THE EFFECT OF AUDITORY STIMULUS INTENSITY ON THE REACTION TIME OF SCHIZOPHRENICS

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Introduction

Two earlier studies (Venables and Tizard, 1956a, b) on the reaction time (RT) of schizophrenics have shown that as the intensity of a visual stimulus is increased beyond an optimum point, RT to the stimulus increases. This "paradoxical" increase in RT is not shown by normal subjects, whose RT decreases as the intensity of visual stimulus increases. It was also found that the paradoxical phenomenon with visual stimuli was only shown on an initial occasion of testing. When the experiment was repeated twenty-four hours later, although there was no alteration in the mean level of RT, the pattern of increase in RT with increasing intensity, previously found, was absent.

Studies by Pieron (1919) and Chocholle (1954) have shown that with normal subjects the RTs to auditory stimuli also decrease as the intensity of the stimulus increases. The present experiments were carried out to determine whether with schizophrenics the effect on RT of a strong auditory stimulus would be similar to the paradoxical effect of a strong visual stimulus. A preliminary experiment with five female schizophrenics and an auditory stimulus of 1,000 c.p.s. at intensities of 30, 45, 60, 70 and 90 db. presented through earphones indicated that no paradoxical effect was present, and the relationship was one of decreasing RT to increasing auditory stimulus intensity.

This finding, which was contrary to that which had been obtained with visual stimuli with schizophrenics, made further experimentation necessary.

Method

To establish that the experimental conditions and type of subject were similar to those with which paradoxical effects had been observed in the previous studies using visual stimulation, subjects were tested with visual as well as auditory stimuli. Subjects were allocated at random to one of two groups, one of which made 20 consecutive responses to each of five intensities of visual stimuli, and then to each of five intensities of auditory stimuli, while the other group responded first to the five auditory intensities and then to the five visual intensities. In each set of five intensities responses to the first served as a practice run, and the intensity of stimulus for this practice run was the same for all subjects. The remaining four stimuli were presented in balanced Latin Square order to obviate order effects. The use of a practice run was thought to be necessary because the preliminary experiment had suggested that the responses

to the first auditory stimulus might be markedly longer than those to the remaining stimuli among which no order effect was apparent.

The subject reacted to the appearance of the stimulus by switching it off with a small toggle switch, after which he returned the switch to its previous position to await the next stimulus. A switch rather than a key was used as its action was more easily understood by severely ill schizophrenics. Auditory stimuli of frequency 1,000 c.p.s. were presented by means of earphones fed from a pure tone audio-generator. The practice stimulus in each case was of 60 db., and the test series were of intensities 30, 50, 70 and 90 db. These intensity values are referred to a level of 0·0002 dynes/cm^2 at 1,000 c.p.s. The visual stimulus consisted of a ground glass screen 0·75 inches in diameter, illuminated from the rear. Change in intensity was made by the insertion of neutral density filters behind the screen. The practice stimulus was 60 foot candles, and the test series used intensities of 16, 135, 600 and 1,500 foot candles. A forewarning bell, which could be heard with the earphones in place, preceded by three seconds the onset of the stimulus which was turned off by the subject's reaction. If the subject failed to respond, the stimulus remained on for three seconds. The cycle of warning and stimulus was repeated once every eight seconds. Twenty responses were given to each intensity of stimulus and a three-minute rest period was allowed between each series of twenty responses. Measurement of the time of each response was made to the nearest milli-second. Sixteen male and sixteen female schizophrenics were tested. The mean age of the male patients was 38·3 S.D. 7·28 years and of females 43·6 S.D. 9·8 years; all patients in this and the other experiments reported here were under fifty-five years of age. All were non-paranoid chronic schizophrenics who had been in hospital longer than two years. None had had leucotomy or were receiving physical treatment at or near the time of the experiment.

Results

In order to avoid the possible effects of warm up and end spurts, only responses 6–15 of the total twenty responses to each intensity of stimulus were used for analysis.

TABLE I

Mean Values of Reaction Time (in seconds) Obtained with Various Intensities of Visual and Auditory Stimulation

	Stimulus Intensities (foot candles and decibels)				
Experiment 1	Visual Stimuli				
	16	135	600	1,500	N
Group A*	·74	·67	·69	·74	16
Group B	·77	·71	·69	·68	16
Experiment 1	Auditory Stimuli (1,000 c.p.s.)				
	30	50	70	90	
Group A*	·97	·90	·78	·71	16
Group B	1·17	1·05	·97	·75	16
Experiment 2	Auditory Stimuli (white noise)				
	60	75	95	115	
Single occasion	·95	·88	·80	·77	8
Experiment 3	Auditory Stimuli (200 c.p.s.)				
	50	70	90	98	
Single occasion	·73	·67	·57	·53	8

* Where Group A is group tested first on visual stimuli and then on auditory stimuli, and Group B is group tested first on auditory stimuli and then on visual stimuli.

The upper part of Table I shows the