Cromwell—the looseness of the construct of attention as applied by various researchers to various tasks.

This criticism has gained even greater empirical support from a recent attempt by Kopstein and Neale (1972) to examine the interrelationships among five presumed tests of attention within a schizophrenic sample. They used some of the most popular tasks in the schizophrenia literature—RT, size estimation, the Benjamin Proverbs, object sorting, and vigilance. Rather surprisingly, none of the usual indices of attention derived from these tests intercorrelated higher than 0.3. This was within a schizophrenic sample of acute and chronic patients; quite possibly higher interrelationships would occur if correlations had been computed for a combined group of schizophrenic and normal persons. However, these might then reflect mostly the gross differences between schizophrenics and normals across a very wide variety of tasks (Chapman and Chapman 1973), so the present data probably allow a more sensitive appraisal of the common variance shared by these "attention" measures.

Given this tremendous heterogeneity in the factors tapped by the various tasks, it seems particularly appropriate to focus on a single task in an attempt to delineate the nature, extent, and universality of any attentional disturbance in schizophrenia. To this end, nonattentional explanations will also be considered where relevant, in hopes that such a consideration may in some cases indicate where the attentional hypotheses have been overextended. The goal is, then, to examine the empirical status of RT studies in schizophrenia and to clarify the usefulness of the various theoretical models that have been invoked to explain these research findings.

The Work of Shakow and His Colleagues: Their Basic Data

Asking a psychopathologist to free-associate to the word "reaction time" would most likely lead to the dominant response: Shakow. Indeed, the RT task has been an integral part of this prestigious investigator's research and theory on schizophrenia for over four decades. Actually, the simple RT experiment has a history in psychiatric research dating back to Kraepelin in the 19th century. Early reports (Obersteiner 1874, Scripture 1916, Wells and Kelly 1922, and Saunders and Isaacs 1929) noted the slowness of response characteristic of psychotics and especially of schizophrenics on the RT task. The prominent place of these measures in current research on schizophrenia, however, clearly stems from the systematic series of investigations begun at Worcester State Hospital by David Shakow and his colleagues (Shakow 1972).

Their initial publication (Huston, Shakow, and Riggs 1937) went considerably beyond confirming earlier suggestions that chronic schizophrenics were slower than normals in simple RT. They found that the mean RT of these patients was significantly slowed to either visual or auditory stimuli and also in a discrimination visual RT task. Testing over a period of 9 months showed little change in this level of performance. To control the effects of cooperation, this group of researchers consistently employed a 5-point rating scale ranging from A to E, and used as subjects only those patients rated in the two top categories. As a further check on possible cooperation effects, Huston, Shakow, and Riggs compared the fastest RT of those schizo-

phrenics rated most cooperative (A) with that of normal controls. Again, the chronic schizophrenics showed significantly poorer performance.

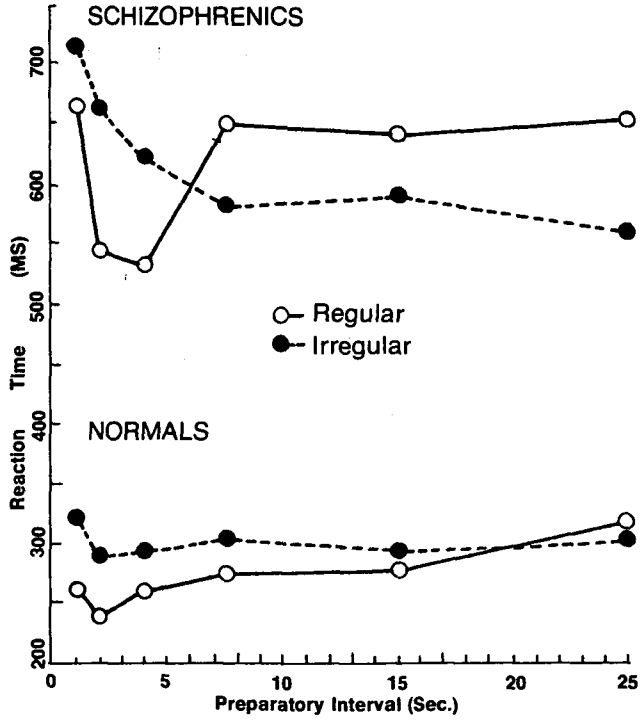
Most importantly, this early study contained the procedural elements—regular and irregular series of preparatory intervals (PIs)—that were to become the focus of much later research. Regular series involve the presentation of a block of RT trials with identical PIs between warning signal and imperative stimulus. Irregular series, on the other hand, consist of randomized presentations of several different PIs. Presumably the regular series allows the subject to learn when to expect the imperative stimulus and therefore to prepare maximally to respond quickly to it. Huston, Shakow, and Riggs found that the chronic schizophrenics were significantly slower than normals in responding to each of six PIs ranging from 0.5 to 10 seconds whether part of a regular or an irregular series. In addition, however, schizophrenic patients, unlike normals, were unable to improve their RTs in regular as compared to irregular series when the PI exceeded 2 seconds. Given this failure of the schizophrenics to obtain consistently faster RTs under the supposedly beneficial regular PI condition, the authors concluded that some deficit in the ability to prepare for quick response was indicated. The regularity that appears to allow the development of a peak of readiness in normal persons at the time of the required response was hypothesized not to help the schizophrenic patients, especially at the longer preparatory intervals. The quality that seemed crucial to fast response time was the ability to establish a "mental set," and schizophrenics were apparently not as effective in producing such attentional states.

The Set Index

Further support for the importance of the relationship between regular and irregular series in characterizing schizophrenic RT was provided by the classic Rodnick and Shakow (1940) study. Using a simple visual RT task with preparatory intervals of 1, 2, 4, 7.5, 15, and 25 seconds, they first replicated results of the earlier study. Their subjects were 25 hospitalized schizophrenics and 10 normal controls of approximately the same intelligence and educational background. The results were very comparable to those of the Huston, Shakow, and Riggs (1937) investigation, although the point after which schizophrenics failed to benefit from the regular as compared to irregular presentation was the 4-second PI rather than the 2-second PI, as illustrated in figure 1.

While fair discrimination between the schizophrenic and normal groups was possible, using overall RT alone, the theoretical limitations of this measure were clearly recognized. Referring to the earlier findings of overall slower simple RT in schizophrenics, Rodnick and Shakow (1940, p. 214) note: "Dissociation from environmental stimuli, lower motivation, less intense concentration of attention or inability to attain a high level of preparation might all contribute to the slower motor response." Moreover, these authors hoped that the RT task could be developed into a practical diagnostic tool. Usage for decisions on individual cases dictated that the discrimination between schizophrenic and normal groups be made as complete as possible.

Figure 1. Reaction times of schizophrenic and normal subjects[1]



Note.—**Mean reaction times are shown of 25 schizophrenic and 10 normal subjects at the various preparatory intervals of the regular and irregular warning procedures.**

[1]**Reprinted with permission from: Rodnick, E., and Shakow, D. Set in the schizophrenic as measured by a composite reaction time index.** *American Journal of Psychiatry*, **97:214-225, 1940.**

In order to accomplish these aims, Rodnick and Shakow computed a set index that took advantage of several key aspects of the schizophrenic's performance when compared to that of the normal group: (1) the early crossover of the mean RT curves for regular and irregular series, specifically the fact that schizophrenics usually had slower regular than irregular RT at the 7.5- and 15-second PIs; (2) the longer overall RT, specifically the much larger value of the highest mean RT among all the preparatory intervals, and (3) the tendency to show minimal RT at a PI longer than 2 seconds, whereas normals consistently showed their fastest mean RT for the 2-second, regular-series PI. Their final index consisted of:

$$\text{Set index} = \frac{1}{2}\left(\frac{M_{7.5\ R}}{M_{7.5\ I}} + \frac{M_{15\ R}}{M_{15\ I}}\right) M_H + \frac{M_{2\ R}}{M_{4\ R}} \cdot M_{2R}$$

where M_H = the highest mean RT for any of the regular or irregular PIs; M_{2R}, M_{4R}, $M_{7.5R}$, and M_{15R} represent the mean RTs of the 2-, 4-, 7.5-, and 15-second regular series, respectively; and $M_{7.5\ I}$ and $M_{15\ I}$ represent the mean RTs of the 7.5- and 15-second irregular series, respectively. By including these several factors, Rodnick and Shakow felt they created an index which "is not affected to as great a degree as simple reaction time by such factors as cooperation and motivation" and therefore "can serve as a criterion of normality with respect to the ability of the schizophrenic to reach a high level of preparation in adaptive situations" (p. 224).

With this set index, the schizophrenic and normal groups were shown to be discriminated without any overlap, a degree of separation that Shakow (1963) notes is to his knowledge unique among psychological studies of psychopathology. Actually, since the index was tested on the same data from which it was derived, it may have capitalized on some chance distinctions between their schizophrenic and normal RTs to achieve this unprecedented level of discrimination. However, that the set index provides a very high (but not perfect) degree of separation of chronic schizophrenics and normals has been demonstrated with another sample (Tizard and Venables 1956). Furthermore, Czuder and Marshall (1967) have since extended its use to 10- to 16-year-old schizophrenic children and matched normal children with only 10 percent overlap between groups.

Probably even more critical to Rodnick and Shakow's (1940) suggestion that the set index may have clinical value are studies which show discrimination between different clinical groups. Thus, Huston and Senf (1952) demonstrated that their modified set index differentiated their samples of chronic schizophrenics and neurotics almost perfectly, despite the fact that neither group showed the crossover of regular and irregular curves when only 2-, 5-, and 10-second PIs were used. Apparently, the longer overall RT and greater tendency toward crossover of the chronic schizophrenics were sufficient to create this marked separation. In the same study, the chronic schizophrenics were also differentiated from a group of manic-depressives, depressed type; but greater overlap was present for these two groups. Unfortunately, the exact amount of overlap is not reported.

Tizard and Venables (1956) found that the set index produced an excellent discrimination between mentally retarded adults and chronic schizophrenics, even to the extent that the two retarded individuals who fell into the schizophrenic range had been previously described as schizoid. Similarly, the previously cited study of schizophrenic children (Czuder and Marshall 1967) also used a mentally retarded comparison group. In this study, the low IQs of the schizophrenic children allowed matching with the IQs of cultural-familial retarded children. The set index separated these two groups with 20 percent overlap remaining. These last two studies suggest that, contrary to the criticism of Knehr (1954), this index taps something other than primarily an intelligence factor.

While studies of chronic schizophrenics thus support the ability of a set index to distinguish this group from other diagnostic groups at a statistically significant level, the discriminability is most impressive with normal, neurotic, and retarded groups and less so with manic-depressive (depressed) patients. Actually, though, its diagnostic utility is most damaged by the results of two studies with early or acute schizophrenics. The Huston and Senf (1952) study included an "early schizophrenic" group (mean hospitalization = 1 year) and concluded that they were differentiated from both chronic schizophrenics and neurotics, but were comparable to the manic-depressive, depressed type patients on the set index.

A later study (Zahn and Rosenthal 1965) employed a sample of schizophrenics with less than 2 months' total hospitalization, thus more clearly conforming to classification as acute cases. The major comparison group consisted of nonschizophrenic psychiatric patients (including character disorders, anxiety reactions, and depressions) that were of similar age and length of hospitalization. On the set index, the acute schizophrenics significantly differed from both the nonschizophrenic patients ($p < .005$) and from a chronic schizophrenic sample ($p < .01$) from a previous study, falling between the two.

It should be noted that the authors employed the group medians rather than the means for these analyses, since three nonschizophrenic patients showed scores highly discrepant from the rest of the group. Statistical testing of mean differences probably would not have yielded such clear significant differences. In any case, Zahn and Rosenthal conclude that the overlap between acute schizophrenic and nonschizophrenic patients is considerable and that such an overlap suggests the index is not applicable for diagnostic purposes. Since it is with acute rather than chronic schizophrenics that any diagnostic tool would be used, this study appears the most relevant of any for evaluating the set index as a diagnostic measure. A remaining possibility mentioned by Zahn and Rosenthal is that their study may have overestimated the differences between chronic and acute schizophrenics, since these acute cases were from the armed services and had therefore passed the initial medical and psychiatric screening. Moreover, some appeared in full or partial remission when tested.

In summary, high scores on the set index are not universal among nor unique to schizophrenics. Even if differential diagnosis is not possible on this basis, however, these scores do appear to measure a meaningful dimension within schizophrenic groups. Rosenthal et al. (1960) found a significant and very high correlation (rho = 0.89) between the set index and a clinical rating of the severity of schizophrenic disorganization for 10 chronic schizophrenics. Further evidence that this measure is relatively independent of intelligence is provided by the nonsignificant correlation of 0.26 with the Progressive Matrices in this study.

The fact that the overall mean RT of the patients studied by Rosenthal et al. (1960) correlated 0.82 with the mental health rating suggests, however, that this aspect of the RT performance can account for most of the variance in the set index, despite Rodnick and Shakow's (1940) efforts to include other salient characteristics. Indeed, Rosenthal et al. report a rho correlation of 0.92 between the set index and mean RT within their small sample of chronic schizophrenics. If one accepts Rodnick and Shakow's interpretation of overall mean RT level as heavily influenced by cooperation and motivation factors, this very strong relationship between the set index and mean RT suggests that these possibly extraneous elements affect the set index very heavily also. Indeed, the set index continued to correlate about 0.50 with cooperation ratings in the Worcester studies (Shakow 1963). However, the direction of the effect here remains unclear. It may well be that the more disorganized schizophrenic subjects were prevented from appearing more cooperative by their chaotic mental state. We will consider these issues further in the section on motivational influences on RT.

Two final studies are relevant to this topic, despite their focus on mean RT rather than the set index, since they bear on the clinical interpretation of RT differences within schizophrenic groups. Cancro et al. (1971) obtained RT data from 30 female schizophrenic patients within 2 to 3 weeks after hospitalization and before the start of medications. RTs were obtained to four stimuli (red and green lights and low and high tones) presented in a random series. They distinguished (1) simple RT, consisting of trials in which the imperative stimulus was identical to the previous one; (2) ipsimodal RT, in which the stimulus was in the same modality but not identical to the last one; and (3) cross-modal RT, in which the stimulus switched modalities from the previous stimulus. These measures were correlated with the number of nights the patients spent in any mental institution during a 3-year followup period.

The median RT under all conditions was positively related to the outcome measure, with correlations ranging from 0.26 to 0.60. For simple RT, the correlation with outcome was 0.50. Addition of cross-modal and ipsimodal RT substantially improved the multiple correlation with future hospitalization for the reactive but not the process schizophrenic group.

Confirmation of the prognostic significance of mean RT was recently reported by Zahn and Carpenter (1976). Acute schizophrenics who improved after about 4 months of hospitalization were distinguished upon admission and before medication by having overall faster RT than acute schizophrenics who did not improve

during this period. This was in spite of comparable levels of rated global psychopathology at admission testing. Interestingly, more specific aspects of RT performance, such as the set index, showed only insignificant trends toward differentiating the two opposed prognostic groups. Whether they would become more salient and significant with a larger sample is unclear. Zahn and Carpenter note that possibly these specific RT aspects are more closely tied to current psychiatric condition while only simple mean RT relates strongly to prognosis.

In summary, then, the set index devised by Rodnick and Shakow (1940) has been shown to yield significantly and often markedly higher scores for chronic schizophrenics than for any other diagnostic group for which direct comparisons have been made. Acute schizophrenics, on the other hand, are comparable to psychotically depressed patients and overlap more than slightly with nonpsychotic patients. Therefore, the set index does not appear to measure a quality that is unique to schizophrenia, although it does appear more characteristic of schizophrenics.

The most potent clinical interpretation of set index scores relates to severity of disorganization within the schizophrenic diagnostic group. In addition, basic RT measures have moderate predictive value for outcome of schizophrenia, at least as indexed by improvement over 4 months of hospitalization and days of hospitalization over 3 subsequent years.

The theoretical implications of these findings are unfortunately obscure. Shakow and his colleagues have emphasized the schizophrenic's deficit in the ability to prepare for the critical stimulus, or to establish an optimal mental set. This conclusion was based most directly on the differential effect of varying preparatory intervals in regular and irregular series. The set index was designed to tap these aspects of schizophrenic RT performance in addition to the larger overall mean RT, but in practice the set index appears to reflect chiefly the latter. Since overall mean RT may be greatly influenced by factors other than mental set, such as motivation, withdrawal from external stimulation, and motor speed, the set index results do not appear to directly confirm the Shakow formulation. In the next three sections we shall review studies which bear more directly on the set explanation.

An Early Test of the Set Formulation

As has been noted, it was the inability of schizophrenics to respond faster on regular compared to irregular series for the PIs greater than 2 seconds that first led Huston, Shakow, and Riggs (1937) to posit a mental set deficiency. Normal subjects often are able to take advantage of the predictability in the regular series to decrease their RT relative to an irregular series for PIs as long as 15 seconds (Rodnick and Shakow 1940) or in some cases even 25 seconds (Olbrich 1972).

Tizard and Venables (1956), in their replication of the Rodnick and Shakow (1940) study, noted and tested several alternative explanations for this effect. First, they used the median RT at each PI to evaluate whether the findings with means had been unduly influenced by a few very long RT trials, which might indicate that chronic schizophrenics were prone to "block" on certain trials. The median RTs, however, led to the same results. A second possibility was that the early crossover of regular and irregular RTs was a direct function of the overall slowing, rather than a separate phenomenon. Therefore, fast schizophrenic responders (mean RT < 1 sec) were compared to slow schizophrenic responders (mean RT > 1 sec). The pattern of results was the same for both groups. Actually, though, virtually all schizophrenics in this sample were greatly slowed in comparison to the normal group, so this did not provide a strong test of the second alternative. A more convincing examination of this possibility will be reported later.

A third hypothesis considered by Tizard and Venables (1956) was that fatigue or inhibition increased faster for the schizophrenics than the normals, and somehow contributed to the crossover pattern despite the fact that the order of the regular series had been systematically varied across subjects. For each PI of both regular and irregular series, comparisons were made between pairs of trials 2 plus 3, 5 plus 6, 8 plus 9, and 11 plus 12. No evidence of a trend toward decrement in RT performance within blocks of trials was found.

Finally, they examined the possibility that the central tendency of the chronic schizophrenic group masked the ability of many individual schizophrenics to maintain the normals' pattern of responding faster in regular than in irregular series after all but the longest PI. Again, little support was found for the hypothesis, with only 2 of 25 chronic schizophrenics showing a regular RT faster than an irregular RT for any PI greater than 4 seconds. As a result of these negative findings for their

four alternate hypotheses, Tizard and Venables (1956) concluded that the Rodnick and Shakow (1940) attentional formulation was most viable.

The Effects of Preparatory Intervals in Regular Series

Subsequent to the above study, a series of investigations was undertaken by Shakow, Zahn, and Rosenthal at NIMH to examine the regular and irregular series of RT trials as separate phenomena. The mental set construct appeared especially cogent for the regular trials, since it was assumed that maintaining the task set for the longer PIs was more difficult than for the short PIs. The longer time period presumably increases the likelihood that various distractions will interfere with the "major set," a term that has been used by Shakow (1946 and 1950) to denote the mental set most appropriate to a given task. The schizophrenics' unusually steep increase in RT with increasingly long PIs in regular series was entirely consistent with this explanation. However, an as yet untested possibility was that the longer PIs led to a slower experimental pace which itself was the key to the schizophrenics' deficit.

Zahn, Shakow, and Rosenthal (1961) examined this factor by introducing a condition in which the PI remained short (2 sec) but the intertrial interval (ITI) was lengthened substantially (to 14 sec). The pacing of the imperative stimuli was thereby matched to that of a long PI with the usual short ITI (a 12-sec PI with a 4-sec ITI). A regular series of each of the above two conditions followed a traditional 2-second PI regular series with a 4-second ITI, controlling for immediately preceding context. All subjects were given both possible orders of the two pace-matched conditions following the standard 2-second PI series.

By focusing on the change from the initial standard 2-second PI series, Zahn, Shakow, and Rosenthal (1961) were able to demonstrate that the short PI with the long ITI did not lead to significant slowing, but the long PI with the standard ITI did lead to slowing for their 26 chronic schizophrenics. Neither produced significant slowing for the 14 normal controls, which is consistent with their typically much flatter slope of increasing RT with longer regular PIs. Furthermore, the pattern was the same whether mean RT, median RT, or the mean of the three fastest trials at each PI was employed, eliminating the possibility that a very few slow trials were producing the differences. Therefore, the investigators concluded that the length of the PI rather than the tempo of the trials was the crucial determinant of the schizophrenic deficit at the longer PIs. This supported the attentional explanation, since an inability to prepare for quick responding, or maintain the "major set," would be most damaging during the preparatory interval rather than the ITI.

Two limitations to the conclusions should be noted. First, since the design was not balanced by the use of a long PI/long ITI condition, an optimal examination of the effect of ITI duration could not be made. The special case of a short PI at a pace equal to that of a long PI did allow inferences about the effect of PI length as separated from tempo. However, even these results may have been influenced by the fact that the PI in the slow-paced short PI condition was identical to that used in the initial 2-second standard regular series, while the long PI regular series involved a change of PI.

The powerful influence of the preceding block of regular RT trials was cited to explain another aspect of these results. The slow-paced short PI condition and the long PI condition could be compared not only for each case following the initial standard 2-second PI series, but also for the instances when each was presented as the third block of regular trials. In this latter instance, the mean RT of slow-paced short PI series also shows significant deficit for the schizophrenic group. Zahn, Shakow, and Rosenthal (1961) account for this by noting that this block of short PI trials had been preceded by the block of long PI trials, a situation which had been shown in another study to produce slowing among schizophrenics. Thus, the effect of the preceding long PI series seemed to override any influence of the slower pacing. While this appears the likely explanation, the possible additional influence of two consecutive slow tempo series (the long PI and the slow-paced short PI) could not be fully examined in this study, since in no case was the long PI series followed by a short PI series that was not slowly paced.

As mentioned above, another study systematically examined the influence of the order of the regular PI blocks on schizophrenic performance. Zahn, Rosenthal, and Shakow (1961) undertook an investigation focusing on previous findings that suggested a sharp increase in schizophrenic RT between PIs of 4 and 7.5 seconds in regular series, but they found no consistent trend for such a "critical PI." They noted, however, that their

chronic schizophrenic sample responded differently than the normal group to blocks of 14 RT trials with regular preparatory intervals presented in descending order. When compared to an ascending order of blocks of regular PIs ranging from 1 to 10 seconds, the descending order for the schizophrenic group tended to result in less improvement in RT at the shorter PIs.

In this first study with only seven chronic schizophrenics, the difference in slope between the ascending and descending RT-PI curves was only nearing acceptable statistical significance ($p < .10$) when mean RT was used. A second study using 12 chronic schizophrenics and 9 normal subjects and a broader range of PIs successfully replicated this effect, demonstrating that ascending and descending orders led to different slopes for schizophrenics ($p < .01$) and that this difference was greater for patients than for normal controls ($p < .01$). For normal subjects, the curves for the two orders were in fact virtually identical.

Zahn, Rosenthal, and Shakow (1961) interpret these findings as indicating that chronic schizophrenics are unduly influenced by the preceding context, in this instance the last block of trials. In the descending sequence, the longer PIs of the preceding block apparently hinder the development of the optimal mental set for the earlier imperative stimulus in the current block of trials. Consistent with Shakow (1950), they argue that the difficulties experienced by the schizophrenic trying to maintain a set during the longer intervals may lead to "withdrawal":

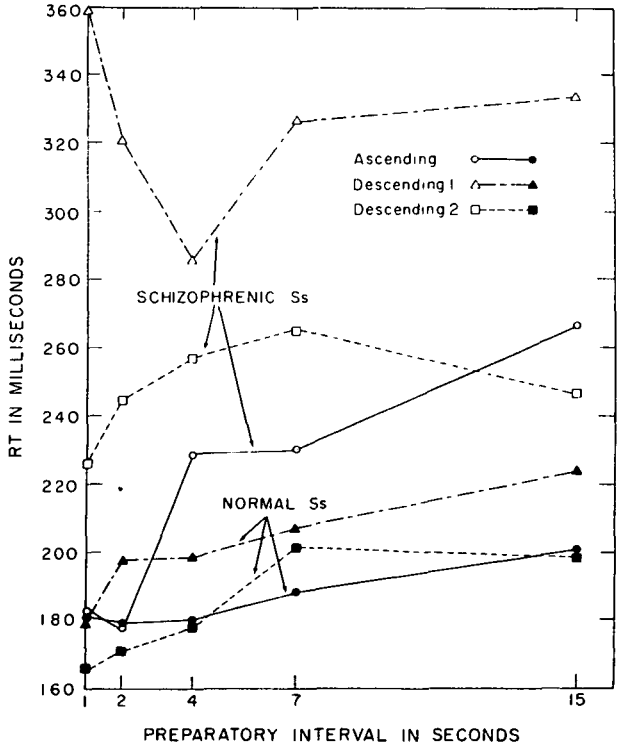
> This process presumably involves both decreased alertness to external stimulation (inability to establish a "major set"), especially to task relevant stimuli ("ready" signal, stimulus), and increased attention to irrelevant stimuli (intrusion of "minor sets"). [Zahn, Rosenthal, and Shakow 1961, p. 168]

These effects of withdrawal then presumably continue during the shorter, less demanding PI blocks, slowing the schizophrenic's reaction time.

One other possible explanation is recognized by these investigators. The patient's general level of arousal may be affected to a greater degree by a series of long PIs. Either a decrease or an increase in the basal arousal might be associated with a deficit on the next PI block, depending on whether the schizophrenic is initially physiologically hypoaroused or hyperaroused. Moreover, they note that the "withdrawal" hypothesis and the "hyperarousal" hypothesis are not intrinsically contradictory, but may refer to coexistent states in the schizophrenic.

One final aspect of this study deserves mention, since it provides a more convincing test of the possibility, raised by Tizard and Venables (1956), that the RT-PI relationship characteristic of chronic schizophrenics is due to the general slowing of reaction time. The six fastest schizophrenic patients in the Zahn, Rosenthal, and Shakow (1961) study were found to match the seven slowest normal controls in mean RT under "optimal conditions"—namely, for the 2-second PI in the ascending order. However, as shown in figure 2, these schizophrenics already show greater slowing than the normals at the next longer PI, and were found to show the greater difference in slopes for ascending and descending series ($p < .001$) that characterized the entire

Figure 2. RT as a function of the PI in ascending and descending regular series[1]



[1]From: Zahn, T.P.; Rosenthal, D.; and Shakow, D. Reaction time in schizophrenic and normal subjects in relation to the sequence series of regular preparatory intervals. *Journal of Abnormal and Social Psychology*, 63:161-168, 1961. Copyright © 1961 by the American Psychological Association. Reprinted by permission.

schizophrenic sample. Thus, the abnormally marked effect of the duration of PIs on chronic schizophrenics does not appear to be a direct function of their general level of RT, but must be explained as a separate phenomenon. This is consistent with Shakow's emphasis on these RT-PI relationships as evidence of deficient attentional mechanisms rather than of the motivational or motor difficulties that may be factors in the overall simple RT level.

The Effects of PIs in Irregular Series

From the preceding two studies, it appears that the hypothetical construct of mental set has some explanatory power for the RT performance of chronic schizophrenics on series of regular PI trials. However, as Rosenthal et al. (1960) had noted, this construct and the related ones of major and minor sets (Shakow 1950 and 1962) seemed less relevant to irregular series of PIs. Chronic schizophrenics typically showed the opposite RT-PI relationship for the irregular procedure than for the regular procedure. That is, the schizophrenic group reacted most slowly on the shorter PIs and faster on the longer PIs, to a much greater extent than seen in the normal group (Rodnick and Shakow 1940 and Tizard and Venables 1956). Two reports from the NIMH investigators have focused on the determinants of schizophrenic performance in the irregular PI condition.

Zahn, Rosenthal, and Shakow (1963) describe two very similar studies in which chronic schizophrenics and normals were administered auditory RT trials with an irregular ordering of PIs, arranged so that every PI followed every other PI at least once in each block of trials. The absolute levels of RT for the chronic schizophrenics were, as usual, greater than for normals. By computing the slope of the RT-PI curve for each subject, they also confirmed earlier findings of a significantly steeper negative slope of RT, as a function of increasing PI, for the schizophrenic than for the normal sample.

Most importantly, Zahn, Rosenthal, and Shakow (1963) provide evidence that the duration of the PI that immediately precedes the current one has an unusually strong control over schizophrenic performance. While a significant effect of the preceding preparatory interval (PPI) was also present for the normal subjects, chronic schizophrenics were influenced to a significantly larger extent. The nature of this effect is such that RT becomes a positive function of the PPI, as illustrated in figure 3. Thus, when mean RT is averaged across all PIs and plotted as a function of PPI, RT tends to increase as the duration of this interval on the last trial becomes longer.

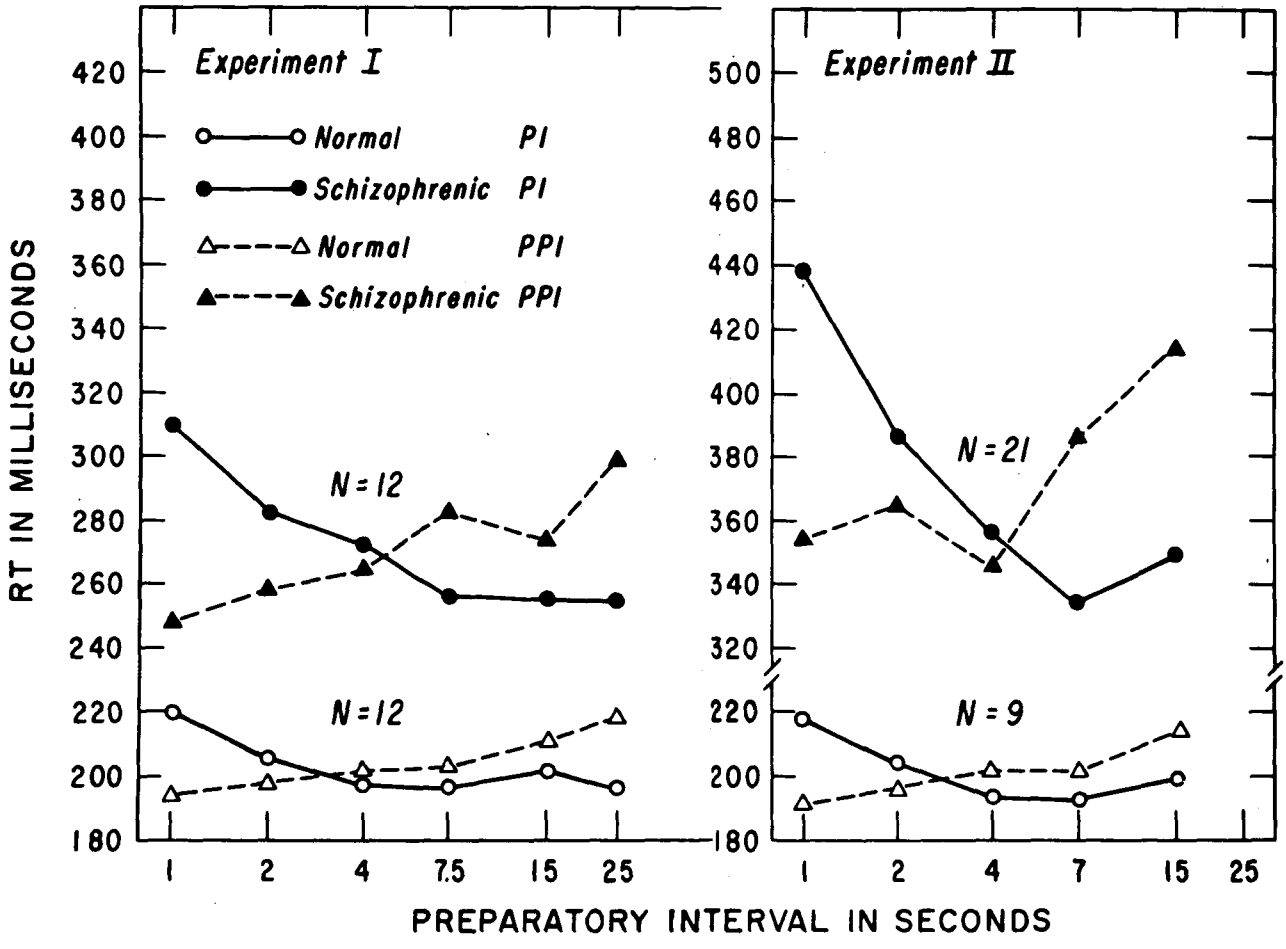
Evidence is presented that not only the overall slope of this function, but also the retarding effect of a PPI longer than (as compared to shorter than) the PI, are significantly greater for the chronic schizophrenic than for the normal groups. The amount of slowing associated with the PPI when longer than the PI also tends to increase with the magnitude of the PPI-PI difference, while no clear systematic RT changes seem to relate to this discrepancy when the PPI is shorter than the PI.

In the irregular series, the shorter the PI, the more likely that the PPI is a longer one and that the PPI-PI discrepancy is large. Therefore, the unusually strong influence of the PPI on chronic schizophrenics may account for retardation of reaction time at the shorter PIs in the irregular procedure.

The marked effect of the PPI is linked in Zahn, Rosenthal, and Shakow's (1963) interpretation with the same schizophrenic deficit in maintenance of the major or task-oriented set that had been used to account for performance in the regular PI procedure. In this case, the optimal mental set would presumably involve being continually prepared for the demand stimulus from the shortest to longest possible PI after the warning signal. Not even normal subjects show an ability to maintain their peak state of readiness uniformly across these PIs, but schizophrenic patients appear to allow the preceding trial to interfere exceedingly with development of an optimal preparedness on the current trial. Shakow (1950, 1962, 1963, and 1971), as we have noted, refers to such irrelevant, intruding aspects as "minor" sets. Schizophrenics are viewed as simplifying this difficult task by basing their attentional deployment for the present trial to an unrealistic extent on the PI of the preceding trial. Attending to the PPI therefore produces minor sets, while the major set requires consideration of the full range of possible PIs.

This explanation in terms of task simplification assumes that the unpredictability of the PIs in the irregular procedure is a crucial determinant of the greater dependence on the PPI and, therefore, of the characteristic negative slope of RT with increasing PIs. Since the RT curve for schizophrenics in the irregular PI condition seems to be due largely to the retarding effect of a long PPI, however, it could be the properties of a long PPI per

Figure 3. RT as a function of PI and PPI[1]



Note.—The effect of the preparatory interval and the preceding preparatory interval on reaction time performance in schizophrenic and normal subjects is illustrated.

[1]From: Zahn, T.P.; Rosenthal, D.; and Shakow, D. Effects of irregular preparatory intervals on reaction time in schizophrenia. *Journal of Abnormal and Social Psychology,* 67:44-52, 1963. Copyright © 1963 by the American Psychological Association. Reprinted by permission.

se rather than the unpredictibility of the next PI that are the critical element. As noted by Zahn, Rosenthal, and Shakow (1963), the previous studies (Zahn, Rosenthal, and Shakow 1961, and Zahn, Shakow, and Rosenthal 1961) had demonstrated that a series of long PIs led to RT slowing for both present and subsequent trials. Perhaps a single long PPI could have a similar effect. The most recent study in this NIMH series examined these factors of sequence and unpredictability independently to clarify their impact.

To separate the random presentation of different length PIs from their unpredictability, Zahn (1970) informed his subjects before each trial of a randomized series whether a "short" (2-sec) or "long" (12-sec) PI

would be used. He compared this "information" condition to the usual irregular and regular procedures using the same two PIs, counterbalancing the order of these conditions across two sessions. Subjects included both "back ward" and "early chronic" schizophrenics from a State hospital, the latter having a median of 2.0 years since their first hospitalization. Over half of these patients were taking ataractic drugs at the time of testing, a situation that had not characterized the earlier studies in this series.

For the 2-second PI, Zahn found that the combined schizophrenic group was less able to profit from the information about the next PI than was the normal control group. (The pattern was similar for each schizophrenic group although the "early chronic" group had faster overall RT.) This was evident in larger absolute slowing of RT from the regular to the irregular, informational condition and in greater slowing relative to the total RT difference between regular and standard irregular conditions. Despite this difference, both schizophrenics and normals produced significantly faster RTs in the informational as compared to the conventional irregular series. Therefore, the factor of unpredictability apparently does contribute to RT slowing in irregular series for both schizophrenics and normals, but eliminating this element does not affect schizophrenics as much as normals.

While not explicitly noted by Zahn, this evidence argues against the Zahn, Rosenthal, and Shakow (1963) explanation of schizophrenic performance in the irregular procedure as a response mainly to the unpredictability of PIs. If not knowing when to expect the imperative stimulus led the schizophrenics (more than normal subjects) to develop stronger minor sets based on the PPI that interfere with the optimal major set, then the information about the next PI should have aided schizophrenics more than normals. Specifically, the schizophrenics should have been able to attend selectively to that period after the warning signal in which they had been told the demand stimulus would appear, regardless of the PPI. It should be noted, however, that using only two PIs may not provide an optimal test of the role of unpredictability. The usual irregular procedure employs four to six different PIs and involves a greater degree of unpredictability than the present procedure.

The alternative explanation suggested by Zahn, Rosenthal, and Shakow (1963)—that the long PI per se has stronger detrimental effects on schizophrenics—gains some support. Zahn (1970) reports that on the 12-second PI trials, there were no significant differences among conditions, although the usual longer overall mean RT of the schizophrenics was present. This implies that unpredictability does not have a noticeable role in determining RT at the longer PIs, unlike its role at the short PIs. Apparently, the maintenance of focused attention for the longer period is not impaired by the possibility that the critical stimulus might appear earlier. In effect, this confirms the earlier evidence (Zahn, Rosenthal, and Shakow 1963) that the longer rather than shorter PPI has the most potent effect on schizophrenic RT.

If the characteristic slowing of chronic schizophrenics at the shorter PIs in the irregular procedure were mainly due to the intrinsic impact of long PPIs, it would be predicted that eliminating the unpredictability factor could not reduce the RT of an irregular procedure to the level of the regular procedure. Indeed, Zahn (1970) finds that both schizophrenics and normals remain significantly impaired in the predictable but irregular condition when compared to the regular condition. Furthermore, as noted, the schizophrenic group shows more remaining impairment than the normal group.

Unfortunately, this interpretation also fails to receive consistent support. If the intrinsic properties of the long PPI rather than the unpredictability of the next PI led to the characteristic schizophrenic performance on irregular PI series, then the PPI should continue to have a significantly greater effect on schizophrenics than normals for the 2-second PI trials when the subject knows which PI to expect. Zahn's results show only a trend for this greater PPI effect in the information condition, while the effect is significantly greater for the schizophrenics than normals ($p < .01$) in the standard irregular procedure. This cannot be taken as strong disconfirmatory evidence, but may indicate that the influence of long PPIs alone may not account for the remaining schizophrenic deficit in the information condition.

Zahn (1970), furthermore, provided a test of whether the time element involved in irregular PIs was critical to the remaining impairment on predictable but irregular series of trials compared to regular series. While he conceptualizes this time factor as allowing an "anchoring" effect of long PPIs on time estimation, his results are relevant to other possible explanations of the retarding effects of long PPIs as well (e.g., withdrawal, arousal

changes). In order to eliminate the time factor while retaining irregular and regular conditions of stimulus presentation, a spatial choice RT task was substituted for the simple RT task used in the earlier experiment. The subjects were the "early chronic" schizophrenics who participated in the first experiment, minus one who would no longer cooperate, and the same normal controls.

In each condition, subjects were required to press down a middle pushbutton until one of two white lights was presented 2 seconds later. The subject then had to jump to press the telegraph key located below the illuminated bulb as quickly as possible. Two telegraph keys corresponding to the two white lights were each located 14 inches from the "ready" pushbutton. The regular condition involved consistently responding to either the right or left stimulus, designated before the block of trials began. In the irregular condition, the subject had to press the correct key in response to a randomized, unpredictable ordering of the two visual stimuli. The "information" condition differed from the irregular procedure only in that a green light over one of the white stimulus bulbs turned on at the beginning of each trial to indicate which imperative stimulus would be presented.

For this spatial rather than temporal irregularity, normal subjects, when informed beforehand which stimulus would be presented next, were able to react just as fast as they did on regular trials. The schizophrenic group, however, still showed a mean RT to this information condition that was significantly slower than that for the regular condition. Thus, again the elimination of unpredictability in the irregular series appears to aid normal more than schizophrenic individuals. The schizophrenic group's deficit cannot, therefore, be assigned chiefly to faulty expectancies or overdependence on the preceding trial due to the inability to predict the selected imperative stimulus.

Zahn notes that some effect of disrupted time estimation is suggested for both normals and schizophrenics, since both groups showed more improvement in the information condition of the spatial choice RT task than they had in the parallel condition of the simple RT task with varying PIs. An additional finding also supports the contribution of the time element to the schizophrenics' performance, although it is not mentioned by the investigator in this context. In the spatial choice RT task, the schizophrenic group did not show any greater slowing from the regular to irregular condition than did the normal group. Thus, when spatial rather than temporal irregularity is employed, the effects of unpredictable changes in stimulus conditions may be similar for schizophrenics and normals. (See the section on choice versus simple RT for a more thorough evaluation of this possibility.) This leads to the conclusion that the impaired schizophrenic performance at the short PIs of an irregular PI series may be *partially* due to the time element intrinsic to long PPIs. Unfortunately, a difference in the response complexity involved in the spatial and temporal RT tasks precludes any clear attribution of these differences to the temporal factor.

Recognition of the possible contribution of specifically temporal irregularity does not, however, eliminate the need to explain the schizophrenics' deficit in the information condition of Zahn's spatial choice RT data. Since the PI was fixed at 2 seconds for all trials in this task, the retardation of schizophrenic RT in this condition cannot be due to long or variable PPIs. Hypotheses about schizophrenics' withdrawal or changed arousal in the demanding long PI situation (Zahn, Rosenthal, and Shakow 1961) could conceivably be extended to account for performance in difficult situations generally.

However, this would not explain why the information condition but not the presumably *more* difficult irregular condition of the spatial choice RT led to greater slowing among schizophrenics than normals. Furthermore, at least one study (Zahn 1964) suggests that chronic schizophrenics show less change in basal autonomic arousal across situations varying in demandingness (including an RT task) than do normal persons.

Zahn's (1970) own interpretation stresses the effects of "irregularity per se" on schizophrenic patients. He suggests that the schizophrenics failed to make appropriate adjustments in their preparatory sets even after receiving information about the next trial. Viewing the irregular presentation of stimuli as a more complex situation than the regular procedure, Zahn offers an extension of Shakow's (1962 and 1963) set theory "by positing that the impairment will increase as a function of the number of separate elements of the situation that must be incorporated into the set. One might say that schizophrenics are differentially affected by preparatory set complexity" (p. 142).

This emphasis on task complexity yields a plausible account of the slowing on information as compared to regular conditions, and for the simple RT task generally.

Like the above explanations, however, it fails to explain the lack of greater schizophrenic slowing on the irregular condition of the spatial choice RT experiment, since this appears to require a more complex preparatory set than does the impairing information condition.

In summary, perhaps the soundest conclusion from Zahn's (1970) multifaceted results is simply that schizophrenics did not profit as greatly as normals from increased predictability of stimulation in two kinds of irregular RT series. The results thus suggest that schizophrenics are not pushed to rely on the PPI mainly because of their inability to cope with the unpredictability of subsequent stimuli. However, the reason for the abnormally strong PPI effect on schizophrenic performance is not clear.

Explanations of the effect of irregular stimulus conditions that emphasize the complexity of the required set appear consistent with results for temporal but not spatial irregularity. Since spatial inconsistency seems not to be comparable to temporal inconsistency for these schizophrenics, perhaps separate theoretical treatment is necessary. On the other hand, the greater response complexity in the spatial choice relative to the simple RT task may confound the comparison of these two types of stimulus irregularity. At the present time, no hypothesis offered by this group of researchers can adequately accommodate Zahn's (1970) results for both types of stimulus inconsistency. We shall see later, however, that Zahn's failure to find differential impairment for schizophrenics on choice RT, compared to simple RT, is not a consistent one in the literature. Moreover, in the section on choice RT, we will find that such results may be due to methodological limitations of the experimental designs.

Further Examination of the Effects of Stimulus Sequence on Schizophrenic Reaction Time

The Effect of Cross-Modal Stimulus Shifts

In the studies thus far reviewed, important differences between schizophrenic and normal individuals in the RT situation have been revealed when regular and irregular PI series are considered. Manipulation of the length of this foreperiod is, of course, only one possible source of stimulus regularity or irregularity. The attempt by Zahn (1970) to introduce spatial irregularity illustrates another possibility, although we have seen that it may not be comparable to temporal irregularity.

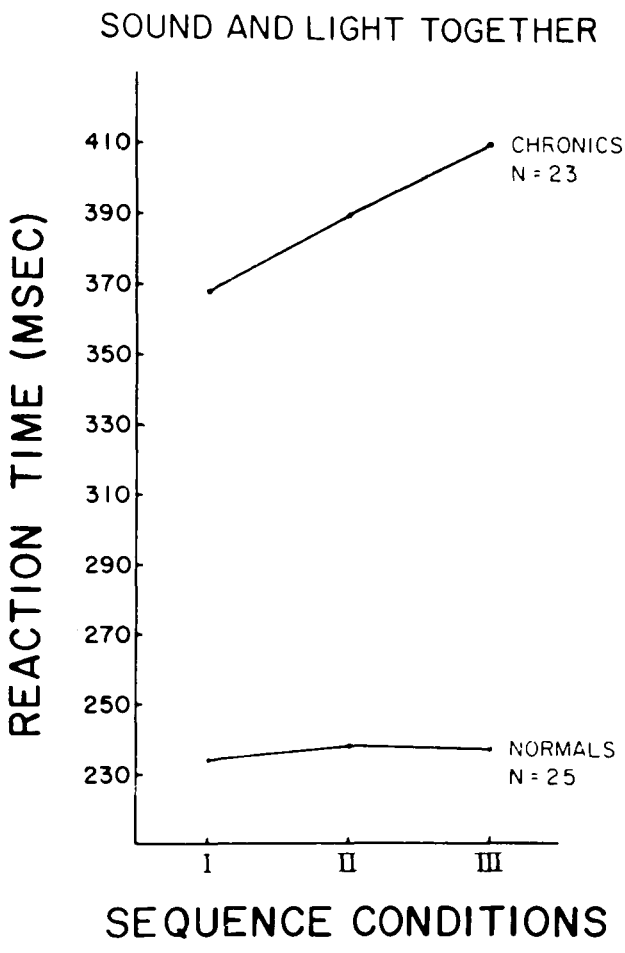
A series of studies by Sutton, Zubin, and their collaborators has focused on the effects of sequential changes in still another variable—the sensory modality of the stimulus. Their original experiment (Sutton et al. 1961) employed four stimuli in two sensory modalities (red light, green light, high tone, and low tone) as imperative stimuli. These were presented in an irregular order, with the subjects instructed to respond as quickly as possible to each. The same finger-lift response was required for each stimulus, avoiding any response competition or decision-making factors.

The mean RT on trials in which the stimulus was identical to the previous one was used as a baseline for overall RT level. Slowing of RT due to stimulus sequence was examined separately for trials involving changes in stimulus within the same modality and changes across modality. Sutton et al. (1961) found that chronic schizophrenics were slowed significantly more than normals by cross-modal changes in stimuli, and somewhat but not significantly more by ipsimodal changes. These data are summarized in figure 4.

A more detailed analysis of these effects was made in three subsequent experiments reported by Sutton and Zubin (1965). The first differed from the original study chiefly in the larger number of trials and the use of new hospital admissions rather than chronic patients. The additional trials allowed separate analyses for RTs to light and sound and for process and reactive schizophrenics. Reactive schizophrenics (on the basis of the Phillips Scale) were found to be somewhat faster overall than process schizophrenics but not significantly different in their pattern of response to ipsimodal and cross-modal shifts, so their data were combined for further analyses. Unexpectedly, this male schizophrenic sample showed significantly greater increments in RT than normal controls due to stimulus change only when the current trial involved an auditory stimulus. For these trials, both ipsimodal and cross-modal changes resulted in significantly greater impairment for schizophrenics than for the normal controls.

Sutton and Zubin's (1965) second experiment was modified by the addition of a response uncertainty factor, in the form of separate response keys for each of the four stimuli. This four-choice reaction time situ-

Figure 4. Mean simple RT for chronic schizophrenics and normals[1]



Note.—**Mean simple reaction time as a function of type of stimulus sequence is illustrated for chronic schizophrenic patients and normals. I = same stimulus; II = ipsimodal stimulus; III = cross-modal stimulus.**

[1]**From: Sutton, S., and Zubin, J. Effect of sequence on reaction time in schizophrenia. In: Welford, A.T., and Birren, J.E., eds. *Behavior, Aging and the Nervous System,* 1965. pp. 562-597. Courtesy of Charles C Thomas, Springfield, Ill.**

ation is in many ways similar to Zahn's later work (1970) with spatial choice RT, in that stimulus and response inconsistency are present simultaneously. Sutton and Zubin recognized the confounding influence this might have, but wondered whether stimulus sequence would have similar effects when such response uncertainty was present. The subjects in this second experiment were chronic schizophrenics (greater than 2 years' continuous hospitalization) and normal hospital and research staff members. Basically the results are similar to those in the simple RT situation in that cross-modal changes in stimuli from light to sound produced significantly greater slowing of RT for male patients than for male normals. Again no significantly larger retardation occurred when the current stimulus was visual. However, in addition, examination of the data from female schizophrenics included in this sample showed no differential effect of stimulus change for any condition. Furthermore, in this experiment no such effect was present for males for ipsimodal changes on auditory trials.

Finally, their third study examined the possibility that cumulative sequential effects were differentially strong for schizophrenics. Simple RT to low tone stimuli were therefore compared on trials that had been preceded by either one, two, three, or four red light trials, or one, two, three, or four high tone trials. The patient group was similar to the new admission sample used previously in the first of these three studies. No clear evidence for a buildup of such a retarding effect could be found for either schizophrenics or normals. Male schizophrenics were significantly more slowed on cross-modal as compared to ipsimodal shifts when either one or four stimuli had preceded the current trial, but not when two or three had preceded.

The most recently published cross-modal RT study from this research group (Waldbaum, Sutton, and Kerr 1975) has again demonstrated the significantly greater retardation effect of cross-modal sequences upon male schizophrenics when compared to normal individuals. While similar trends emerged for RT to light and sound trials, the lack of separate analyses by modality makes it impossible to conclude whether both revealed significant differential cross-modality slowing in this study.

The overall impression that one gains from these studies is that retardation of RT due to cross-modal changes in stimuli is certainly under some conditions more pronounced in schizophrenics. However, the inconsistency of this effect across sex and (sometimes) stimulus modality would appear to restrict its theoretical implications. It is, nevertheless, interesting to find that stimulus inconsistency in the form of cross-modal shifting tends to have an impact on schizophrenics that is similar to (but possibly less pervasive than) inconsistency of PIs.

Zubin's Neuronal Trace Model

Zubin (1975) has formulated a hypothesis to account for these similar effects of varying types of stimulus irregularity on the RT performance of schizophrenics. He notes that Waldbaum, Sutton, and Kerr (1975), like Zahn (1970), had employed a condition eliminating stimulus uncertainty by informing the subject what the nature of the next stimulus would be. Consistent with Zahn's findings, Waldbaum, Sutton, and Kerr found that under these conditions the differential retardation of RT by stimulus inconsistency—in this instance, cross-modal shifts—was reduced but was still significantly greater for schizophrenic than for normal subjects. Moreover, when guessing the modality of the next trial was used as an index of expectancy, the schizophrenics showed no tendency toward unrealistic expectations and in fact continued to display differential cross-modal slowing even on trials for which they guessed correctly. Thus, the role of false expectancies in generating the schizophrenic's undue influence by prior stimuli was again found to account for at best only part of their RT slowing. An alternative source of the effects of the PPI and cross-modal stimuli seems necessary.

Zubin suggests a model based on the assumption that facilitating and inhibitory neural traces have greater duration in schizophrenics than in normals. Basically, the processing of a given RT stimulus is hypothesized to leave a facilitating trace for similar future stimuli and an inhibitory trace for dissimilar stimuli. Zubin cites neurophysiological evidence that the neural substrates for attention and for suppression may be closely intertwined, supporting his postulation of inhibitory traces for attention to nonpresent but potentially competing stimuli. In the case of a series of ipsimodal and cross-modal stimuli, then, the facilitation or inhibition from previous stimuli is assumed to center on the modality variable, while for an irregular PI series, the focus is on PI duration.

Consistent with this model, Zubin notes that in the modality experiments, a stimulus identical to the previous one results in the fastest RT, an ipsimodal stimulus the next fastest RT, and a cross-modal stimulus the slowest RT. This progression would parallel decreased facilitation and increased inhibition of the stimulus in neural pathways. These tendencies would then be present in both normal and schizophrenic persons, as was typically the case in the modality studies. In schizophrenic individuals (particularly process schizophrenics), however, the immediate effects of stimulation are assumed to persist longer. Thus, the impact of prior stimuli, at any given point, will be stronger both in facilitating similar stimuli and in inhibiting dissimilar stimuli.

The stronger impact of prior stimuli on schizophrenics has been noted in instances of the PPI, blocks of long PIs, and, in some circumstances, the cross-modal shift. One virtue of Zubin's proposal is that such disproportionately retarding influences on RT for schizophrenics can be accounted for in the absence of stimulus unpredictability and faulty expectations (Waldbaum, Sutton, and Kerr 1975 and Zahn 1970). Thus, the cognitive or conceptual elements that are often associated with Shakow's discussions of mental set are not implied in Zubin's model. Exactly why conditions of stimulus uncertainty should further retard RT of both schizophrenics and normals is not clear for Zubin, although he speculates that the effective energy of the stimulus may be reduced or the criterion for stimulus perception increased in this situation.

This model also leads to hypotheses that modality shifts should have increased effects after several successive presentations of another stimulus and should be decreased when the intertrial interval is increased. The first effect should be especially strong for schizophrenics, while the latter should not be as marked for schizophrenics as for normals. The third study reported by Sutton and Zubin (1965) is cited in support of the former prediction, since schizophrenics were differentially slower when a modality shift followed four presentations of another stimulus but not when fewer identical stimuli preceded the modality change. While provocative, this finding is complicated by the fact that, compared to ipsimodal trials that followed the same number of identical stimulus presentations, cross-modal shifts produced retarded RT after either one or four presentations of another stimulus. Thus, a clear-cut incremental effect was not demonstrated (Sutton and Zubin 1965), and further investigation of this prediction seems indicated.

In summary, Zubin's model (1975) does appear to be consistent with most of the basic data on schizophrenic performance under conditions of irregular stimulus presentation. In most instances, predictions based on this model do not differ from those of Shakow's set theory, but Zubin's proposal does appear to have enough specificity to allow some differential hypotheses. Its easier adaptation to data that show the limited influence

of stimulus unpredictability has already been mentioned. A more crucial comparison would seem to involve the effects of intertrial intervals, however. Shakow and his colleagues (e.g., Zahn, Shakow, and Rosenthal 1961) have emphasized the duration of the preparatory interval, and not the tempo of stimulus presentation, as the crucial influence on schizophrenic performance. On the other hand, the increased duration of facilitatory and inhibitory traces in schizophrenics assumed by Zubin's model should lead to predictable changes in the effects of the prior stimuli when the intertrial interval is manipulated. Data on this issue will be presented later.

At least one body of data seems to contradict the predictions of this neural trace model. While Zubin has accounted for the retardation of RT due to the dissimilarity of the present relevant stimulus from the prior stimuli, he has not dealt with the effects of concurrent irrelevant stimuli. Schizophrenics have been shown in several studies to be disproportionately slowed in RT by such distracting stimuli, even in the instance of simple RT to a series of identical stimuli (e.g., McGhie, Chapman, and Lawson 1965*b* and Payne and Caird 1967). Zubin's proposals would appear to predict that the repeated identical imperative stimuli would create stronger cumulative facilitatory traces for schizophrenic than for normal individuals. Dissimilar stimuli, including irrelevant stimuli, should be inhibited more strongly by schizophrenics than by normals. The combination of these two factors would appear to lead to the prediction that schizophrenics would actually be less, rather than more, impaired by distracting stimuli in this situation. As will be seen in a later section, interference theories of schizophrenic performance (e.g., Broen 1968, Shakow 1962, 1963, and 1976, and Storms and Broen 1969) can more readily account for the effects of irrelevant concurrent stimuli while also providing a place for the influence of prior stimuli.

The Case of PPI = PI and PPI-PI Confounding

Two recent studies have suggested that an important addition to earlier findings of PPI effects needs to be made. Nideffer et al. (1971*a* and 1971*b*) point out that previous studies (e.g., Zahn, Rosenthal, and Shakow 1963 and Zahn and Rosenthal 1965) had not analyzed the effects of PPIs equal to PIs within an irregular PI series of RT trials. Often this possibility was precluded by omitting the PPI = PI case when forming the irregular ordering of preparatory intervals. At other times, the PPI = PI trials had been grouped with the PPI < PI trials. Yet Nideffer et al. (1971*b*) argue that Shakow's set theory would predict that it is on such trials that schizophrenics should react fastest within the irregular series, since any set intruding from the previous trial would be task relevant. The reader will realize that Zubin's neuronal trace model leads to the same prediction.

Indeed, in both studies, Nideffer and his collaborators have found that schizophrenics respond significantly faster on PPI = PI trials than on either PPI < PI or PPI > PI trials. This is most convincingly demonstrated by Nideffer et al. (1971*b*), whose study involved a randomized series of auditory RT trials with PIs of 1, 2, or 8 seconds. The subjects consisted of 30 chronic schizophrenics, 30 acute schizophrenics, 30 chronic nonschizophrenic psychiatric patients, and 30 acute nonschizophrenic psychiatric patients. The PPI = PI facilitation can be seen in figure 5, along with the fact that PPI > PI tends to have a stronger retarding impact than PPI < PI, consistent with the earlier set theory studies (Zahn, Rosenthal, and Shakow 1963).

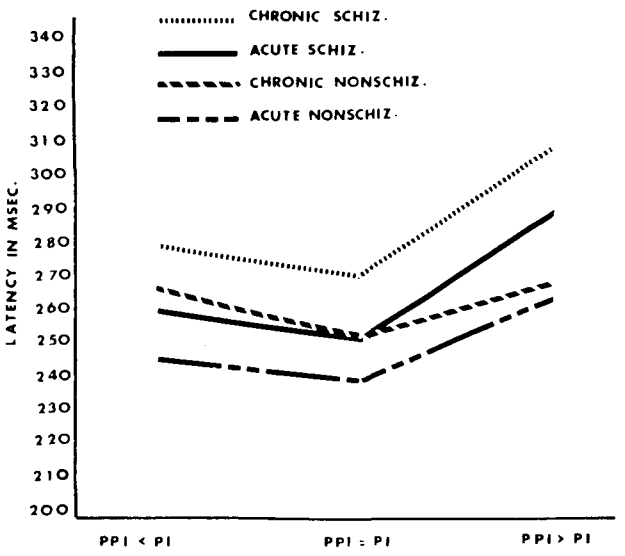
In addition to the above finding, Nideffer et al. (1971*b*) report other sources of support for Shakow's formulation. The PPI = PI condition not only produced the fastest RT within schizophrenics' trials, but aided the schizophrenics relatively more than the nonschizophrenics. This supports the stronger influence of the prior trial for schizophrenics.

Moreover, when anticipatory responses (those preceding stimulus presentation) were considered, schizophrenics were found to show significantly more than nonschizophrenics both when PI was 8 seconds and when PPI < PI. Since the 8-second PI was the longest used, these two conditions can probably be best summarized by the PPI < PI categorization. That is, when the previous stimulus had occurred quickly after the warning signal, the schizophrenics showed a greater tendency to "jump the gun" on the current trial. This seems to offer rather clear and specific support to the role of expectancy and Shakow's minor sets in schizophrenic RT performance. The more frequent anticipations due to this inappropriate set would not have been predicted from Zubin's model, for instance, since sensory facilitation or inhibition can operate only with the occurrence of the stimuli.

Finally, Nideffer et al. (1971*b*) report that when all

PIs are grouped, the PPI > PI condition produces the slowest RT for schizophrenics, consistent with the assumption that they are more prone to be caught "off guard" due to the influence of the previous longer PI. The authors argue, however, that the statistical significance of this result is dependent on a confounding of the PPI-PI relationship with PI. "That is, when PPI > PI the result may be attributable either to the shift from long to short PI or to the fact that the current PI necessarily has to be in the short part of the PI range. It is well known that PI's of one second, for example, yield relatively long RT's" (Nideffer et al. 1971*b*, p. 364). When they analyzed their data with PI held constant at 2 seconds, the PPI > PI effect was not significant. Therefore, they conclude, "the finding of PPI > PI leading to slower RT, as a sensitive index of schizophrenia, should be viewed with great caution" (p. 364).

Figure 5. RT latency as a function of PPI-PI relationship[1]



Note.—Subjects were acute and chronic schizophrenic and nonschizophrenic patients.

[1]From: Nideffer, R.M.; Neale, J.M.; Kopfstein, J.H.; and Cromwell, R. The effect of previous preparatory intervals upon anticipatory responses in the reaction time of schizophrenic and nonschizophrenic patients. *Journal of Nervous and Mental Disease,* 153:360-365, 1971*b*. Copyright © 1971 by The Williams & Wilkins Co. Reprinted by permission.

If, in fact, the PPI > PI retardation effect was due to the confounding that these authors propose, a major reconsideration of the presumed intruding effect of prior preparatory intervals would be necessary. However, this does not appear likely. First, at least one study (Zahn 1970) has found a significantly greater slowing effect of PPI > PI for schizophrenics than normals when PI is held constant ($p < .01$). Unfortunately this investigation differs in several ways from the Nideffer et al. (1971*b*) study, so their divergent findings may be explained in more than one way.

Specifically, Nideffer et al. (1971*b*) compare schizophrenic patients with nonschizophrenic psychiatric patients rather than normal controls. The significance of the PPI > PI relationship (with PI controlled) might be attenuated by a greater tendency for nonschizophrenic patients than for normals to respond slowly in this situation. In this instance, the PPI > PI effect would truly not be a sensitive index of schizophrenia per se, but more generally of psychiatric disorder. An at least equally probable explanation of the discrepant results, however, is that Zahn (1970) employed PIs of 2 and 12 seconds, yielding a larger PPI-PI difference than the 1-, 2-, and 8-second PIs used by Nideffer et al. Previous data (Zahn, Rosenthal, and Shakow 1963) have shown that the PPI > PI retarding effect increases with the PPI-PI difference for schizophrenics.

While the Nideffer et al. (1971*a*) study also found a nonsignificant PPI effect when PI was controlled, it is unable to resolve the contribution of these two factors. It did involve a comparison of schizophrenics and normals, like the study of Zahn (1970), but the PIs were restricted to 0.4, 1.0, and 2.0 seconds. Thus, the PPIs were only minimally discrepant from the PIs in all cases. This atypical PI array led not only to nonsignificant PPI > PI effects but also to a nonsignificant influence of the PPI = PI condition when PI was controlled.

A direct comparison of the PPI > PI retarding phenomenon for schizophrenics, nonschizophrenic psychiatric patients, and normal controls with an adequate range of PIs would best decide this issue. Even in its absence, however, the Nideffer et al. (1971*b*) explanation must be questioned on logical grounds. These authors suggest that the presumed greater PPI > PI effect in schizophrenics "may be primarily because they are debilitated by short PI's rather than because the short PI's were preceded by long ones" (p. 365).

The reader will recall, however, that in the *regular*

PI series the schizophrenics actually show their best performance at the relatively short PIs. Even when some definite slowing at the very short PIs has occurred for schizophrenics in the regular procedure (e.g., Rodnick and Shakow 1940), this mean RT has still been quicker than that at the same PI in the irregular procedure. In sum, the performance of schizophrenics in the irregular PI series appears attributable to the sequence of PIs and very likely to the PPI-PI relationships rather than to any deficit related to short PI per se.

The "Crossover Effect" Reconsidered

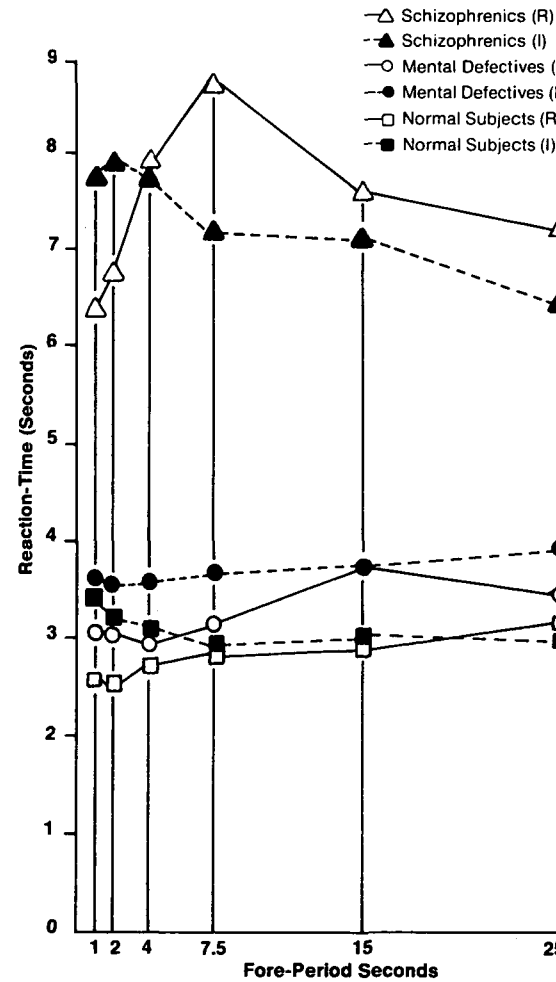
The Specificity and Durability of the Findings

Our examination of the determinants of schizophrenic RT performance has focused on the separate phenomena associated with regular and irregular modes of stimulus presentation. As was noted by Rodnick and Shakow (1940), however, the early crossover of the regular and irregular RT curves plotted as a function of PI is one of the most striking differentiators of chronic schizophrenic and normal performance. A recent study of this phenomenon (Bellissimo and Steffy 1972) has noted that the crossover was found in 7 of 11 studies which examined the interaction between regularity and duration of PI. In only one study was the magnitude of this crossover actually statistically significant, but visual inspection reveals the same trend in the curves of the other studies. Moreover, using a somewhat different procedure for presenting regular and irregular trials, Bellissimo and Steffy (1972 and 1975) and Steffy and Galbraith (1974) have repeatedly demonstrated significant crossover effects for process schizophrenics.

The characterization of the early crossover as evidence of schizophrenic deficit was criticized by Knehr (1954). His own study resulted in crossover of RTs from regular and irregular PI series for both schizophrenics and normals between PIs of 2 and 10 seconds. However, several procedural differences probably invalidate a comparison of his data with the RT studies of the Shakow group. Most importantly, Knehr used a 90° knob twist as the response rather than the typical key release or press, and employed only two rather than the typical 4 to 6 PI lengths. Shortly thereafter, the Tizard and Venables (1956) study replicated the Rodnick and Shakow (1940) earlier crossover (see figure 6) for chronic schizophrenics than for normals, taking care to ensure comparability on such matters.

That such a crossover is not a direct result of the general level of RT was first suggested by Tizard and Venables' (1956) examination of fast and slow responders within their chronic schizophrenic sample. Steffy, as cited by Cromwell (1975), has recently found that the crossover of process schizophrenics remains even when

Figure 6. Mean RTs under regular and irregular conditions[1]



Note.—Subjects were 25 schizophrenics, 10 mental defectives, and 10 university graduates. R = regular and I = irregular.

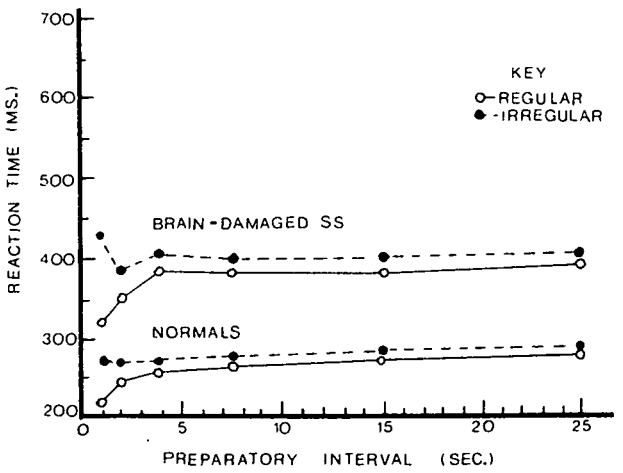
[1]Reprinted with permission from: Tizard, J., and Venables, P.H. Reaction time responses by schizophrenics, mental defectives, and normal adults. *American Journal of Psychiatry*, 112: 803-807, 1956.

the overall level of RT is reduced to the normal range by the experimenter's urging and support. Furthermore, the fact that generally slow responders need not show an early crossover can be seen in Olbrich's (1972) investigation of brain-damaged patients. Despite an overall RT level comparable to that of chronic schizophrenics in some studies, these brain-damaged patients continued to respond faster on regular than irregular trials even at the longest PI of 25 seconds. Nor did they show any marked abnormality of slope on regular or irregular series, as can be seen in figure 7.

The early crossover effect is not completely specific to or universal among schizophrenics, however. A group of aged men (65 to 81 years old) were found by Botwinick, Brinley, and Robbin (1959) to show this crossover between PIs of 6 and 15 seconds, appearing to fall at about 10 seconds (see figure 8). This crossover point is definitely earlier than that found for most younger normal groups, but still later than that found for most chronic schizophrenics, although their crossover point has varied a fair degree from study to study.

That only certain subgroups of schizophrenics are subject to this deficit is quite clear, even though the classification of affected and unaffected members re-

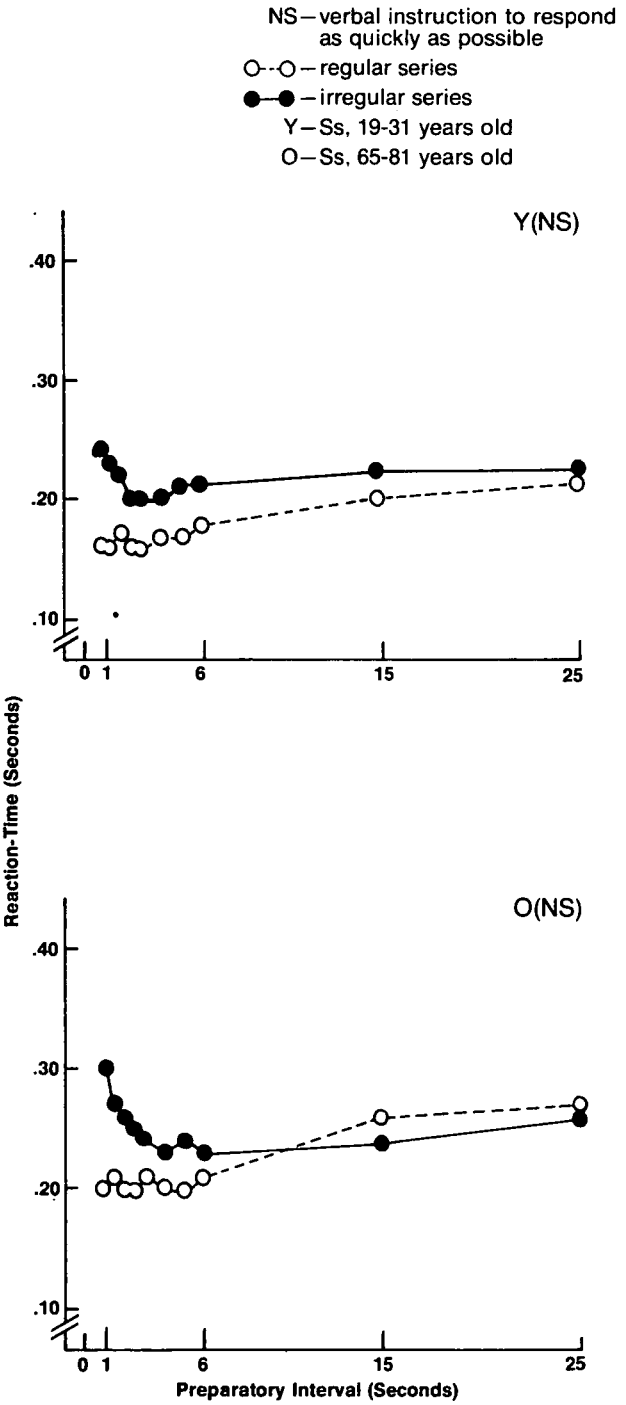
Figure 7. Mean RTs at the various PIs of the regular and irregular procedure[1]



Note.—Subjects were 20 brain-damaged and 20 normal subjects.

[1]From: Olbrich, R. Reaction time in brain-damaged and normal subjects to variable preparatory intervals. *Journal of Nervous and Mental Disease*, 155:356-362, 1972. Copyright © 1972 by The Williams & Wilkins Co. Reprinted by permission.

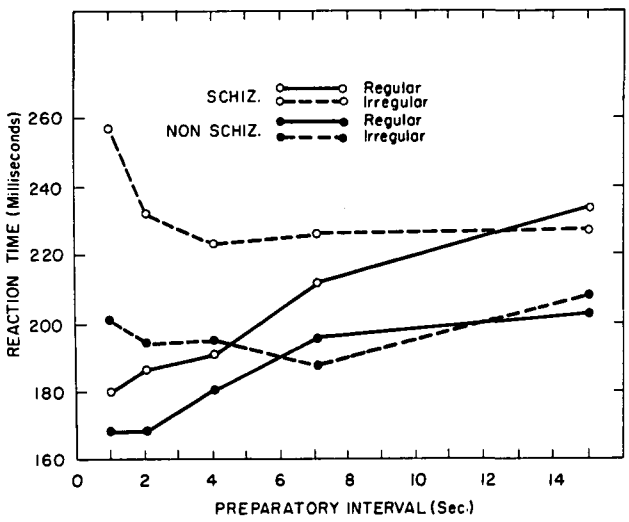
Figure 8. Mean RT as a function of the PI[1]



[1]Reprinted with permission from: Botwinick, J.; Brinley, J.F.; and Robbin, J.S. Maintaining set in relation to motivation and age. *American Journal of Psychology*, 72:585-588, 1959.

mains somewhat ambiguous. Zahn and Rosenthal (1965) found that their sample of acute schizophrenics maintained a faster median RT for regular compared to irregular trials for PIs slightly longer than their nonschizophrenic psychiatric controls, as illustrated in figure 9.

Figure 9. Median RT at each PI under regular and irregular procedures[1]



Note.—Subjects were acute schizophrenics and nonschizophrenic controls.

[1]From: Zahn, T.P., and Rosenthal, D. Preparatory set in acute schizophrenia. *Journal of Nervous and Mental Disease,* 141:352-358, 1965. Copyright © 1965 by The Williams & Wilkins Co. Reprinted by permission.

Their crossover at the 15-second PI is slightly earlier than that typically found for normals, but far from the 4- to 8-second range characteristic of chronic schizophrenics. In two recent studies by Steffy and his collaborators (Bellissimo and Steffy 1972 and Steffy and Galbraith 1974), process but not reactive schizophrenics showed the early crossover. These two categories of unaffected schizophrenics may overlap considerably, since Zahn and Rosenthal's (1965) acute cases were from the armed services and therefore had demonstrated enough premorbid competence to pass the initial psychiatric screening.

Steffy's Redundancy-Associated Deficit Model

Steffy and his colleagues and students at the University of Waterloo have reexamined the set theory explanation of the crossover phenomenon of the Shakow group. As noted earlier, this explanation had viewed the crossover as the result of an inability of schizophrenics to maintain an optimal mental set for the amount of time demanded by the longer PIs. The predictability of the regular series, therefore, could not be fully utilized. Bellissimo and Steffy (1972) have suggested that if performance on long PI trials in the regular series actually becomes slower than in the irregular series, one of two factors must be operating: (1) the short PIs in the irregular series have an alerting or "reminder" value, leading to facilitation of faster RT on succeeding long PIs or (2) the redundancy of information characteristic of repeated identical PIs results in actual impairment in regular series. The first possibility could be viewed as consistent with Shakow's formulation, if short PIs were considered to help reestablish a major set. The second would appear less relevant to a theory based on expectancy and set than to hypotheses postulating rapid accumulation of inhibition.

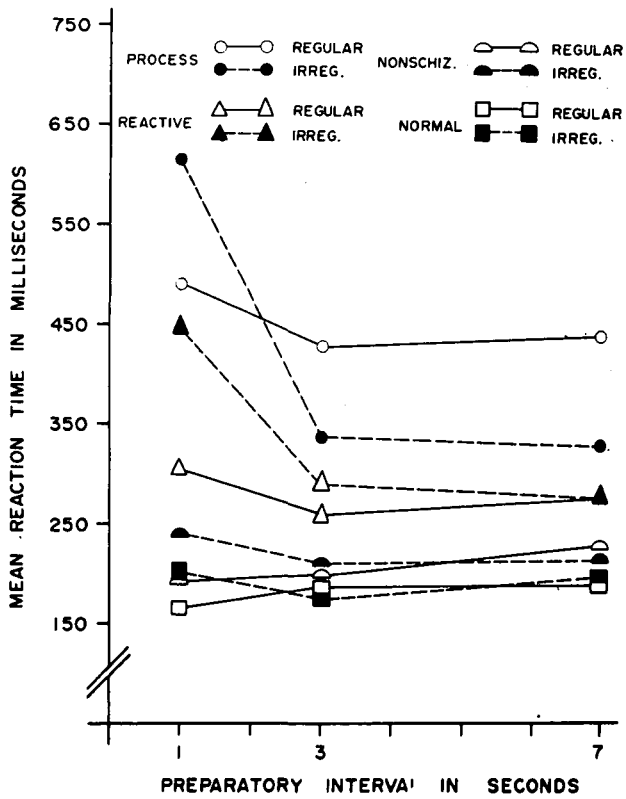
As pointed out by Cromwell (1975) in a review of recent schizophrenia research, the existing data do not support the first possibility. Schizophrenics appear to benefit even more than normals from trials within an irregular series in which PPI = PI and are retarded in comparison for both PPI > PI and PPI < PI, as was shown in figure 5 (Nideffer et al. 1971*a*, and 1971*b*). A similar situation led to the consistent trend for identical stimuli to evoke faster RTs than ipsimodal or cross-modal stimuli (Sutton and Zubin 1965). Moreover, this finding appears most consistent with Shakow's theory since the set from the prior trial would be most task relevant in this case (Nideffer et al. 1971*b*).

Then if both PPI > PI and PPI < PI trials contribute a slowing effect, how can the regular series RT ever average longer than the irregular series RTs? The second possibility may be the answer. Bellissimo and Steffy (1972) argue that in the regular series, the process schizophrenic is benefited by the PPI = PI relationship at first but then rapidly loses this advantage as identical PIs continue. Evidence for this "redundancy-associated deficit" is presented from an experiment in which series of four identical PI trials were embedded in a larger irregular PI series. Thirty-six female schizophrenics

(process and reactive), 18 female nonschizophrenic patients (mostly with neurotic or character disorder diagnoses), and 18 female hospital employees served as subjects.

The fourth identical trial in these mini-regular series was taken as an index of regular PI performance, while the irregular series performance was computed from trials at the same target PIs of 1, 3, and 7 seconds that immediately followed randomized "filler" PIs of 2, 4, 5, 6, or 8 seconds. A significant crossover was demonstrated for process schizophrenics only (figure 10). Furthermore, analyses of the relationship between RTs at the various positions within the four-trial mini-regular conditions supported the hypothesis that an initial speeding of RT after the first trial gave way to subsequent slowing. This phenomenon can be recognized by careful inspection of the RTs for the four positions within these series in figure 11, focusing on the process schizophrenic group.

Figure 10. Mean RT as a function of regular and irregular modes of presentation for PIs of various durations[1]



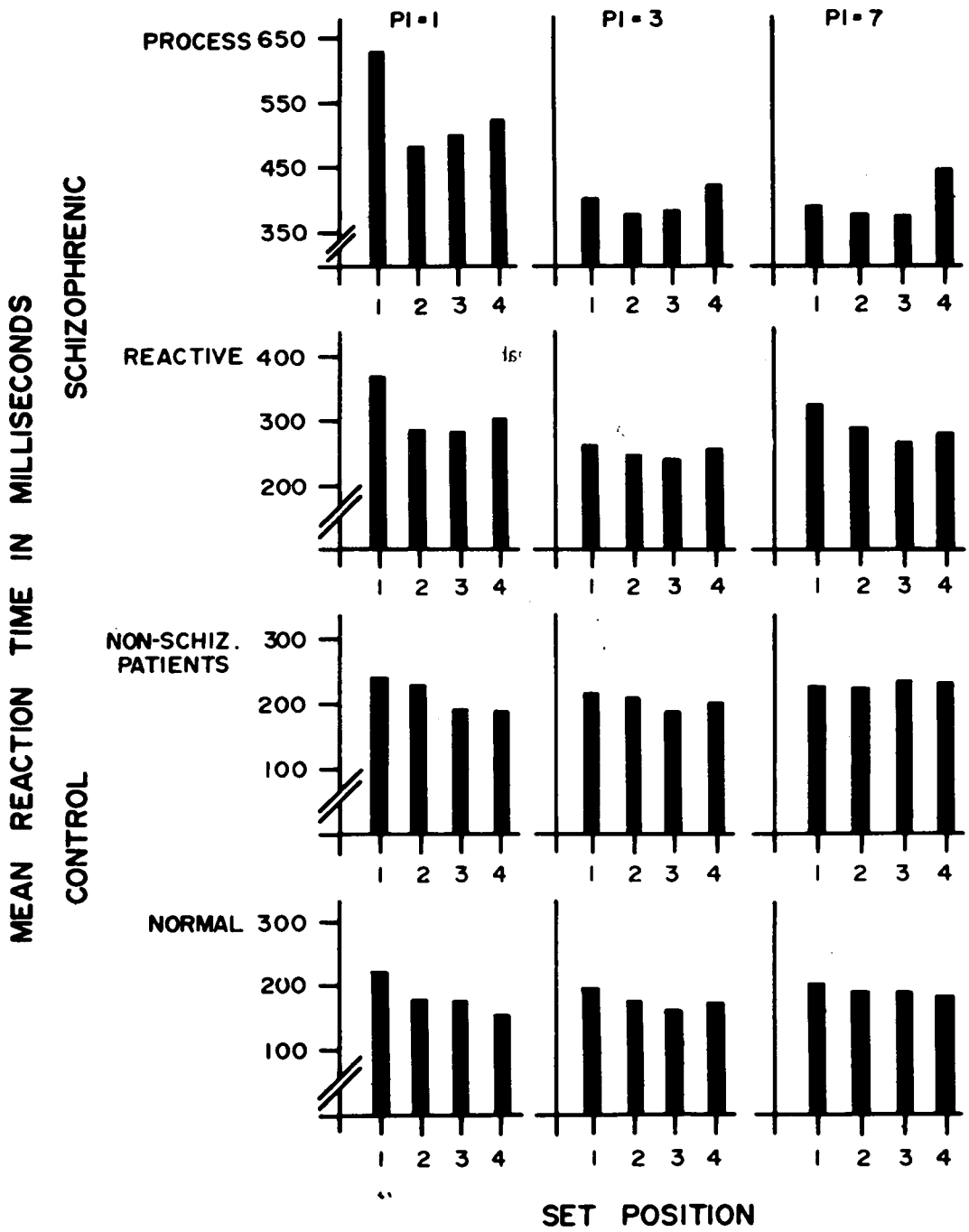
[1]From: Bellissimo, A., and Steffy, R.A. Redundancy-associated deficit in schizophrenic reaction time performance. *Journal of Abnormal Psychology*, 80:299-307, 1972. Copyright ©1972 by the American Psychological Association. Reprinted by permission.

Bellissimo and Steffy (1972) admit that a set explanation could be constructed, inferring that the process schizophrenics drifted away to irrelevant stimuli or intruding minor sets after the second identical trial. However, this seems an example of the ability of set theory to be adapted to almost any outcome in RT experiments, a property that has recently drawn criticism from Chapman and Chapman (1973). Without evidence that such intrusion is occurring here, the inhibitory proposition of the authors appears to be at least equally tenable.

These intriguing results need further examination under the original regular and irregular PI series conditions of the Shakow group, however. The generally negative slope of the regular series curve for the process schizophrenics is atypical of results from the traditional procedures. Most notably, the opportunity to take advantage of stimulus predictability appears much more restricted in the mini-series of four regular trials embedded in an irregular series than in the original regular PI series. In fact, unless the pattern of occasional groupings of four identical PIs is clearly discriminable, the subject might easily experience irregularity as the expectable situation, thereby making the mini-regular series quite unlike the traditional regular condition.

In this context, it is interesting that previous data on related phenomena are in some cases inconsistent with the Bellissimo and Steffy (1972) results. Sutton and Zubin (1965) had examined the RTs to four identical stimuli (either red lights or high tones) for cumulative effects. They found no evidence for a slowing of RT over the sequence, and in one condition even discovered significantly more continued improvement for schizophrenics than for normal controls. Their samples were somewhat dissimilar, since Sutton and Zubin tested new, nonmedicated admissions while Bellissimo and Steffy's patients were medicated and had longer current hospitalizations. The focus on process schizophrenics characterized only the latter study. Thus, whether subtype, medication, or procedural differences account for the discrepant findings is unclear.

Figure 11. Mean RT as a function of position within sets of regular trials[1]



[1]Reprinted with permission from: Bellissimo, A., and Steffy, R.A. Redundancy-associated deficit in schizophrenic reaction time performance. *Journal of Abnormal Psychology*, 80:299-307, 1972.

Tizard and Venables (1956), as Bellissimo and Steffy recognize, also failed to find evidence for such a gradual retardation of RT within the regular series for chronic schizophrenics. This is particularly striking, since they examined longer series (12 trials) of identical trials rather than the embedded four-trial procedure allowed. The crossover was nevertheless present without any apparent buildup of fatigue or inhibition, suggesting that other undiscovered factors may differentiate schizophrenics' responses to regular and irregular series at the longer PIs (or that the PPI < PI condition sometimes does lead to an actual facilitation of RT, as a perusal of Zahn, Rosenthal, and Shakow's [1963] data tables suggests).

Venables and Tizard (1956) and Tizard and Venables (1957) did find evidence that schizophrenics show greater increases in RT to long series of identical stimuli than do normal subjects. The procedures here were less typical of those usually used in examination of regular and irregular PI crossover, however. For the Shakow and McCormick (1965) study that involved more conventional regular series, on the other hand, Bellissimo and Steffy (1972) report a replotting of the data that suggests an increased RT over trials for schizophrenics and a decrease for normals.

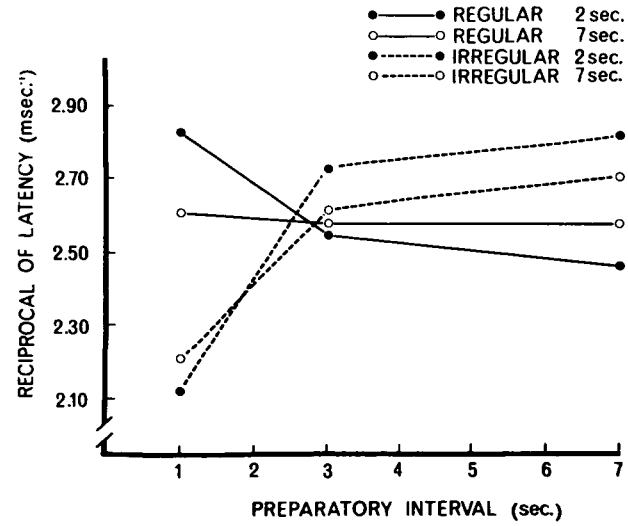
Obviously, the role of redundancy-associated deficit in producing the crossover effect cannot be considered conclusively established at this point. The role of an inhibitory process in some aspects of the crossover phenomenon does gain support, nevertheless, from the Steffy and Galbraith (1974) experiment. Series of four regular trials were again embedded in the context of an irregular PI series, but the crucial manipulation was the intertrial interval (ITI). All 42 process schizophrenic subjects were tested with both a 2-second and a 7-second ITI, counterblanced for order over 2 testing days.

The authors argue that Shakow's set theory would predict that the longer ITI is either not influential in producing lengthened RTs in regular series (Zahn, Shakow, and Rosenthal 1961) or should lead to more deficit since minor sets have more time to form. An inhibitory or suppressive explanation of the impact of regularity would forecast less deficit on regular trials in the long compared to short ITI condition. By extension, the Shakow formulation would predict greater crossover or no change at the long intertrial interval, whereas the inhibitory hypothesis definitely predicts less crossover.

The results support the inhibitory position, since the crossover magnitude was significantly greater for the 2-second than for the 7-second condition. The regular trials more nearly show a significant interaction with length of ITI than do the irregular trials, so Steffy and Galbraith conclude that the regular trials are the primary source of this difference. This indirectly (and somewhat indecisively) supports the redundancy-associated deficit hypothesis. The results are illustrated in mean reciprocal latencies in figure 12, the conversion being employed to reduce heterogeneity of variance. Unfortunately, the authors do not provide a summary of the untransformed data.

Thus, the utility of some kind of inhibitory construct seems to be supported. Certain questions do remain, however. The authors' discussion of the inhibitory process would lead to the prediction that RTs for regular trials should be affected in the same direction at all PIs when the ITI is changed. Specifically, the curve for regular trials should show slowing at each PI when the ITI is decreased. On the contrary, figure 12 shows that RT at the 1-second PI tended to get faster (indexed by the larger reciprocal of latency) when the ITI was decreased. One would think it is at this shortest PI that the

Figure 12. Crossover patterns for 2- and 7-second ITIs[1]



[1]From: Steffy, R.A., and Galbraith, K.A. A comparison of segmental set and inhibitory deficit explanations of the crossover pattern in process schizophrenic reaction time. *Journal of Abnormal Psychology*, 83:227-233, 1974. Copyright © 1974 by the American Psychological Association. Reprinted by permission.

effect of inhibition would be most apparent, since the overall tempo of the stimulus presentation is fastest. At least this would appear the case for the two types of inhibition considered by Steffy and Galbraith—reactive inhibition (a "fatigue" effect) and defensive inhibition against stimulation itself.

This is relevant to the interface between the set and inhibitory positions as they relate to regular series. The latter may have utility for explaining how the regular series trials can actually lead to slower RTs than the irregular series at the longer PIs. Could a similar process also account for the basic finding that schizophrenics show a significantly steeper positive slope of RT as a function of PI for regular trials? Steffy and Galbraith do not claim to explain this aspect, but a careful look at their regular curves suggests that something relevant to this possibility is happening. Shortening the ITI tends to lead to faster RT at the 1-second PI but slower RT at the 7-second PI. If these trends proved reliable, they might be a clue to the processes which lead to the steeper schizophrenic slope.

At the moment, however, it appears that Shakow's set construct more readily accounts for this aspect of schizophrenic RT performance, and the inhibitory hypothesis is most relevant for the extra slowing that allows actual crossover to occur. It was the steep positive slope of the regular trials that originally led to the hypothesis that schizophrenics have a deficient ability to maintain a mental set (Huston, Shakow, and Riggs 1937), so this aspect of the RT is more critical to the utility of set theory than most others. Thus, it appears quite possible that different segments of the schizophrenic RT phenomena may be determined by different processes, rather than being consistent with any single present theoretical formulation. However, the various processes may still be subsumed under the broad heading of attention, since this concept has often included selective, inhibitory, and maintenance aspects of the subject's contact with his environment.

Before leaving this study, it should be noted that certain of the results contradict Zubin's model. Interestingly, although inhibition is also central to this explanation of schizophrenic RT performance, Zubin predicts just the opposite of Steffy's hypothesis for regular trials. The facilitation that Zubin would expect by shortening the ITI on regular trials was generally not seen, except possibly at the 1-second PI. On the irregular trials, Zubin would predict that inhibitory traces would lead to retardation of RT to a greater extent for the shorter intertrial interval. While the trend is again apparently not statistically significant in itself, the faster RTs at the 3- and 7-second PIs of the shorter compared to longer ITI curve do appear to contribute to the overall significant crossover differences. Thus, the direction of changes for both regular and irregular PI presentations is generally the opposite of what Zubin's facilitatory and inhibitory trace formulation would predict.

The most recent studies of the Steffy research group have further explored temporal processes in the RT performance of schizophrenics. Three related studies by Bellissimo and Steffy (1975) examined the extent to which the crossover effect is dependent on the length of the surrounding PIs in the mini-regular-series procedure. Process schizophrenics continued to be slower on the regular than on the irregular trials at the longer PIs, regardless of whether surrounding "filler" trials were longer, shorter, or of about the same length. Thus, the presence of crossover in the Bellissimo and Steffy procedure does not appear to depend mainly on PPI effects. However, the point of the crossover was influenced by the context of "filler" PIs, appearing to occur about 1 to 2 seconds before the PI distribution mean for these studies. Thus, consistent with our discussion of the Nideffer et al. studies (1971*a* and 1971*b*), PPI effects appear to have a clear impact on schizophrenic RT performance, but probably cannot be the sole explanation for the crossover phenomenon.

The crossover at the longer PIs can be successfully "treated," however, by temporal discrimination training, according to a doctoral dissertation by Kaplan (1974) of the Steffy group which was reported by Cromwell (1975). A process schizophrenic group who had shown the crossover in preliminary testing was trained in judging lengths of time and lengths of PIs. A post-test revealed that their crossover had disappeared while that of a schizophrenic control group trained in shape recognition remained.

In interpreting this finding, Kaplan suggests that the process schizophrenic may become increasingly tense in the RT situation and that the information available in the regular trials serves only to aggravate his plight since he is unable to apply it successfully. Thus, the regular condition is especially debilitating and leads to the crossover. With training in the use of the available information, however, their performance can be facilitated.

If one assumes that the improvement is primarily due to changes in the regular series performance, this investigation appears to offer a role for both the Shakow and Steffy hypotheses. The initial inability to utilize the consistency of the regular series is the characteristic that Shakow emphasizes as the deficiency in developing a major set, and should be most apparent at the longer PIs. The subsequent tension buildup and RT debilitation constitute Steffy's defensive inhibition, and also should operate mostly at the long PIs where the schizophrenics' set handicap is greatest. Finally, the training may enhance the major set by allowing more accurate expectancies of stimulus onset and, therefore, prevent the development of defensive inhibition.

Of course, this is a highly speculative account of the processes involved, but it does serve to illustrate the possible complementarity of the two positions. Neither formulation alone appears able to account readily for all aspects of schizophrenics' behavior in the multifaceted RT situation. In fact, this view of the RT data as multiply determined is further reinforced by yet another group of studies—those manipulating motivational conditions.

The Role of Motivational Factors

The reader should by this point have gained an appreciation for the complexity of the differences between schizophrenic and normal individuals in the various RT situations. This should be even more the case when the performance of different subgroups of schizophrenics is recalled. Most importantly, we have seen that hypotheses about schizophrenic deficits in attending to task-relevant stimuli are based not so much on the overall level of RT as on slope as a function of PI, PPI effects, the crossover phenomenon, and other concomitants of regularity or irregularity of stimulus presentation. Likewise, proposals of underlying inhibitory determinants (which may also operate through attentional mediation) have focused on the latter specific patterns rather than on the mean simple RT itself. Given these facts, we can deal with the many studies of motivational influence on RT in a pointed and sophisticated way.

Isolation of the Fundamental Deficit

A motivational explanation for the performance of schizophrenics on RT tasks was offered as early as 1944, shortly after the initial Worcester studies employing various PIs in regular and irregular procedures. Hunt and Cofer (1944) included both the basic slowness and the patterning in their hypothesis:

> . . . the slowness and the excessive variability of the reaction times of schizophrenics and their failure to maintain a set to react might be taken to indicate a partial extinction of their responses to social stimuli. One should remember in this connection that the response used in these studies of reaction time is motivated by an experimenter's instructions. According to this interpretation, more complete uncooperativeness would represent a more complete extinction of social responses in these patients. Apathy would represent a more generalized extinction or weakening of the interests learned in the course of social interaction. . . . Furthermore, the notion that extinction consists of substituting some other response for the one extinguished would allow for the incorporation of the clinically discerned preoccupations characteristic of schizophrenics into this interpretation, for instance, as substitute responses of an implicit sort. [p. 995]

It is noteworthy that Hunt and Cofer focus on presumably long-term processes that underlie the development of attentional disturbance and idiosyncratic preoccupations. Thus, they did not deny the existence of failures to maintain a major set, but rather postulated that these were secondary to the apathy and "withdrawal from reality." This differs in an essential way from a presumption that the RT performance is a reflection of momentary fluctuations in motivation.

Much the same distinction has been made by Shakow (1962) in discussing the problem of subject cooperation in studies of schizophrenia:

> The data from such studies . . . carry the implication of having been collected under optimal conditions—both external and internal. When there is suspicion that nonoptimal conditions are present, justifiable doubt of the validity of the findings arises. The argument may be offered that this poverty in cooperativeness is intrinsic to the psychosis and that therefore any attempt at the separation of its effects is at best academic. This thesis has validity to the extent that poor cooperation is intrinsic. The argument, however, runs into the difficulty of not making a distinction between the intrinsic effects of attitude and other, temporary, or superficial, effects. [pp. 3-4]

Not being willing to make the *a priori* assumption that uncooperativeness was completely intrinsic to the dis-

order, the Shakow group always used an A to E rating scale of cooperativeness. Only patients with ratings of A or B were generally employed in their studies, so the results are more likely than those of some other investigators to reflect the optimal performance of the subjects.

It should be recognized, however, that not even careful selection of patients for cooperativeness will settle the issue that Hunt and Cofer raised. Moreover, probably no experimental manipulation can settle it in studies of persons already schizophrenic. Ultimately, their hypothesis concerns the causal interrelationships between schizophrenic symptomatic behaviors. Some investigators (e.g., Rosenbaum, Mackavey, and Grisell 1957) are willing to assume that even deficiencies in "basic biological motivation" may be eliminated by introduction of primary aversive stimuli. However, it seems just as possible that a truly intrinsic defect in motivation may continue to have residual effects on performance despite the manipulation of such extrinsic factors.

Thus, the issue of whether the deficit underlying schizophrenic RT performance is fundamentally an attentional or a motivational one will likely not be solved by studies of the "structure" of existing psychopathology. "Developmental" studies of persons at high risk for later schizophrenia may allow eventual understanding of the time sequence in which various types of deficits appear and thereby shed more light on this question (Garmezy and Streitman 1974).

The Effects of Motivational Manipulations

Realizing, then, that changes in incentive conditions may not answer the question of fundamental deficit, we can nevertheless expect such studies to clarify the contribution of temporary or superficial motivational factors. Buss (1966) has argued that if schizophrenics are undermotivated, the introduction of positive or negative reinforcers should result in greater improvement for schizophrenics than for normals. This is based on the assumption that normals are sufficiently motivated under baseline conditions anc should, therefore, be nearer their peak performance than schizophrenics. An even more convincing demonstration would involve schizophrenics becoming equally fast in RT as normals.

First, we will focus on studies employing social reinforcement or punishment. Praise, encouragement, or urging led to greater improvement for schizophrenics in simple RT in one study (Stotsky 1957), equal improvement in RT for schizophrenics and normals in three studies (Benton, Jentsch, and Wahler 1960, Goodstein, Guertin, and Blackburn 1961, and Klein, Cicchetti, and Spohn 1967), and less improvement for schizophrenics than normals in complex RT in one study (Stotsky 1957). In addition, one study found that social reward failed to produce any significant improvement in disjunctive RT (Cavanaugh, Cohen, and Lang 1960). In no study does positive social reinforcement lead to equivalent RTs for schizophrenics and normals.

Social (verbal) punishment has not yielded any clearer evidence that overall RT level in schizophrenics is due to lack of motivation. Three studies comparing normal with schizophrenic groups found that verbal punishment was equally effective in improving their RT (Goodstein, Guertin, and Blackburn 1961, Klein, Cicchetti, and Spohn 1967, and Van Dyke and Routh 1973). Two studies did find that verbal punishment appeared more potent than verbal reward in reducing RT (Cavanaugh, Cohen, and Lang 1960, and Goodstein, Guertin, and Blackburn 1961), but this seems to be the case for both schizophrenics and normals (Goodstein, Guertin, and Blackburn 1961 and Klein, Cicchetti, and Spohn 1967).

The impact of social motivation on schizophrenic RT, therefore, appears not generally different than its effect on the performance of normal subjects. This indicates that schizophrenics, when compared to normals, are not slowed in RT because of a temporary lack of motivation that can be easily eliminated by social manipulations. This data would also at first appear contrary to another motivational formulation—that of Garmezy (1966). Garmezy predicted that schizophrenics should be especially sensitive to social aversive stimuli. The direction of such effects was hypothesized to be dependent on whether the aversive stimuli were presented contingent on poor performance, whether the subject could escape the social censure by improved responses, and on other subtle situational factors.

As we have seen, no evidence of differential sensitivity to social censure for schizophrenics when compared to normals was found in the RT studies. The direction of effects also appears disconfirmed in two studies in which "noncontingent" censure was applied (Goodstein, Guertin, and Blackburn 1961 and Van Dyke and Routh 1973). However, these latter results may not be critical to Garmezy's position, since the RT task is

possibly inappropriate to a test of his directional predictions. Unlike the judgment and discrimination situations from which the hypothesis was derived, the simple RT experiment allows no distinct "right" and "wrong" responses, but records only the subjects' RT latency. Thus, presenting social censure "noncontingently" after RT trials may be rather meaningless unless a clear discrimination between fast and slow trials is assumed. Moreover, even the lack of special sensitivity to censure in these studies might reflect the fact that the patients are often on phenothiazines (Garmezy 1974).

It is possible to argue that the results from the above studies may be consistent with the position that schizophrenics are lacking in social responsiveness. This insensitivity to social stimulation is what Hunt and Cofer (1944) and more recently Maher (1966) have suggested as an explanation for the RT performance of schizophrenics. While one might have expected that social motivation would lead to less improvement for schizophrenics than normals, this formulation would certainly not predict that schizophrenics would be more affected by the manipulation of this type of motivating condition. On the other hand, this position should imply different consequences for primary or "biological" reinforcers. If schizophrenics are further below their peak performance than normals in the typical RT experiment because only social reinforcement (the experimenter's approval) is involved, then introduction of primary reinforcers should lead to greater improvement in RT for schizophrenics than for normals.

Indeed, several experiments with primary aversive stimuli do tend to show this. Pascal and Swensen (1952), using a complex discrimination RT task, introduced very loud white noise at the onset of the PI that continued until the subject made the correct response. Under this condition the schizophrenic patients gradually responded faster, so that not only was their overall improvement from baseline greater but also their absolute RT was no longer significantly greater than that of the normal controls. This study is not wholly comparable to most RT experiments, since (in Pascal and Swenson's experiment) two toggle switches were used for the responses and the PI was always very short (1 sec). However, the trend for aversive white noise or electric shock to result in greater RT improvement for schizophrenics than for normals has been found in four other studies (Grisell and Rosenbaum 1963, King 1962, Lang 1959, and Rosenbaum, Mackavey, and Grisell, 1957).

Primary Aversive Stimuli: Reinforcing, Arousing, Alerting, or Punishing?

While there does appear to be a differential impact for such primary aversive stimuli, what is the nature of their effects? Lang (1959) argued that presenting such intense stimuli may have an arousing effect on chronic schizophrenics who are presumably at a lower level of arousal than normals. His experiment seemed to support the position that noncontingent stimulation led to similar improvement. Karras (1962), however, pointed out that Lang's aversive stimuli were always terminated fairly soon after the RT responses, so they may still have been operating as negative reinforcers. Comparing contingent and continuous white noise presented during a visual choice RT task, Karras found that escape from aversive white noise led to improved performance, noncontingent stimulation to impaired performance, and contingent nonaversive stimulation resulted in no significant improvement from a control condition for the mean RT of chronic schizophrenics. Thus, the motivating role of aversive stimuli was supported.

Subsequently, Lang and Buss (1965) and Buss (1966) noted that another explanation was still possible. The onset of the aversive stimulus may have an alerting value since it is simultaneous with the presentation of the imperative stimulus. Therefore, "it is the presence of accompanying stimuli rather than their motivational properties that enhances performance" (Buss 1966, p. 293). This view emphasizes that the aversive stimuli help to focus attention on the imperative stimulus without having motivational effects.

Actually, the Pascal and Swensen (1953) experiment had introduced the aversive white noise at the beginning of the PI rather than simultaneous with the demand stimulus. Since the PI was only 1 second, however, this may still allow the alerting function to operate. Karras (1968) has provided a more direct test of this possibility. Again using a visual choice RT task, he ran two conditions in which the same aversive noise was presented with the onset of the stimulus light. In one condition, this aversive noise terminated immediately with the keypress, while in the other termination was delayed 2.5 or 3.5 seconds after the response. In the immediate escape condition, the schizophrenics improved significantly in RT but not in the delayed condition, which also should have provided the alerting quality. Again, the negative reinforcing aspects appear crucial.

One final interpretation views a combination of attentional disturbance and punishment as contributing to the Karras results. Broen and Storms (1966 and 1967) and Storms and Broen (1969) have suggested that the attention of schizophrenics is disrupted by their greater tendency to respond to nondominant stimuli. In fact, they view increased response competition as central to most schizophrenic behavioral disorganization, as we shall see in a later section. In the RT task, many types of competing responses will harm performance, since the critical measure is speed rather than number of right or wrong responses. In Karras's experiments with choice RT, the alternate key adds an additional source of response competition.

Broen (1968) sees the main influence of contingent aversive stimuli in improving performance to be the suppression of incorrect competing responses rather than the strengthening of the correct response. Aversive stimuli presented noncontingently may instead increase response interference and further impair performance, as in Karras's (1962) continuous loud noise condition. (Interestingly, these directional predictions are very similar to those of the Garmezy [1966] model for censuring conditions, although based on different theoretical grounds.) Broen's emphasis on punishment of incorrect responses rather than negative reinforcement of correct responses appears a viable alternative for the Karras (1962) data to which it was applied. Since immediate termination of the aversive stimulus proved crucial to its effectiveness in the Karras (1968) study, some allowance for a strengthening of the correct response appears necessary. Broen and Storms' formulation remains a fascinating and integrative one, however, and is capable of accounting for diverse experimental and clinical data on schizophrenic attentional disturbance and responses to reinforcing and punishing stimuli (Broen 1968).

The Empirical Chasm Between Motivational and Attentional Studies of Schizophrenic RT

While primary aversive stimuli appear to lead to greater reductions in RT level for schizophrenics than normals, what relevance does this have for the RT phenomena central to the models of Shakow, Zubin, and Steffy? Does it imply that the schizophrenics' RT performance can be fully attributed to insufficient motivation rather than selective and/or inhibitory attentional processes? This appears to be an issue that has yielded little direct experimentation, despite its obvious importance. The studies reported in this section have virtually all focused on the changes in overall mean or median RT, while the attentional formulations have been most concerned with the patterning of performance as a function of PIs and stimulus regularity.

The import of these studies of overall RT level for the models of Shakow, Zubin, and Steffy appears limited. As we have seen, Rodnick and Shakow (1940) long ago recognized that overall RT was probably greatly influenced by motivation and other nonattentional factors. Broen's formulation has provided a reasonable explanation of even these motivational experiments without sacrificing the role of attentional disturbance, but even without this laudable integration, the other attention formulations appear essentially untouched by their results.

The critical methodological and theoretical element is the analysis of patterning changes under different motivational conditions in the RT slopes across PIs, and in the PPI impact, the crossover effect, cross-modal slowing, and ITI variations. Of course, such investigations of already schizophrenic individuals would not eliminate the possibility that an irreversible motivational defect underlies the attentional dysfunction, as discussed earlier. They could, however, reveal whether less intrinsic hedonic deficiencies produce the diverse RT patterns.

Some relevant data do exist. If we assume that the schizophrenics with fastest RT represent an especially well-motivated subgroup, their patterns of RT performance can be compared to normals. The reader will recall that Zahn, Rosenthal, and Shakow (1961) found that schizophrenics and normals matched on their RT level at the short PI nevertheless differed in the usual way at longer PIs in regular series. Zahn, Rosenthal, and Shakow (1963) presented similar data for the irregular series. However, these demonstrations suffer from their interindividual nature, since not only cooperativeness but also the acute/chronic (Zahn and Rosenthal 1965), process/reactive (Bellissimo and Steffy 1972), and paranoid/nonparanoid distinctions (Shakow and McCormick 1965 and Goldberg, Schooler, and Mattsson 1968) appear to affect the overall RT level. Thus, such matching may be selecting along dimensions other than the supposed motivational one.

At least one published study (Rosenbaum, Mackavey, and Grisell 1957) did attempt to explore motivational

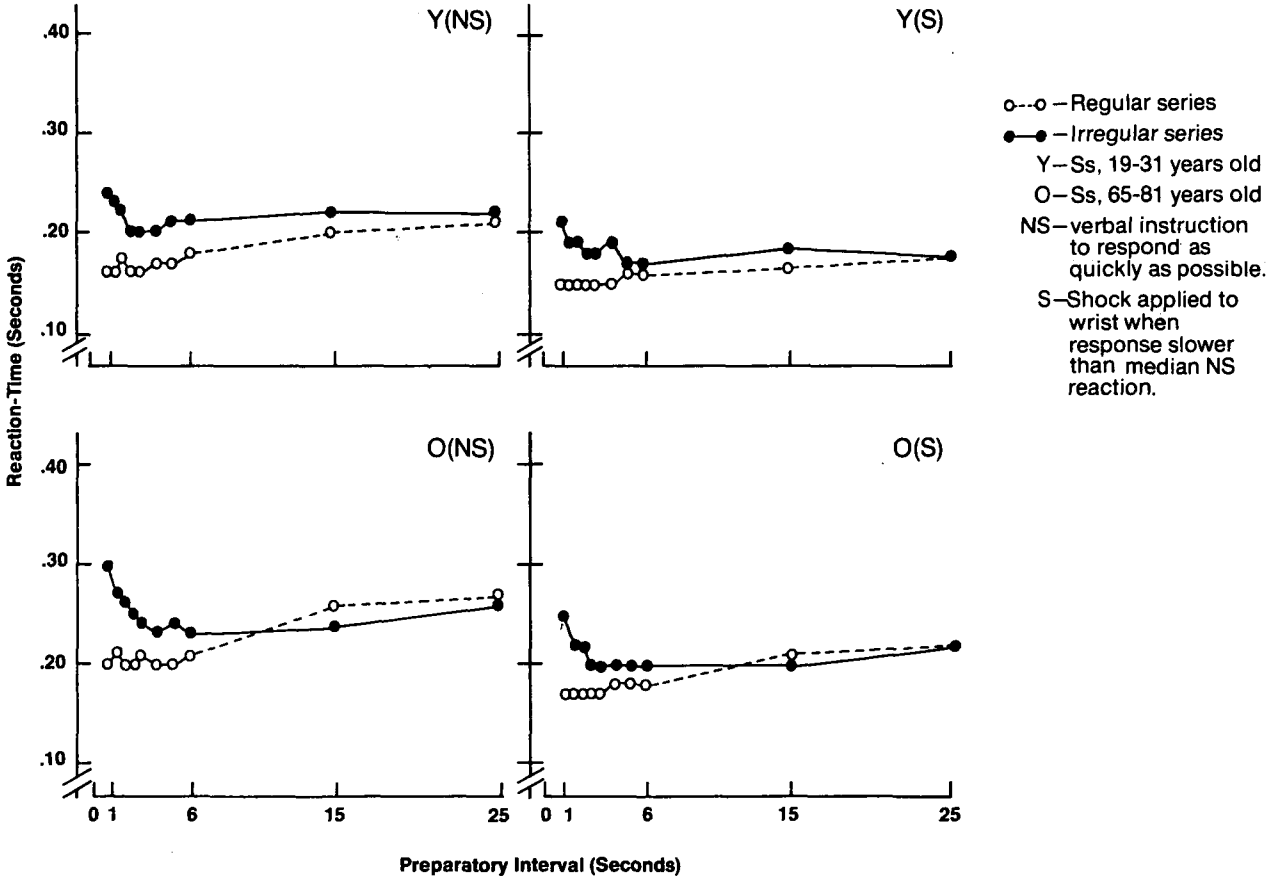
effects on schizophrenic RT patterning in a within-subjects design. Unfortunately, procedural variations appear to have led to results for which this finer-grained analysis was not possible. As Rosenbaum, Mackavey, and Grisell (1957, p. 367) state:

> Since the normal subjects were not appreciably faster on the regular than the irregular procedure, the effect of biological and social motivation on the typical schizophrenic failure to benefit from the regular preparatory set could not be investigated.

Cromwell (1975) reported that Steffy has examined the effects of praise and urging on the crossover phenomenon of process schizophrenics. In this unpublished work, Steffy found that the crossover persisted even when overall RT was reduced to within the normal range. This appears to demonstrate that the crossover requires more than a purely motivational explanation and it exemplifies the type of study required in this area.

That even electric shock need not alter the basic RT-PI patterning is apparent in the study of mental set in aging cited earlier. Botwinick, Brinley, and Robbin (1959) explored the separate effects of motivation and set by administering mild electric shock each time the subject's RT was longer than the median RT for the same PI condition in a baseline series. As can be seen in figure 13, while summed RTs decreased significantly for

Figure 13. Mean RT as a function of the PI[1]



[1]Reprinted with permission from: Botwinick, J.; Brinley, J.F.; and Robbins, J.S. Maintaining set in relation to motivation and age. *American Journal of Psychology*, 72:585-588, 1959.

both the older and younger groups in the shock condition, the crossover between the 6- and 15-second PIs for the older men was not significantly changed. Thus, at least in this nonschizophrenic sample, primary aversive stimuli have motivational influence that appears independent of the ability of subjects to maintain an optimal task set at the longer intervals.

Self-Presentation and Impression Management

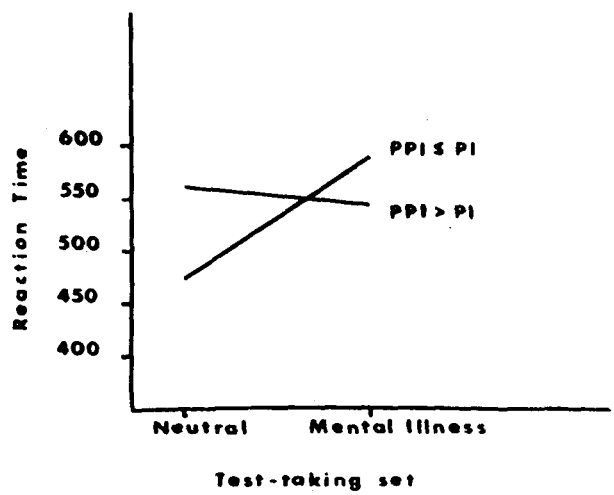
In recent years another type of motivational explanation for psychopathology has been applied to schizophrenic RT data. Rather than general undermotivation, undersensitivity to social stimuli, or oversensitivity to social censure, this position views at least some schizophrenics as being specifically "motivated to appear irrational, emotionally disturbed, and incompetent to other people" (Fontana and Klein 1968, p. 250). Such individuals are referred to as "sick presenters," whereas persons motivated to appear competent and rational are "healthy presenters." Sometimes this impression management is viewed as an alternative to any attribution of psychological deficit in schizophrenia (Fontana and Klein 1968). Chronic psychiatric patients are hypothesized to be more characterized by this self-presentation style than acute psychiatric patients. This viewpoint has received recent popular exposure through the writings of Braginsky, Braginsky, and Ring (1969) and Braginsky and Braginsky (1973).

Two studies have compared the deficit and self-presentation explanations to schizophrenics' RT performance. The first (Fontana and Klein 1968) involved simple auditory RT with a fixed 2-second PI, and is therefore subject to the same limitations noted earlier for studies examining only overall RT level. Furthermore, the authors found that, contrary to their initial prediction, "healthy presenters" among the schizophrenic sample in one hospital building actually showed significantly slower mean RTs than the "sick presenters" after being told they were responding as slowly as most patients. Fontana and Klein argue that this occurred because, in this desirable treatment building, healthy presenters wanted to look enough like patients to stay in the hospital, while sick presenters wanted to look hopeful enough to remain in this building rather than a custodial building. This interpretation is not only post hoc but also seems to vitiate any usefulness of differentiating patients on the basis of their presenting style, since the direction of their presentation is not stable.

Ryan and Neale (1973) have recently provided a test of the impact of impression management on the RT-PI function and the PPI-PI relationships in irregular series. They note that the Braginsky view would predict that chronic schizophrenics should respond in a way that makes them look sick and ensures their continued hospitalization. Acute schizophrenics, on the other hand, are more likely to present themselves as healthy to shorten their hospitalization. These tendencies should intensify when the patients are told that they are taking "mental illness" tests that will influence the length of their hospital stay.

Ryan and Neale tested three groups of schizophrenics using a simple visual RT task with randomized PIs of 1, 2, and 8 seconds. A self-report inventory and a word association test were also administered. The schizophrenics included first admission "acute," "chronic, open ward," and "chronic, closed ward" patients from a State hospital. Half the patients of each group were randomly assigned to a "mental illness" condition and half to a "neutral" condition. Those in the first half were told that the tests were measures of "mental illness" and those in the second half that their hospitalization would not be affected by the results.

Figure 14. Effects of test-taking set on PPI-PI effects on the RT test[1]



[1]From: Ryan, D.V., and Neale, J.M. Test-taking sets and the performance of schizophrenics on laboratory tasks. *Journal of Abnormal Psychology*, 82:207-211, 1973. Copyright © 1973 by the American Psychological Association. Reprinted by permission.

The main effect of the self-presentation manipulation was not significant for the RT data, nor was there any interaction with PI or diagnostic groups. The PPI-PI relationships also failed to show any interaction with the two self-presentation conditions. Thus, in general, the differential effects for acute and chronic schizophrenics predicted by the Braginsky hypothesis were not found. However, the PPI-PI relationships did interact with the conditions such that only with the neutral instructions did PPI > PI lead to significantly slower RT than PPI ≤ PI. In the "mental illness" condition, the PPI ≤ PI trials even showed a trend to be slower than the PPI > PI trials, as shown in figure 14. This finding is contrary to previous results and needs replication, but it suggests that test-taking attitude may have some effect on schizophrenic RT performance in irregular PI series. Ryan and Neale appropriately conclude that while such test-taking attitudes may be influential enough to warrant experimental control, there is no evidence to support self-management theory to the exclusion of deficit theories of schizophrenic behavior.

Conclusions: Status of Motivational Explanations for Schizophrenic RT Performance

Present data, then, do not appear to support a motivational explanation as a substitute for attentional or inhibitory dysfunction in accounting for the more complex aspects of schizophrenic RT performance. However, this appraisal rests primarily on the lack of positive evidence, rather than on any clear exclusionary data. The studies of Zahn, Rosenthal, and Shakow (1961 and 1963) and Steffy (unpublished) do suggest that the configuration of steeper RT-PI functions and their crossover is probably not dependent on the overall speed of responding. Since motivational studies have focused almost exclusively on this latter measure, they are not directly relevant to the phenomena on which the theories of Shakow, Steffy, and Zubin are based.

Furthermore, it appears that even the motivational basis for schizophrenics' overall RT slowing is open to multiple interpretations. Compared to normals, schizophrenics have not shown special benefit from social reward or punishment, but have shown such benefit under conditions of primary aversive stimulation. This may constitute support for the view that schizophrenics fail to be adequately motivated by social stimuli (Hunt and Cofer 1944 and Maher 1966), but also may be plausibly explained as suppressing competing attentional responses (Broen 1968).

The possibility that a defect in motivation at a very fundamental level (e.g., Hunt and Cofer's extinction of social responsiveness or Rado's [1956] and Meehl's [1962] anhedonia) results in the apparent deficient maintenance of focused attention is particularly difficult to research. It may not be subject to the transient stimulations that have been typically applied. As we have noted, developmental investigations appear a more hopeful tack for resolution of this issue.

Actually, even the discovery of certain underlying motivational bases for set deficiencies would not contradict Shakow's formulation. His postulation of "segmental cravings" as a source of the preoccupation with minor irrelevant sets suggests that idiosyncratic goals (but not generalized insufficient motivation) would be consonant with Shakow's view (1962 and 1976). This implies an active control over responding that Chapman and Chapman (1973) argue seems unlikely in many instances—as, for example, when a schizophrenic's word association becomes a disorganized sequence of responses to isolated strong impinging stimuli. However, it is, nevertheless, noteworthy that Shakow has entertained the possibility that the cause of major set deficiencies in schizophrenics lies in purposeful, though often unsuccessful, attempts to satisfy more basic needs. In the next section, we will review several theories that take the opposite view—that a primary attentional or cognitive deficit underlies all motivational and affective disturbances.

The Impact of Extraneous Stimuli

The tendency of the schizophrenic to respond to irrelevant stimuli has played a key role in many formulations of attentional dysfunction, including some of those already discussed. It is the clinical phenomenon that most strikingly suggests that deviant attention may be the fundamental cognitive disorder in schizophrenia. McGhie and Chapman (1961) have provided excellent examples of schizophrenics' descriptions of such experiences:

> Everything seems to grip my attention although I am not particularly interested in anything. I am speaking to you just now but I can hear noises going on next door and in the corridor. I find it difficult

to shut these out and it makes it more difficult for me to concentrate on what I am saying to you. Often the silliest little things that are going on seem to interest me. That's not quite true; they don't interest me but I find myself attending to them and wasting a lot of time this way. I know that sounds like laziness but it's not really.

I am easily put off what I am doing or even what I am talking about. If something else is going on somewhere, even just a noise it interrupts my thoughts and they get lost. If I am somewhere where there is a lot going on I am swinging from one thing to another instead of concentrating on one thing and getting it done. [Reprinted in Buss and Buss 1969, p. 51.]

Unlike the complex stimulus situations of daily life, most of the experiments upon which the Shakow theory is based were characterized by the simplicity of their stimulus conditions. Typically, only a warning stimulus and an imperative stimulus were presented, and other stimulation was limited to that incidentally present in the experimental setting or occurring internally. Yet even under such restricted conditions, Shakow hypothesized that these irrelevant stimuli were the source of the schizophrenics' inability to maintain the major set. It was the active formation of minor sets to these irrelevancies that disturbed the major, task-appropriate set, not an empty lapse of attention. This is clear in Shakow's (1962) discussion:

> It is as if, in the scanning process which takes place before the response to a stimulus is made, the schizophrenic is unable to select out the material relevant for optimal response. He apparently cannot free himself from the irrelevant among the numerous possibilities for choice. In other words, that function which is of equal importance as the response to stimuli, namely, the protection against the response to stimuli, is abeyant. . . . These irrelevant associations, to which the normal is also subject but to a much lesser degree, would appear to arise from three sources: chance distractors from the environment; irrelevancies from the stimulus setting; and irrelevancies from past experience. [p. 9]

The central role of the selective process is obvious here, and provides the link between the schizophrenics' abnormal patterning of RT as a function of regular and irregular PIs. In regular PIs, the internal distractors from the patient's past experience were postulated to be interfering with sustaining preparedness, to an increasing degree as the point of peak readiness became further removed in time from the warning signal. Hallucinations, unusually salient kinesthetic stimuli, and chance environmental events were also sources of minor sets during regular PI series. In the irregular series, the nonidentical PPI became an additional source of irrelevant stimulation which the schizophrenic could not screen out or at least weigh appropriately. Thus, minor sets to these recently experienced preparatory intervals, particularly if they were longer than the present one, resulted in faulty regulation of the timing of the patient's optimal preparedness.

In all these simple stimulus conditions, then, remaining irrelevancies are presumed to be the cause of attentional disturbance, even when they are not observable by the experimenter. While not directly supporting the internal type of interference, Shakow's basic assumption that schizophrenics are more subject to distraction appeared to be sustained in a study conducted at Worcester State Hospital in 1936. Finally published in full detail by Shakow and McCormick (1965), the experiment involved a visual RT task in which the subject was to respond only to one of two colored lights appearing in the same aperture. Specifically, the imperative yellow stimulus had to be discriminated from a distracting red stimulus. These two lights were presented alternately either one, three, or five times and then followed by a single yellow presentation. Thus, irrelevant minor sets established by attending to the alternating pattern could be measured by their impact on the final RT to the single yellow stimulus.

Shakow and McCormick found that compared to normal controls the chronic schizophrenic patients were significantly more retarded on this last single stimulus than on the previous paired one. Thus, the extraneous stimuli appeared to be more distracting to them, although normal subjects also showed a similar impairment to a lesser degree. In addition, the authors report that the normal subjects often showed their slowest RT of the alternating series to the yellow stimulus just preceding the final single one, as if they were concentrating on "beating the game" by getting ready in advance for the single stimulus. They seemed to establish "a subsidiary set that was helpful in minimizing the disturbance" (Shakow and McCormick 1965, p. 93).

This apparent trend for normal subjects to use "subsidiary" sets to their benefit seems to complicate the attribution of schizophrenic slowing to the intrusion of minor sets. If the minor set was due to an in-

ability to screen out the distracting red stimuli, then normal persons would presumably show faster RTs by selectively ignoring these irrelevancies. The establishment of beneficial subsidiary sets implies that the normal subjects may in fact have paid such close attention to the distractors that they learned to anticipate the single stimulus, especially after the third or fifth alternating pair, for which the authors find significant evidence of subsidiary sets. If so, the normals appear to differ in their ability to utilize all relevant information rather than to screen out irrelevant stimuli.

The McGhie-Chapman-Lawson Studies of Distractibility

Even if this alternate interpretation of the Shakow and McCormick data is sound, the work of other investigators clearly demonstrates that truly irrelevant stimuli do retard schizophrenic RT disproportionately. The research of a British group of psychologists—McGhie, Chapman, and Lawson—is one example. After gathering the clinical interview data from which the previous quotes were taken (McGhie and Chapman 1961), these researchers conducted a series of experimental studies that further clarified the nature and pervasiveness of schizophrenic distractibility (Chapman and McGhie 1962, McGhie, Chapman, and Lawson 1965*a* and 1965*b*, and Lawson, McGhie, and Chapman 1964 and 1967). Irrelevant stimuli were introduced in a wide variety of perceptual, immediate memory, and psychomotor tasks—among the latter, simple RT.

McGhie, Chapman, and Lawson's (1965*b*) study focused most fully on the psychomotor effects. Schizophrenic, nonschizophrenic psychotics (depressive and paranoid), and normal subjects were administered eight tests from Fleishman's (1954) battery, first under standard conditions and then with added distracting stimuli. Included were both a visual and an auditory simple RT task, differing somewhat from the Shakow work in that no warning stimulus was used. Instead, the intertrial interval was varied randomly between 5 and 10 seconds, creating a situation similar to but not identical with an irregular PI series. After baseline performance, further trials were administered under first auditory distraction from an irregular metronomic rhythm and then visual distraction from randomly flashing white lights.

The schizophrenics (mostly chronic) were as usual significantly slower on the basic RT performance than were normals, as was also true of the other six psychomotor tasks. However, over and above this, the schizophrenics were significantly more impaired than normals by both visual and auditory distraction on the visual RT task and by visual distraction on the auditory RT task. Auditory distraction with visual imperative stimuli also resulted in significantly greater retardation for schizophrenics than for the combined depressive and paranoid psychotic group. Comparisons that were not significant showed trends in the expected direction.

Interestingly, this greater distractibility was generally not present on the simpler motor speed tests such as the Circle Maze and Punch Board but was evident to an even more marked degree on a task demanding continuous attention to an unpredictable visual stimulus. The affected and unaffected tasks appear to differ in several ways—simple vs. complex, self-paced vs. experimenter-paced, and intermittent vs. more continuous demands for attention—and it is not possible to weigh their importance. However, the data do clearly show the disproportionate influence of irrelevant stimuli on schizophrenic performance for at least some psychomotor tasks, including simple RT.

McGhie, Chapman, and Lawson (1965*b*) interpret these and their other experimental studies in light of the theory of attentional dysfunction that had emerged from clinical material. McGhie and Chapman (1961) had viewed a defect of attentional functioning, specifically its selective and inhibitory aspects, as the fundamental deficit in schizophrenia. An inability to focus selectively on relevant stimuli and to inhibit distracting input was thus hypothesized to underlie other schizophrenic cognitive deviance (e.g., language and associative disturbances) and to lead secondarily to the social withdrawal and other noncognitive symptoms characteristic of nuclear or "true" schizophrenia.

Similar basic defects in selective attention had been postulated by Weckowicz and Blewett (1959), Payne, Matussek, and George (1959), and earlier writers such as Cameron (1938) and Cameron and Magaret (1951) in somewhat different contexts. Very few investigations by other researchers have employed RT tasks, however, in support of these formulations. In fact, even McGhie, Chapman, and Lawson (1965*a*) leaned most heavily on perceptual and memory tests for their theoretical support. Distractibility on these tasks appeared more obviously connected to an inability to screen out the

irrelevant stimuli, presumably without as much possible confounding by motor response factors.

The Payne and Caird Study and Overinclusion

One notable exception to this concentration on other experimental tasks is the study of Payne and Caird (1967). They administered both simple and discrimination RT trials to samples of paranoid schizophrenics, nonparanoid schizophrenics, and nonschizophrenic psychiatric patients. Like McGhie, Chapman, and Lawson (1965*b*), they omitted the warning stimulus "in order to maximize the effect of the distractions and in order to make the task as difficult as possible for overinclusive patients" (Payne and Caird 1967, p. 114). Various distracting stimuli were used, including tones of either the same or a different frequency as the imperative stimulus and "meaningful" distraction in the form of recorded laughter and conversation.

According to Payne's formulation of overinclusion as the primary cognitive deficit in some schizophrenics, irrelevant stimuli should interfere with RT more for overinclusive schizophrenics than for schizophrenics mainly characterized by retardation, the second performance factor emerging from the earlier Payne and Hewlett (1960) work. The nexus with the selective attention deficit hypothesized by McGhie and Chapman can be seen in Payne's (1966) prepublication analysis of the Payne and Caird study:

> If it is the case that overinclusive thinking results from some defective "filter" mechanism, the function of which is to screen out irrelevant stimuli, then this defect should make overinclusive patients very distractible in the reaction-time situation. Indeed, a simple reaction-time task for such patients should often become a discrimination reaction-time task, because irrelevant stimuli, instead of being "screened out" when they occurred, could be attended to and "processed" along with the relevant stimulus. Errors would not necessarily occur, but reaction time would be delayed. Similarly, in a multiple choice reaction-time task, overinclusive subjects should behave as if they were processing more information than that conveyed by the stimulus array, since irrelevant stimuli would not be screened out but would be processed along with the relevant stimuli. Again, errors need not occur, although reaction times should be slower. They should also be more variable, since the number of unintentional distractions present should be variable [p. 88].

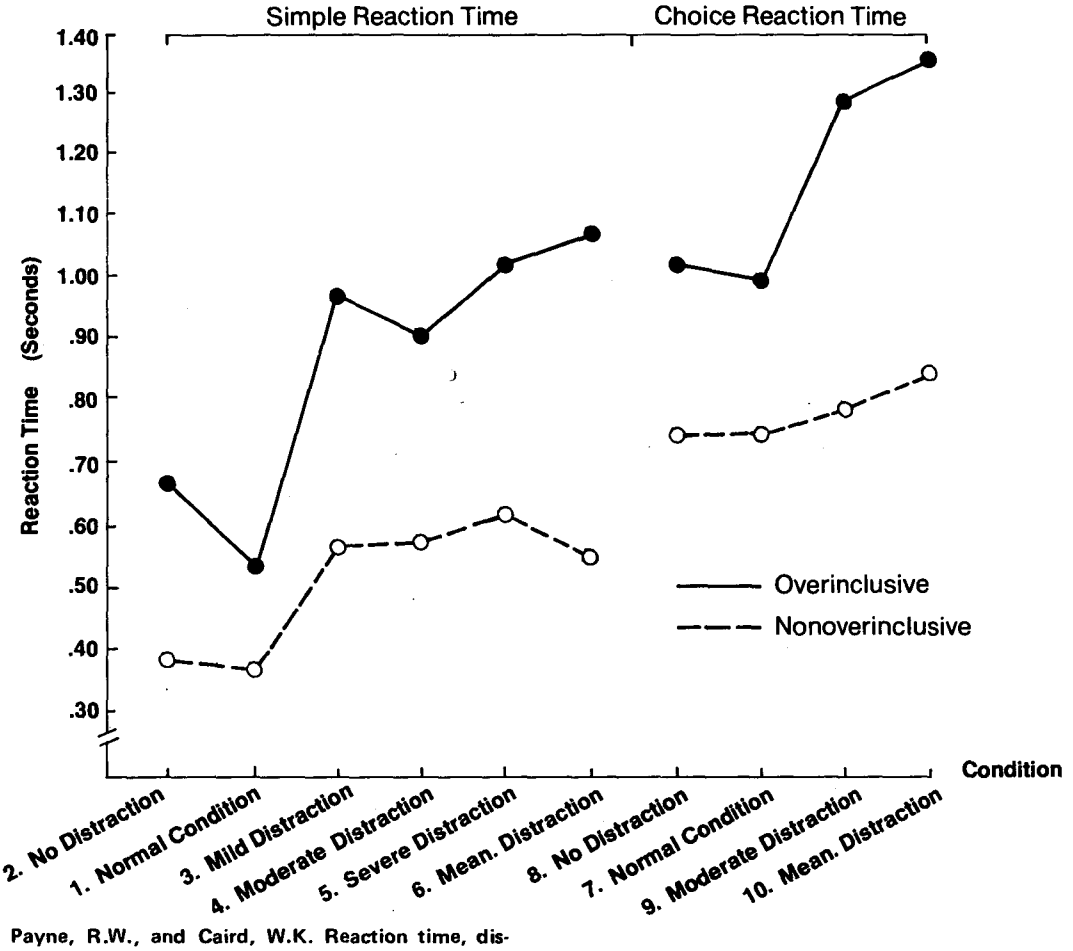
Payne and Caird's subjects were administered the Benjamin Proverbs to get an index of overinclusion and three simple motor speed tests for the retardation index. Although Hawks and Payne (1971) have recently found that the average number of words given to the proverbs is contaminated by a talkativeness factor, this index of overinclusiveness did produce meaningful results that appear not to be explained by the surplus factor. Under normal administration (no added extraneous stimuli), both overinclusion and retardation correlated significantly with the slowed schizophrenic RT, with retardation appearing a slightly stronger contributor. However, when distraction was added and selective attention would be expected to be more critical, the correlations with overinclusion increased to greater than 0.60, while the relation to retardation became very low and typically nonsignificant.

When split into separate subgroupings on the basis of the overinclusion index, the overinclusive schizophrenics were significantly slower in RT under all conditions than the nonoverinclusive group, as illustrated in figure 15. The overinclusive group also tended to be more greatly impaired by distraction than the nonoverinclusive group. Thus, Payne and Caird suggest that overinclusive thinking is related to RT slowing, especially when distractors are present. The slowed RT of the overinclusive group under even normal testing conditions and under a special no distraction (earphones and blindfold) condition is viewed as probably due to these patients' greater internal distractors, including possible distracting fears stimulated by the earphones and blindfold in the predominantly paranoid overinclusive schizophrenics.

Time-Linked Impairment From Extraneous Stimuli

As we have noted, both the McGhie-Chapman-Lawson and the Payne-Caird studies omitted the warning signal from their RT procedures to maximize the impact of distraction. Ironically, some research now suggests that even this supposedly alerting and helpful signal may in some instances impair schizophrenic RT. Fedio et al. (1961) found that schizophrenic subjects could be discriminated from normals on simple RT with a warning signal even when they could not on trials without a warning signal. Indeed, the schizophrenics tended to be slower when a warning signal was present, suggesting that this early stimulus may distract or threaten rather than help to facilitate RT in this group.

Figure 15. Impact of distraction on RT for overinclusive and nonoverinclusive patients[1]



[1]From: Payne, R.W., and Caird, W.K. Reaction time, distractibility and overinclusive thinking in psychotics. *Journal of Abnormal Psychology*, 72:112-121, 1967. Copyright © 1967 by the American Psychological Association. Reprinted by permission.

Recently, Steffy (1976) and Steffy and Galbraith (1975) have presented evidence that indicates that the impact of stimuli preceding the imperative stimulus may vary as a function of time. Extraneous visual stimuli were introduced on three "probe" trials within series of 25 standard regular trials. Steffy and Galbraith (1975) demonstrated a tendency for process schizophrenics to be notably slowed when these additional stimuli preceded the imperative stimulus by 1, 3, or 9 seconds, but only slightly retarded when intervening intervals were 5 or 7 seconds in length. Steffy (1976) reported replications of this tendency for a quadratic effect over time.

Although this quadratic tendency does not always reach traditional levels of statistical significance, its possible meaningfulness is supported by the fact that Elgin Prognostic Rating Scale (Becker 1959) scores for the process schizophrenics showed a strong positive correlation with the probe-induced retardation of RT at the 9-second interval ($r = +.70$) but a tendency toward a negative correlation at the 7-second interval ($r = -.19$). Drawing on Epstein's (1966) and Epstein and Coleman's (1970) postulation of poorly modulated arousal as a primary aspect of schizophrenia, Steffy and Galbraith (1975) interpret the time-linked RT impairment as

reflecting a process of massive protective inhibition:

> The inhibitory response might be characterized as slow to rise, as proportionate to the excitatory event after a few seconds, and then as overshooting the required level of inhibitory response needed at the longer durations. [p. 323]

While the importance of various stimulus parameters in producing such a time-linked variation in RT needs further investigation, the possibility that the attention and information processing of process schizophrenics may fluctuate predictably in the first few seconds after a stimulus is a provocative one. Shortly, we will review other attempts to characterize the relation between attention and information processing in schizophrenia within the RT situation. However, first a brief exploration of two somewhat opposing theoretical explanations of the apparent selective attention dysfunction in schizophrenia may be helpful.

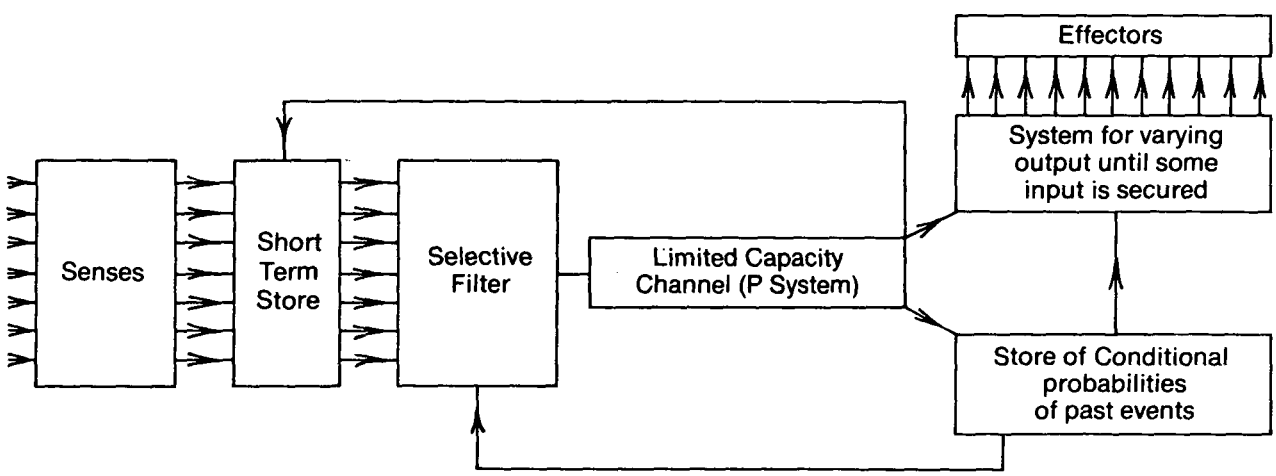
Implications of the 1958 Broadbent Model

Both the McGhie-Chapman-Lawson group and Payne have drawn from the model of normal information processing that was proposed by Broadbent in 1958 (Lawson, McGhie, and Chapman 1964, McGhie 1969, and Payne 1966). They have particularly emphasized the stimulus selection (filtering) necessary for efficient processing, an aspect that was dictated by Broadbent's early postulation (1958) of a limited-capacity informational channel as a link between sensory input and response output. A closer look at the 1958 Broadbent model may help to clarify the implications of such a filter dysfunction.

By reference to figure 16, the reader will note that stimuli impinging on the nervous system are first registered by the sensory receptors and then entered into short-term storage. In the 1958 Broadbent model, further processing of particular stimuli occurred only if they were selected by the filter for entry into the limited capacity channel. Selection was determined both by the physical properties of the stimuli and the motivational states of the organism.

After input has been selected from short-term storage, conditional probabilities from long-term storage of past contingencies act to predict and reduce signal redundancy and to select stimuli that have previously maximized the probability of appropriate reinforcement. Thus, the conditional probabilities influence the selective filter in such a way as to make the stimuli entering the limited-capacity information-processing channel more relevant to and efficient for the organism's adaptive behavior.

Figure 16. A tentative information-flow diagram for the organism, as conceived by Broadbent (1958)[1]



[1]Reprinted with permission from: Broadbent, D.E. *Decision and Stress.* New York: Academic Press, Inc., 1971.

Both Payne (1966) and McGhie (1969) have localized the hypothetical deficit in the filter mechanism, and have thereby provided a more specific formulation than had earlier been proposed by Shakow (1962 and 1963). Broen (1968) has suggested that Broadbent's model allows even further specification. The reduced selection for relevancy that appears to characterize at least some schizophrenics, he notes, may be a disorder in the usage of the conditional probabilities to influence the selective filter. Therefore, the fundamental defect "could be in the long-term store, the filter, or transmission to the filter" (Broen 1968, p. 181).

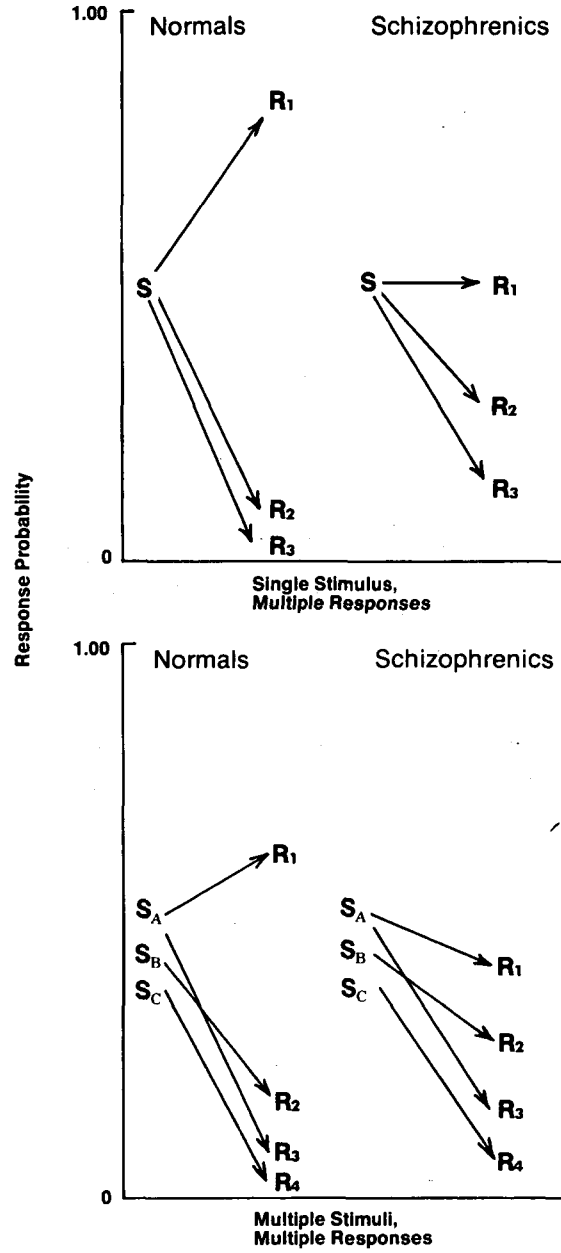
Broen concludes that some reversible rather than permanent loss seems likely, since many of Payne's overinclusive schizophrenics apparently had a good prognosis. Drawing on the thinking of Callaway and Stone (1960), he suggests that increased arousal may be a factor that would reduce probabilistic coding in such a way as to lead to reversible loss of filtering for relevancy. This causal role of increased arousal, in less detailed and specific form, was also entertained in McGhie and Chapman's (1961) suggestion that an inhibitory dysfunction of the reticular activating system might underlie the filtering deficiency.

Broen and Storms' Collapsed Response Hierarchies Theory

As we have seen, Broen (1968) has provided a provocative elaboration of the hypothesis that schizophrenics are characterized by selective filter dysfunction. However, Broen's own preferred formulation is phrased in quite different theoretical terms—those of Hull-Spence behavior theory. It shares the virtues of specificity and apparent testability with the elaborated application of Broadbent's model of attention. However, it is distinct in that it focuses more on the response than the stimulus side for the explanation of schizophrenic attentional deviancies.

Broen and Storms (1966 and 1967), Broen (1968), and Storms and Broen (1969) have made the construct of response hierarchies the central element of their theory. These hypothetical orderings of response probabilities have presumably been partially collapsed in schizophrenic individuals, resulting in stronger competition between the dominant and subordinate responses for any given situation, as shown in figure 17. Random fluctuations of response strength around the values

Figure 17. Probability of occurrence of alternate responses[1]



Note.—A theoretical illustration is given of the probability of occurrence of alternate responses that are associated to the same stimulus or concurrent stimuli.

[1]Reprinted with permission from: Broen, W.E., Jr. *Schizophrenia: Research and Theory*. New York: Academic Press, Inc., 1968.

shown in this figure result in greater overlap of response probability for the schizophrenics than for the normals, so that a less than maximally appropriate and effective response is more likely to occur. It is noteworthy, however, that Broen and Storms propose that the same ordering of responses within the hierarchies occurs for schizophrenics and normals. Only their relative probability of being manifest in overt behavior is altered.

Broen and Storms use the Hull-Spence conceptualization of drive as having a multiplicative effect on response strength in postulating the sources of the collapsed response hierarchies. An important addition to their theory, however, is that there exists a ceiling of response strength which is lower for schizophrenics than for normals. Thus, after a certain point, the probability of the dominant response in a given situation cannot be increased, and this point is abnormally low for schizophrenics. After the dominant response reaches the response strength ceiling, only the competing subordinate responses can be increased in strength. Therefore, when either the dominant response has high habit strength or the competing responses have high habit strength, the difference between their probabilities is likely to be decreased by the low ceiling of the schizophrenic.

A third condition in which nondominant and often inappropriate responses will occur can best be conceptualized by reference to figure 18. In normal persons (left), the multiplicative effect of increased arousal is hypothesized to increase dominant response strength (RS_D) at a faster rate than competing response strength (RS_C) until RS_D reaches the normal response strength ceiling. After this, further increases in arousal only increase the strength of competing responses and make the relative probability of interference with the dominant response greater. If the schizophrenic is assumed to have a lower response strength ceiling (right diagram), then the dominant response more quickly reaches this ceiling, and increased arousal leads to even greater interference from competing responses than is the case for normals. Thus, high arousal is a third source of especially debilitating response hierarchies for schizophrenics.

As applied to the selective attention studies reported earlier in this section, Broen (1968) has added one crucial distinction. Scanning or stimulus search habits are viewed as the first step by which humans approach complex situations. This is hypothesized to be separate from the attentional responses that are evoked by the stimuli once they have been scanned. Attention to stimuli among the complex array that has been initially searched will be especially directed to those that have been important in past situations.

The schizophrenic, when faced with a situation such as the occurrence of both relevant and extraneous stimuli in an RT task, will show the effects of their greater response competition at both levels. First, nondominant scanning sequences will intrude with greater frequency, but the dominant stimulus-search operations should be the same for normals and schizophrenics. Even if stimulus scanning leads to an equal amount of input for both groups, however, schizophrenics should show more disorganized attentional priorities for the stimuli in the input. Thus, attention to information of relevance in past situations will be more interrupted by competing attentional responses to irrelevant stimuli. The end result will be increased attention to extraneous stimuli and an apparent broadening of cue utilization due to greater randomization among competing attentional tendencies.

In some cases, the Broen and Storms theory leads to predictions of impairment by extraneous stimuli that do not differ from those of the deficient-filter theories of McGhie and Chapman and of Payne. Whereas stimulus overload should lead to particular impairment in the filter theories, however, additional or stronger competing responses should be more directly handicapping according to the collapsed response hierarchy model. These alternatives do not appear to be well-differentiated in the experiments using extraneous stimuli, since Broen and Storms view attending to stimuli as an internal response. Somewhat better isolation of the differential effects of stimulus versus response factors may be possible in choice RT studies, which are the focus of the next major section.

Broadbent's 1971 Model

It is noteworthy in this context that Broadbent (1971) has updated his information-processing model so as to give more weight to response selection aspects occurring beyond the filtering level. This conforms to the increased emphasis on other selection processes posited by experimental psychologists such as Treisman (1960, 1964, and 1969). Broadbent's 1971 model distinguishes between filtering and pigeonholing aspects of information processing. Filtering refers to the process that determines what evidence, or input to the limited

capacity channel, will result from each stimulus. Pigeonholing refers to rules linking this evidence to category states, or possible outputs. Since in this newer model, the filter acts only to weight the various inputs rather than to completely block some stimulus sources, the response selection or pigeonholing mechanisms can be influenced by the full range of impinging stimuli. Output is dependent on the combination of weightings resulting from the filtering and pigeonholing processes, each of which operate on different classes of stimulus characteristics.

Recently, Hemsley (1975) has reviewed some of the basic findings on attention in schizophrenia within the context of Broadbent's 1971 model. Unfortunately, few of these studies have been designed in such a way as to make a clear distinction between filtering and pigeonholing deficits possible. It is to be hoped that future research will allow such a differentiation to be made.

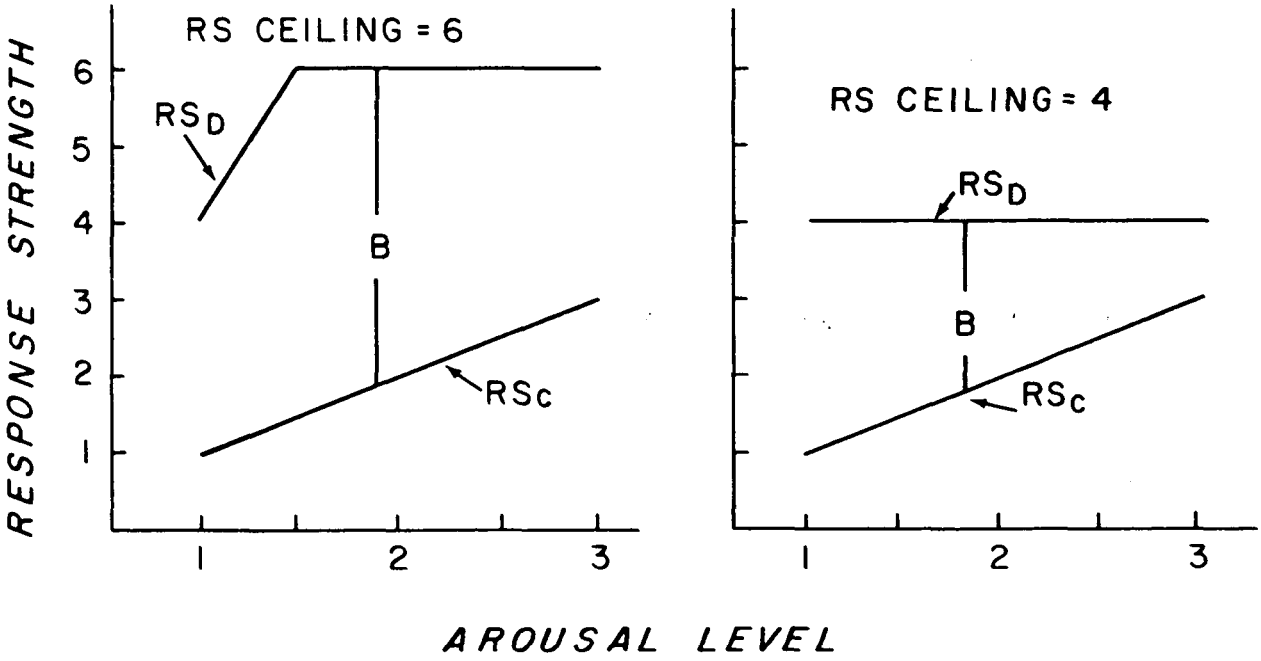
Choice RT and Schizophrenia

As mentioned, choice RT studies may allow further isolation of the stage or stages of information processing that are impaired in schizophrenia. Their promise can be seen by reference to work in normal processing (Smith 1968 and Sternberg 1969). Unfortunately, attempts to employ sophisticated models of information-processing stages to schizophrenia are yet in their infancy. The use of Broadbent's early formulation (1958) has been noted, but many recent developments in this area of experimental psychology have yet to find integration into research on this disorder, as has been pointed out by Marshall (1973).

Simple vs. Choice RT

Many of the studies involving choice RT in schizophrenia have involved a comparison of simple and choice

Figure 18. Relationships of arousal to $RS_D - RS_C$ in normals (left) and schizophrenics (right)[1]



Note.—RS_D = dominant response strength; RS_C = competing response strength.

[1]Reprinted with permission from: Broen, W.E., Jr., and Storms, L.H. A theory of response interference in schizophrenia. In: Maher, B.A., ed. *Progress in Experimental Personality Research*. Vol. 4. New York: Academic Press, Inc., 1967. pp. 269-312.

RTs. Usually, this effort has been motivated by a desire to discover the effects of task complexity on schizophrenic subjects. The more recent comparisons have been attempts to examine the more specific implications of various theories of schizophrenic attention, information processing, and response selection. Chiefly the theories of McGhie and Chapman (1961), Broen and Storms (1967), and Yates (1966) have been the focus. The first two have already been described, and we have noted that stimulus complexity should be especially impairing according to McGhie and Chapman, whereas response competition is central to schizophrenic deficit for Broen and Storms.

Yates's (1966) theory parallels that of McGhie and Chapman (1961) in many ways, but differs in two basic points. Yates postulates that a slowing of information processing is sufficient to explain the McGhie and Chapman findings, without the primary defect in either the selective filter or the short-term memory that McGhie and Chapman suggest. Yates, employing Broadbent's (1958) model, argues further that schizophrenics are deficient in their processing of *relevant* information due to this slowness, and feels that McGhie and Chapman's emphasis on intrusion of *irrelevant* stimuli is unnecessary.

Recently, Chapman and Chapman (1973), two American psychologists unrelated to the British group, have pointed out that Yates's theory is somewhat vague about precisely where the slowness occurs, whether in readout or regeneration of information. Perhaps it is this ambiguity that has led to disagreement about what this as compared to McGhie and Chapman's theory would predict for the simple versus choice RT comparison. Karras (1967*a*) has interpreted Yates's model to imply that (1) both simple and choice RT should be longer for schizophrenics than normals and (2) schizophrenics should be slowed to an absolutely greater amount in choice as opposed to simple RT, since a sequential matching process between stimulus and response should take disproportionately longer for the slow-processing schizophrenic. Court and Garwoli (1968) have concluded that Yates's theory would predict deterioration equal to that of normals with increased task complexity, while McGhie and Chapman's postulation of a perceptual deficit should predict faster deterioration.

The data on this comparison of simple and choice RT are equally inconsistent. All studies have found that choice RT is slower than simple RT for schizophrenics (and normals). However, on the crucial comparison, two studies have found that schizophrenics showed more absolute slowing than normals on choice compared to simple RT (Huston, Shakow, and Riggs 1937 and King 1954), two studies have found equal slowing (Karras 1967*a* and Zahn 1970), and one study has actually found less slowing for schizophrenics than for normals (Benton, Jentsche, and Wahler 1959). When Karras (1967*a*) used a log conversion of his data, he also found significantly less difference for schizophrenics than normals on choice compared to simple RT. Since Benton, Jentsche, and Wahler's (1959) similar finding is based on a reciprocal transformation, this suggests that transformations that artificially put less weight on long individual RT trials may be responsible for this unlikely result.

However, the remaining contradictions in results are not so easy to dismiss. Differences in experimental procedures, techniques of analysis, and samples may account for the conflicting data, but no resolution is readily apparent. Moreover, since several flaws are now recognized in this basic design, we can more profitably move on to a related type of study.

Briefly, though, one point should be made about the Zahn (1970) study, since it allows a comparison of simple RTs requiring the "release and jump" response typical of choice RT procedures with those using the simple key-release response typical of the Shakow and most other research. Zahn found that schizophrenics, when compared to normals, were disproportionately slowed by the more complex response. He interpreted this as due to the presumed necessity to process these two components (release and jump) separately. Thus, he felt that the schizophrenic's mental set was disproportionately affected by response complexity. Since response competition between the two sequential responses could presumably arise, this finding may also be consistent with Broen's analysis (1968). On the other hand, it could also represent simple motor slowness in the schizophrenic, although Shakow (1963) has noted that schizophrenics are able to perform at a normal level in some simple motor tests such as tapping.

Choice RT With Multiple Levels of Complexity

One of the faults in the above attempts to isolate the influences of task complexity is that only two levels of complexity are represented, as has been noted by Court

(1967). She points out that in at least one study (Harwood and Naylor 1963) a cognitive deficit was not apparent in a mixed sample of institutionalized psychiatric patients until four or five items were used. Karras (1967*b*), in reply to this criticism argues that simple and two-choice RT contain enough stimulus to reveal psychological deficit in schizophrenia, since he found that both were significantly slowed when compared to normals. However, this seems to confuse the sources of overall RT level with retardation due to added task complexity.

To use a term from information theory, uncertainty in a task is measured in "bits," each bit representing the amount of information necessary to reduce the possible response alternatives in half. The simple RT task uses only one explicit response (although Payne, Broen, and Shakow might posit more implicit irrelevant responses for the schizophrenic) and therefore involves no bits of response uncertainty. The two-choice RT task requires the processing of one bit to resolve the response uncertainty. Within this formulation, then, it is clear that the restriction of procedures to simple and two-choice RT is a severe one.

Three studies have used a wider range of choices within the traditional discrete RT trial format. In an early investigation, Venables (1958) used a display of eight stimulus lights and the verbal response of saying the number painted on the one that lit. The number of lights used in different blocks of trials was varied so that the effects of increasing the number of equiprobable stimuli could be examined. If increased complexity led to disproportionate impairment in schizophrenia, then schizophrenics would be expected to show greater slowing than normals as the number of possible lights was increased.

Venables employs an equation relating complexity and RT that was suggested by Hick (1952) and extended in more recent information theory (Smith 1968 and Sternberg 1969). Actually, the original base for such analysis was the model of choice RT proposed by Donders (1868), modified by the modern theorists to yield a log/linear relationship between complexity variations and RT. Specifically, the equation is:

$$RT = a + b \log n,$$

where n = the number of equiprobable stimuli, a = the basic motor speed component, and b = the slope of the function relating RT to increases in complexity.

If schizophrenics are differentially handicapped by task complexity, they should show either an exponential increase in RT as a function of the log of the number of stimulus lights, or at least a steeper linear slope as a function of log n. However, Venables, using two schizophrenic samples varying in severity of disorder and a normal control group, found neither to be the case. The only significant difference was in variable "a," schizophrenics being characterized by slower motor speed.

More recent studies by Court and Garwoli (1968) and Scherer (1972) have essentially confirmed these results, although with some interesting procedural differences. Venables (1958) had focused on stimulus complexity, the response being facilitated by having the number to be called out clearly displayed on each light. Broen (1968) therefore argued that increased response competition was not so likely to be involved as was heightened stimulus uncertainty. Thus, the negative results would seem to contradict theories based on a filter defect (e.g., McGhie 1969 and 1970 and Payne 1966) but would not minimize Broen's (1966 and 1968) own emphasis on response selection difficulties.

However, the more recent studies of Court and Garwoli (1968) and Scherer (1972) varied stimulus and response complexity simultaneously. That is, as increasing stimulus possibilities were added, so were corresponding response keys. Moreover, the responses were the more traditional ones of jumping from a start key to the key that corresponded to the presented stimulus, eliminating any possibility that Venables' atypical verbal response was the source of his results. It would appear that any theory that postulates difficulty in information processing in schizophrenia, regardless of the specific stage of deficit, should predict disproportionate increases in schizophrenic RT under these conditions. The fact that neither Court and Garwoli (1968) nor Scherer (1972) found a significant difference in the slope of the log function relating RT and task complexity is thus very curious.

Two further points need recognition. Court and Garwoli (1968) attempted to eliminate the movement or motor speed component of the RTs by analyzing only the time taken to lift the finger off the start button. These so-called "decision" times are, of course, also contaminated with a motor component, but this should be taken into account, as long as it is additive, by the "a" component of the equation. Their procedure does,

however, assume that the stimulus analyzing and response selection process is complete when the subject lifts his finger rather than at some point during the jump to the appropriate key. Scherer (1972), however, had his response keys equidistant from the start key and was able to use the full release-and-jump time as his index of RT, so that this difference does not appear to alter the basic results.

Scherer (1972) did find some evidence of narrowed scanning in long-term nonparanoid patients, as suggested by Broen (1968) and Silverman (1964), despite his generally negative results for information-processing speed. A significant interaction indicated that the nonparanoid chronic schizophrenics were slower when the maximal number of stimuli (five) was used and the critical stimulus light was on the periphery of vision. Court and Garwoli found that nonparanoids were faster overall than paranoids, but reported no evidence of narrowed cue utilization. This may not be contradictory to Scherer's results, though, since he made especially productive use of his stimulus lights for this purpose by placing them far enough apart to account for 45° of visual angle.

Differentiation of Stimulus-Response and Complexity-Competition Aspects

Recently, two investigators have suggested improvements in experimental procedures that may in the future allow more conclusive testing of theories regarding schizophrenic information processing. Karras (1973) has noted that despite the emphasis in interference theories on competing responses that slow schizophrenic responding (Broen 1968, Lang and Buss 1965, and Shakow 1962), no experimental work has distinguished response competition from response complexity. Citing the work of Simon (1968), he points out that response competition can be manipulated independent of response complexity by use of auditory signal presentation to one ear at a time. Response competition is minimized by using the stereotypic response tendency to respond with the hand on the same side as the stimulated ear. High competition can be established by requiring contralateral responses. Since previous auditory choice RT studies presented stimuli to both ears simultaneously, the possibly independent effects of response competition and response complexity could not be optimally examined.

Karras administered simple and choice RT under ipsilateral and contralateral response requirements to three groups of acute psychiatric patients—nonparanoid schizophrenics, depressed patients, and nonpsychotic patients (neurotics or character disorders without depressive symptoms). None of these patients had been on psychotropic drugs for at least 4 weeks before the experimental procedures. Each of the patients was tested under all conditions.

The acute nonparanoid schizophrenics were found to be significantly slowed in simple RT in comparison to each of the other patient groups, but did not show any significant interference by high response competition (contralateral pairing) on simple RT trials. Likewise, response complexity alone (choice versus simple RT with ipsilateral responses) did not produce any greater slowing for schizophrenics. However, when both response complexity (choice RT) and response competition (contralateral responding) were involved, both the schizophrenic and depressed groups slowed significantly more than the nonpsychotic group.

Karras interprets these data as indicating that interference from response competition can augment schizophrenic psychological deficit, but is probably not the primary reason for it, since it did not affect the simple RTs. On the other hand, no primary deficit in speed of processing information (Yates 1966) is found either—as is evidenced by the failure of response complexity to differentially retard schizophrenic RT. Finally, interference is not unique to schizophrenia but is also a significant factor in performance of depressed patients.

The data provide additional support for Karras's suggestion that schizophrenic behavioral deficit is determined by multiple mechanisms. Simple RT and the impaired contralateral complex RT are correlated near zero for these acute nonparanoid schizophrenics, while related quite highly ($r = .74$, $p < .01$) for the depressed group. His view that interference is the primary source of deficit in the depressed group is, however, not clearly supported, since these patients also failed to show any significant effect of high response competition under low complexity conditions.

The recent work of Marshall (1973) does not make the distinction between response competition and response complexity that is so critical in Karras's data, but does isolate stimulus and response complexity in a clearer way than had been done previously. This was a basic flaw in most of the earlier research that compared either

simple and two-choice RT or multiple levels of complexity in choice RT. Since stimulus and response uncertainty were usually varied concurrently in the previous studies, their effects were confounded and precluded any isolation of a defective stage of information processing. This is probably another reason for the conflicting interpretations of what any given theory predicts in these situations.

Marshall provides both a sophisticated use of modern attention and information theory and a choice RT technique that separates stimulus analyzing, response selection, and motor speed components. His task is not the traditional discrete RT one, however, possibly making his data not directly comparable to that of the other studies reviewed here. Because work on the orienting response (Easterbrook and Costello 1970) suggests that schizophrenics may respond to stimuli with a sudden onset differently than normal subjects, Marshall employed a card-sorting task that allowed choice RTs to be measured in a continuous fashion. He notes that this eliminates the contribution of time-uncertainty from the RT. A previous study (Slade 1971) used a similar task but did not separate stimulus and response factors.

Stimulus uncertainty was varied from one to three "bits" by using decks of cards with different combinations of colors and designs on them. Similarly, one to three bits of response uncertainty were presented by requiring sorting in various numbers of ways. Schizophrenics, neurotics, and penitentiary inmates were each tested under every uncertainty condition, the last group serving as a control for institutionalization.

Marshall found that all three components that were isolated—stimulus uncertainty, response uncertainty, and movement speed—were associated with significantly greater impairment in the schizophrenics than in the neurotic or prisoner groups. In addition, the response function with increasing uncertainty was significantly steeper than the stimulus function, indicating that response selection was more difficult than stimulus analyzing for the schizophrenics. These results are most supportive of Broen's (1968) emphasis on response disorganization as the central problem in schizophrenic performance. The disproportionate impairment of schizophrenics when compared to the other groups in complex stimulus analysis situations provides some support for the filter defect theories of McGhie (1969 and 1970) and Payne (1966) as well, although this aspect could also be explained by Broen's hypothesis that scanning is subject to the same kind of collapsed response hierarchy as other schizophrenic behaviors. The latter possibility is ignored by most evaluators of Broen's model, including Marshall, who concludes that none of the theories can account for the processing difficulties at both stimulus and response ends.

More important than the specific findings of the Karras (1973) and Marshall (1973) studies, however, are the methodological advances they represent. Attempts to apply modern information-processing theory and techniques to schizophrenia seem to hold great promise for testing existing theories of psychological deficit and for fostering further theoretical development. Distinctions such as those of stimulus vs. response uncertainty and response competition vs. complexity may refine the attribution of attentional and cognitive dysfunction in schizophrenia to more basic components. Comparison to the work of researchers of normal processing (e.g., Sternberg 1969) suggests that only the roughest start has yet been made in this direction in the area of schizophrenia.

One disclaimer may be necessary, however. It is not entirely clear as yet whether the choice RT situation is a means of further investigating the effects of temporal uncertainty or inconsistency on schizophrenic simple RT. These effects have been central to the theorizing of Shakow and recently of Steffy and of Zubin. Marshall, as we have noted, specifically eliminated what he felt were the contaminating effects of this variable by using the card-sorting task. Yet it is precisely when the stimulus presentation is temporally uncertain (experimenter-paced rather than self-paced) that Shakow (1962 and 1963) has postulated that schizophrenic deficit is most marked.

Further, Zahn's (1970) data, it will be recalled, imply that schizophrenics may be slowed for reasons other than those connected with decision-making in the choice RT situation. Even under conditions of stimulus and response certainty (the information condition), schizophrenics remained significantly impaired while normal subjects did not. Thus, further research is necessary to provide a clearer link between the psychological functions measured by simple versus choice RT in schizophrenia.

RT Differences Within the Schizophrenic Group

A discussion of schizophrenia is not complete until

its heterogeneity has been acknowledged and explored. Greater variability among schizophrenics than among normal controls is a virtual rule in the studies we have discussed. Furthermore, certain theories of attentional deviancies in schizophrenia have made subgroup differences a central issue (e.g., Silverman 1964 and Venables 1964). However, surprisingly little experimental work with RT has focused on such differences. Therefore, despite the promise that these differential characterizations seem to have for attentional theorizing in schizophrenia, we will spend relatively little time on these aspects.

Acute/Chronic Differences

Shakow's studies and comments have generally involved chronic schizophrenic patients, but he shows a clear awareness of the problems that this poses for any etiological implications. Even before the advent of high risk research in schizophrenia (e.g., Mednick and McNeil 1968, Mednick and Schulsinger 1968, Garmezy 1971, and Garmezy and Streitman 1974) made the confounding influences of hospitalization and other secondary experiences so salient to many investigators, Shakow (1962) outlined the ambiguities involved:

> To complicate the problem, we may be dealing with certain effects on functions which have been created by the long period of hospitalization, rather than by the psychosis itself. Actually we do not know if this is so, but we have reason to believe that there are some such effects. Certainly many chronic patients show qualities which are not found in acute patients. Whether these are the direct and indirect effects of hospitalization, or whether they are due to other causes, remains open. They may only be developments of the psychosis to which these patients are naturally susceptible, and which might very well have come about if the patients had not been hospitalized. If there is anything to the laws of learning, however, long habituation to certain kinds of activity or, more correctly stated, to certain kinds of inactivity must result in some atrophy of function. [p. 3]

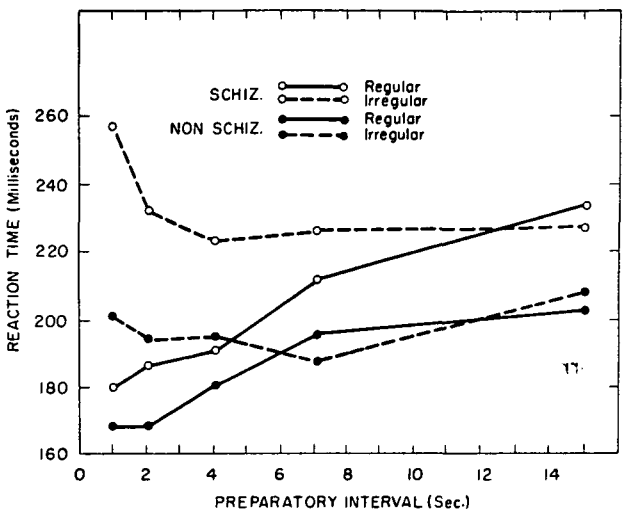
While this would seem to dictate that researchers focus on schizophrenics in the earliest stage possible (or on risk populations), the greater unreliability of diagnosis in early schizophrenia has counterbalanced this dictum. Perhaps increased use of highly standardized and computer-weighted interview material will allow sufficient reliability for future research. Furthermore, greater reliance on longitudinal designs may be necessary in order to answer the related question of whether acute and chronic schizophrenics differ in kind or only in duration of illness.

Regarding RT studies, both Venables (1964) and Broen (1968) have interpreted the marked PPI effect of chronic schizophrenics as indicating a narrowing of attention, in contrast to the broader use of cues that they feel characterizes most acute schizophrenics. Venables (1964) has viewed sympathetic hyperarousal as the cause of this narrowing of the attentional field, whereas Broen (1968) hypothesizes that both acute and chronic schizophrenics have the same basic disorganization of attention, but that chronics are more likely to have learned to restrict their scanning to cope with the flood of irrelevant attentional responses. Silverman (1964) has also suggested that some scanning differences between acute and chronic patients may reflect the adoption of certain coping strategies by the chronic group.

As applied to the PPI effect during irregular PI series, narrowed attention refers to the chronic schizophrenics' disproportionate focusing on the last PI, while normal subjects presumably consider the entire range of PIs in determining how to regulate their preparedness. As Chapman and Chapman (1973) have recently pointed out, this argument is based on the unproven hypothesis that normal individuals actually do process the range of PIs—rather than more efficiently ignore all of them—in limiting their PPI effect. However, accepting the Venables and Broen interpretation for the moment, one would forecast that the PPI effect should certainly be reduced in acute schizophrenics, if not be comparable to that of normals.

Zahn and Rosenthal's (1965) data on acute schizophrenics (less than 2 months of hospitalization) are relevant to this question, although they unfortunately report no direct statistical comparison of the impact of PPIs in acute and chronic groups. As can be seen in figure 19, however, a definite slowing at the short PIs of the irregular series appears for the acute schizophrenics when compared to the nonschizophrenic psychiatric controls. Likewise, the PPI effect (PPI > PI versus PPI < PI) was greater for acute schizophrenics than nonschizophrenics at a highly significant level. Thus, a clearly disproportionate impact of the immediately preceding PI remains. The greater absolute slowing at the short PIs of the irregular series apparent in the Rodnick and Shakow (1940) data (see figure 1 on p. 375) sug-

Figure 19. Median RT at each PI under regular and irregular procedures[1]



Note.—Subjects were acute schizophrenics and nonschizophrenic controls.

[1]From: Zahn, T.P., and Rosenthal, D. Preparatory set in acute schizophrenia. *Journal of Nervous and Mental Disease,* 141:352-358, 1965. Copyright © 1965 by The Williams & Wilkins Co. Reprinted by permission.

gests, however, that it may not be so potent a factor for acute schizophrenics as for chronic schizophrenics.

The recent Nideffer et al. (1971*b*) study provides more direct evidence. In a comparison of acute and chronic schizophrenics, no difference in the PPI effect was discovered. (Indeed, referral back to figure 5 on p. 389 shows that the shapes of the acute and chronic PPI-PI curves are virtually identical although they differ somewhat in absolute level.) Yet the combined schizophrenics' PPI effect was significantly greater than that of nonschizophrenic patients when all PIs are considered (but not when PI is controlled). Therefore, it is clear that at least the sample of schizophrenics studied by Nideffer et al. shows no acute/chronic PPI differences. It may be noteworthy, however, that these "acute" schizophrenics had up to 2 years' total hospitalization. Also, it remains possible that certain more generally slowed chronic schizophrenics (e.g., Rodnick and Shakow's) may be more affected by this recent event.

If the lack of acute/chronic differences is substantiated, it would seem counter to the interpretations of Venables and Broen that the PPI effect represents a narrowing of attention or scanning characteristic of chronic but not acute schizophrenics. It may well be, of course, that chronic schizophrenics generally have more narrowed scanning than acute schizophrenics, but not along a temporal dimension.

One other acute/chronic distinction in attentional theorizing should be noted. Zahn and Rosenthal (1965) found that acute schizophrenics showed relatively greater impairment on irregular as opposed to regular PI series, although a significantly increased positive slope on the regular series was also present. Since external stimuli (the PPIs) appear to be the most disruptive irrelevancies on the irregular trials and internal distractions are presumably the main interference on regular trials, the authors suggest that acute schizophrenics are more susceptible to external than internal irrelevant stimuli. Chronicity may lead to increased interference by internal distractions.

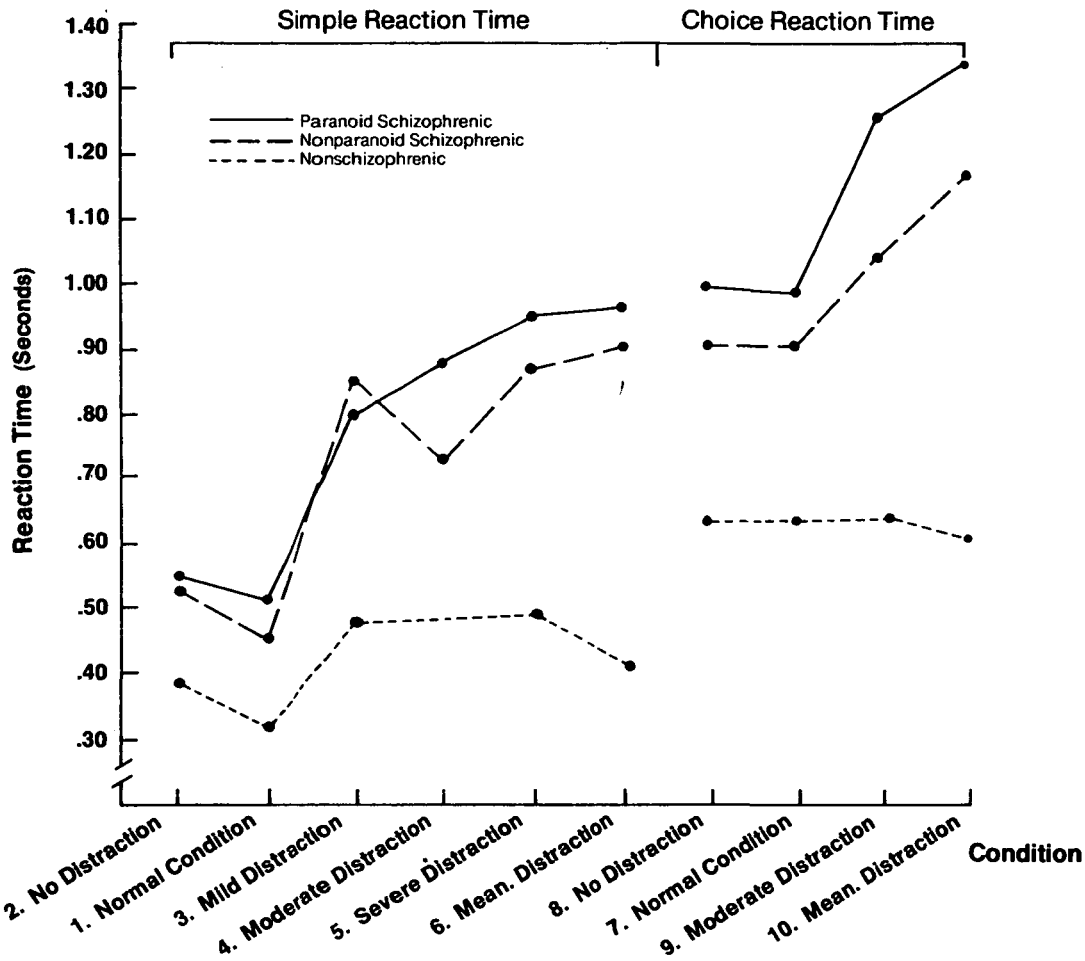
A fascinating study by Inouye and Shimizu (1972) has recently confirmed the impact of one form of internal distraction, hallucinations, on chronic schizophrenic RT. They use the technique of identifying periods of verbal hallucinations by electromyographic activity in the speech muscles, a procedure found to yield very reliable correspondence for a subgroup of chronic schizophrenics (7 of 13 tested). Inouye and Shimizu find that simple visual RT is significantly lengthened during the presence of verbal hallucinations (in comparison to a shorter RT in their absence for each of the seven subjects). Interestingly, the amplitude of the visual evoked response to the RT stimulus light is also significantly smaller when verbal hallucinations are present.

Whether hallucinations contribute equally to RT retardation in acute schizophrenics, and whether this internal distractor leads to a greater slowing at long regular PIs for chronic than for acute patients cannot be answered at this point. However, this and similar psychophysiological techniques may allow further investigation of the role of internal versus external interferences in schizophrenic attention.

Paranoid/Nonparanoid Differences

While McGhie (1969 and 1970) in his review of attention in schizophrenia found the implications of this distinction in symptomatology to be so striking that he

Figure 20. Effect of distraction on RT in three diagnostic groups[1]



[1]Reprinted with permission from: Payne, R.W., and Caird, W.K. Reaction time, distractibility and overinclusive thinking in psychotics. *Journal of Abnormal Psychology*, 72:112-121, 1967.

proposed removing paranoid patients from the schizophrenic category, this differentiation has led to particularly conflicting results in RT studies. The disagreement centers around the Payne and Caird (1967) study. Payne (1961) had suggested that overinclusiveness and delusional thinking are related in that both are "unwarranted generalizations from the facts" (p. 249). Therefore, the Payne and Caird data were analyzed for the paranoid/nonparanoid split, as illustrated in figure 20.

While the mean scores differed significantly, the paranoid diagnosis did not interact significantly with distraction when all subjects were included in analyses of variance. A significant interaction was, however, present when the heterogeneous nonparanoid schizophrenic scores were omitted from the analysis. Thus, paranoid schizophrenics did show greater slowing under distraction conditions than the nonschizophrenic controls and therefore appear to be unusually susceptible to irrelevant stimuli. At the same time, the large variability of the nonparanoid schizophrenics in RT implies that some were more distractible than most of the paranoid group, as McGhie (1969) has noted.

A study by Goldberg, Schooler, and Mattsson (1968) at first seems to show the opposite relationship between RT and paranoid/nonparanoid symptomatology. In their large sample of 480 acutely ill schizophrenics, sim-

ple RT was not significantly correlated to any of the paranoid symptoms rated on Lorr's Inpatient Multidimensional Psychiatric Scale or Burdock's Ward Behavior Rating Scale. However, simple RT was significantly and positively correlated with most of the withdrawal symptoms (although only in the 0.1 to 0.3 range). (A significant but low correlation with the variable Auditory Hallucinations provides additional support for some contribution of internal distractors to schizophrenic RT retardation—in this instance with acute patients.)

The apparent conflict between these two studies may be resolvable by reference to the difference in attentional functions measured. Payne and Caird (1967) found that paranoid schizophrenics tended to be slower under conditions of distraction, where selective attention becomes of greater importance. Goldberg, Schooler, and Mattsson (1968), on the other hand, report correlations with mean overall simple RT that may be more influenced by intensive attention and motivation differences. This analysis gains support from Payne and Caird's findings that the retardation factor correlated more highly than overinclusion (and thus selective attention) under nondistracting simple RT conditions, whereas the latter was more strongly related to mean RT in distraction situations. The fact that Goldberg, Schooler, and Mattsson found the variable Indifference to Environment to be the highest correlate of mean RT seems to reflect the parallel between the withdrawal and retardation factors.

However, this integration of results is not consistent with the data of McGhie, Chapman, and Lawson (1965*b*), who studied RT under distraction conditions similar to those used by Payne and Caird. In this study, auditory distraction impaired the visual and auditory RT of a schizophrenic subgroup with severe hebephrenic withdrawal symptoms significantly more than that of the remaining schizophrenics. In addition, a group of paranoid psychotics (not diagnosed schizophrenic by British standards) tended to be less affected by distraction on the RT task and were often somewhat less distractible than normals on other tasks. Thus, any connection between paranoid delusions and overinclusion or selective deficiencies is thrown into doubt—and so as well is any clear statement about RT and the paranoid/nonparanoid distinction at this point. Possibly better delineation of the patient samples might help clarify this area.

Process/Reactive Differences

Very few published RT studies have made a distinction between process and reactive schizophrenics despite its importance in other areas of research (Garmezy 1968). McGhie, Chapman, and Lawson (1965*a* and 1965*b*) found that their rating scale for this differentiation classified as process schizophrenics a group who were mainly also hebephrenic. McGhie (1969) concludes: "It is probably of little importance whether we label this subgroup 'hebephrenic,' 'nuclear,' or 'process'" (p. 98). For American diagnostic practices, however, this overlap still is a matter of debate (Goldstein, Held, and Cromwell 1968 and Sanes and Zigler 1971).

Sutton and Zubin (1965) failed to find significant differences between reactive and process schizophrenics in the RTs to identical, ipsimodal, and cross-modal stimuli, although reactives tended to be somewhat faster overall. Also, Bellissimo and Steffy (1972) found (as previously noted) that the process but not the reactive schizophrenics showed a significant crossover of regular and irregular PI series. Thus, there is no agreement at this point as to whether regularity and irregularity of stimulus presentation affect process and reactive populations differentially in the RT task. Since PI irregularity appears to produce more dramatic effects on schizophrenics than cross-modal shifts, possibly only the former truly does differentiate these two subgroups.

Level of Global Psychopathology Differences

The most powerful correlate of RT performance within the schizophrenic group that has been demonstrated thus far is clinically rated severity of disorganization. The Rosenthal et al. study (1960), as mentioned earlier, revealed a very high correlation (rho = 0.89) between the set index and a rating of global psychopathology as well as a similar correlation (rho = 0.82) between overall mean RT and this clinical rating. Whether this very strong relationship also exists for other RT aspects (e.g., PPI effects, crossover, and slopes as a function of PI) is unclear at this point. In view of the strength of the demonstrated relationships, however, the importance of examining the extent to which global psychopathology level is confounded with other subgroup differences in RT performance becomes obvious. Perhaps this could help to resolve the conflicting findings

of subgroup differences that have already been discussed.

In summary, then, it is apparent that schizophrenic subgroup differences have been relatively ignored in RT experiments. With virtually universal agreement that at least phenotypic heterogeneity is ubiquitous in schizophrenia, this seems a regrettable state of affairs. RT data have been employed in support of many attentional theories, including some of those postulating subgroup differences (e.g., Venables 1964, Payne 1966, and Broen 1968). Since it appears to have produced rather consistent findings in schizophrenia research generally, RT appears worthy of further attempts to differentiate among subgroups.

Genetic and Environmental Contributions to RT Performance in Schizophrenia

Recently, a few investigators have begun to examine RT performance among the first-degree relatives of schizophrenics in an attempt to establish its role as a possible precursor or predispositional variable for schizophrenia. The populations studied have included offspring of schizophrenic parents reared by either their biological or foster parents, identical twins discordant for schizophrenia, and one set of quadruplets concordant for schizophrenia.

High Risk Studies

Two recent studies have examined RT in children and adolescents born to a schizophrenic mother, a research design that is the most popular variation of the high risk method (Garmezy and Streitman 1974). Marcus (1972) replicated the conditions of the classic Rodnick and Shakow (1940) study with high risk children in grades 5 through 8. Offspring of schizophrenic mothers had significantly slower RTs across all PIs, and for both regular and irregular series, than normal controls. In addition, these high risk children remained significantly impaired in RT under conditions designed to facilitate performance, namely supplying information about the length of the next PI ("information condition") and offering a material reward for fast RTs ("high incentive condition").

The inclusion of other groups of vulnerable or already disturbed children helps to delineate further the meaning of these findings. At one extreme, a sample of child guidance clinic children displaying predominantly internalizing (shy, withdrawn) behaviors was found to be comparable to their normal peers under essentially all RT conditions. Offspring of nonschizophrenic, mainly depressive, psychiatrically disordered mothers showed significant slowing in the initial standard regular and irregular series, but were not significantly different from normal controls under the "information condition" or the "high incentive condition." Finally, a group of externalizing (acting-out) clinic children displayed significant retardation of RT under the standard regular and irregular conditions and under the "information condition," but improved to a level comparable to their normal peers under the material reward condition. Thus, a gradient of RT impairment is suggested, with children of schizophrenic mothers at the severe end due to the more consistent and, at least under the conditions of this study, less easily modifiable nature of their deficit.

Marcus's results do strongly suggest the likely productivity of employing RT tasks in studies of children vulnerable to schizophrenia. However, certain of his findings make an attentional interpretation of these deficits less clear. The overall RT slowing found among the offspring of schizophrenic mothers was not accompanied by the PPI effects, crossover, or increased slope of RT as a function of PI that characterizes adult schizophrenic RT performance. Thus, it remains for future research to determine whether this generalized RT impairment reflects a more subtle attentional deficit or some other factor.

In studies of children at high risk for schizophrenia, the vast range of ultimate outcome must always be considered as a possible obscuring influence on cross-sectional results such as those of Marcus. Since only about 10 to 15 percent of the offspring of one chronic schizophrenic parent eventually are diagnosed as clearly schizophrenic themselves, precursors existing in the preschizophrenic subgroup of high risk children may remain undetected when means for the entire group are the subject of analysis. Perhaps some form of subgroup analysis would have revealed a higher proportion of RT patterns typical of schizophrenia among the offspring of schizophrenic mothers than among the other groups.

This issue of subgroup analysis has recently been studied directly by Asarnow et al. (1976). Various attention-demanding tasks were administered to a small group of adolescents born to schizophrenic mothers

but now being reared in foster homes, a group of matched foster-home adolescents, and a group of adolescents reared by their biological parents. In this sample, overall RT for a series of 15 irregular trials was somewhat but not significantly longer among the offspring of schizophrenic mothers. An attempt to demonstrate redundancy-associated deficit (Bellissimo and Steffy 1972) also failed to reach statistical significance.

While the absolute overall RT slowing of these high risk adolescents was remarkably similar to that of Marcus's (1972) high risk sample during the irregular condition (about 30 msec), the larger variance of scores and smaller size ($N = 9$) of the high risk group studied by Asarnow et al. (1976) may have contributed to a lack of statistical significance. Interestingly, cluster analysis of the latter study's subjects produced one cluster containing a single high risk adolescent who showed a degree of RT retardation typical of chronic adult schizophrenics (459 msec), as well as impaired performance on the other attentional tasks. Another cluster contained four high risk subjects and one foster control adolescent who showed adequate RT performance but who were impaired on other attentional tasks as the amount of information to be processed increased.

While cluster analysis results from such a small sample must be viewed as highly tentative and especially demanding of replication, Asarnow and his collaborators have shown the possible utility of this technique for examining subgroups of high risk children. The probable fruitfulness of further investigations of attentional variables among offspring of schizophrenic parents has also recently been supported by positive findings with another measure of the ability to maintain focused attention over time, the Continuous Performance Test (Erlenmeyer-Kimling 1975 and Grunebaum et al. 1974).

Cross-Fostering, Twin, and Quadruplet Studies

The high risk studies just noted suggest that some type of deficient attentional functioning may be one characteristic of schizophrenia-prone persons, but studies using different research designs are more directly relevant to determining the relative contribution of genetic and environmental factors to any such attentional dysfunctions. Van Dyke, Rosenthal, and Rasmussen (1975) have recently used naturally occurring cross-fostering for this purpose. Four groups were studied, comprising all possible combinations of having been born to a parent who was or was not schizophrenic and having been reared by a parent who was or was not schizophrenic. All subjects except those born to and reared by a schizophrenic parent were adoptees.

An analysis of variance revealed that the groups reared by a schizophrenic parent were significantly slowed in overall mean RT compared to those reared by nonschizophrenic parents. Groups opposed for a genetic background for schizophrenia were not discriminated by their RT performance. No significant differential effect of response condition (traditional manual versus verbal response), length of PI, or length of PPI was associated with either the genetic or rearing factor.

The pattern of consistent RT slowing across all PIs that is here related to rearing by a schizophrenic parent is strikingly similar to that Marcus (1972) found for children born to schizophrenic mothers. Marcus's sample included children experiencing a variety of parenting circumstances, but separate analyses by type of rearing were not performed (nor would they have been productive in all likelihood, because of his smaller sample size). Marcus's subjects were late elementary and junior high school students and thus were not yet into the first major breakdown period for schizophrenia, while the subjects of Van Dyke, Rosenthal, and Rasmussen (1975) were adults already substantially into the age period of highest risk (mean age = 32.8 years). Therefore, whether the pattern of generalized RT slowing has the same developmental implications and correlates in both studies is unclear.

The absence of the typical schizophrenic pattern of RT performance increases the plausibility of nonattentional explanations of these data, however. Van Dyke, Rosenthal, and Rasmussen suggest that reduced spontaneity and self-assurance and preoccupation with family troubles may conceivably result from rearing by a psychotic parent and might contribute to such slowed responses. Again, analysis of patterns of RT performance among subgroups of these subjects may have led to a clearer determination of whether attentional factors were involved.

Two other smaller investigations do, however, also support the lack of any marked genetic contribution to the slowing of RT in schizophrenia. In a unique study of monozygotic quadruplets concordant for schizophrenia, RT data were collected along with many other measures (Rosenthal 1963). Unfortunately, two of the

sisters were too disorganized and disturbed to be successfully tested. The data from the remaining two, however, showed marked differences not only in overall RT level but also in slope across PIs in an irregular PI series of trials. These differences were clearly associated with current clinical state, since the mildly ill sister performed in a manner similar to normal individuals, while the severely ill quad's performance was characteristic of chronically ill schizophrenics.

A further demonstration that severity of psychopathology overrides common genotype in determining schizophrenic RT performance involves identical twins discordant for schizophrenia. Zahn (1976, personal communication) examined 16 twin pairs. Using the set index as the measure of attentional deficit, Zahn found that 13 of 16 index twins had poorer scores than their co-twins. Eliminating 2 possibly concordant cases and 5 in which the diagnosis of the index case is questionable, 8 of 9 remaining definite cases are characterized by larger set index scores for the schizophrenic twin. Furthermore, when the nonschizophrenic co-twins are compared to 38 normal controls (tested on the same procedure but with a different apparatus), the distributions of set index scores reveal almost no difference and are clearly not significantly different. Unfortunately, since these normal controls were not specifically selected and matched to the twins for this study, the last comparison is less than definitive.

Given the present lack of evidence for genetic contributions to RT performance in schizophrenia, other possible sources of attentional deficits reflected in RT patterns deserve further exploration. Singer (1967) and Wynne (1968) have suggested that families with a schizophrenic member are deficient in the ability to share foci of attention during communication attempts. While the RT situation would ostensibly appear quite different than the Rorschach interactions on which this model has been built, the possibility that deviant RT performance is partially the result of rearing influences requires serious consideration. Indeed, Reiss (1976) has recently argued that the study of attentional and perceptual mechanisms may provide the most productive meeting ground for researchers of biological and familial theories of schizophrenia.

Concluding Remarks

Most of the present writer's evaluative statements have been made in the course of reviewing specific studies or theories, and these require no repetition here. Moreover, none of the theories reviewed are consistent with all of the data on schizophrenic RT performance. Some have been more often supported than contradicted, especially those of Broen and Storms, Shakow, and McGhie and Chapman.

Among these, that of Broen and Storms, particularly as explicated in Broen (1968), has the virtue of being elaborate yet more specific than most other formulations in attempting to account for the nature and conditions of schizophrenic psychological deficit. While it posits attentional disturbances in schizophrenia, it is most fundamentally a response interference theory. However, it too has failed to account for some findings, both in this review and elsewhere (Boland and Chapman 1971). Particularly vulnerable is the postulation of a lowered response-strength ceiling in schizophrenia without an attempt to measure this construct independently, as Chapman and Chapman (1973) have noted. Less specific models (e.g., Shakow 1962) suffer few disconfirmations, but are more limited in their ability to yield testable predictions.

Drug Effects on RT

A few general comments can be added regarding drug effects on RT. First, the critical reader will probably have noticed that the possible confounding influence of medications on experimental results has not often been raised here. This is due to the fact that virtually no research supports the impact of the phenothiazines on RT. Four of five systematic studies (Heilizer 1959, Held et al. 1970, Pearl 1962, and Pugh 1968) have found no significant phenothiazine effects on the simple RT of chronic schizophrenics. Only Brooks and Weaver (1961) concluded that RT was changed by the medication, and this improvement of RT with phenothiazines was apparently not tested for statistical significance.

The most relevant of this group of studies for the purpose of this review is the study of Held et al. (1970). In addition to finding no difference between medicated and placebo groups in overall simple RT, they reported no significant effect of the use of placebo rather than active medication on either RT at different PIs or on the PPI effect for an irregular PI series. Thus, the more complex RT phenomena do not seem to be altered by phenothiazine treatment.

The possible drug effects on choice RT, distractibility, and some of the other special RT conditions have not

been adequately investigated. Some studies do, however, report nonsignificant drug effects on these RTs as assessed by the weaker method of correlation within the schizophrenic sample. The impact of medication on the RT of acute schizophrenics has likewise apparently not received systematic evaluation. If, however, the effect of phenothiazines is also found to be nonsignificant in these instances, the RT task would in many ways be strengthened for experimental purposes, since it is now rarely possible to study drug-free schizophrenic patients.

Delineation of the Nature of the Attentional Dysfunction

While an attempt has been made in this review to specify the precise nature of any attentional disturbance indexed by RT performance, often this has not been possible. E.G. Boring, in a posthumously published paper (1970), has recently delineated 10 different meanings of the concept of attention in scientific research. Thus, it is obvious that this word has no single referent. In RT research in schizophrenia, the term often seems to have been used to refer to set, selectivity, intensity, span, and duration of focusing on stimuli. Further research is necessary to establish firmly in which of these aspects of attention the schizophrenic shows disorder, and also whether the subtypes of schizophrenia are characterized by different attentional dysfunctions.

Of course, the repeated conclusion that multiple processes seem to determine schizophrenic RT performance indicates that their disorder is probably apparent in several of these subtypes of attention. We have seen that simple RT without distraction is significantly correlated with psychomotor retardation and withdrawal as well as with overinclusive thinking, while simple RT under distracting conditions correlates primarily with overinclusion (Goldberg, Schooler, and Mattsson 1968 and Payne and Caird 1967). Tentatively, it appears that, without distraction, simple RT taps somewhat more the capacity for intensive attending. Under conditions of distraction, however, simple RT is more likely to index a selective attention factor.

Along the same lines, Shakow's theory has apparently focused on that particular aspect of attention referred to as set. We have noted, though, that he views selective attention as critical to maintaining set. Kahneman (1973), in a recent review of attention in experimental psychology, has used the phrase "selective set" to refer to much the same concept. In addition, however, in the Shakow experiments duration of such an attentional state is critical, since the variation of PIs is central to this work. The breadth of this attentional formulation has thus allowed Broen (1968) to consider it a response interference model, while McGhie (1970) feels it is a selective attention theory.

These, then, are examples of the confusion that has resulted from the broad use of the word attention without clear specification of the meaning intended. It appears that researchers on attentional dysfunctions in schizophrenia could profit greatly by further clarification of the type of attention that their experimental tasks demand and their theories propose. The RT task has seemed to serve such efforts well and, in the context of modern attention and information processing theory, should continue to do so in the future.

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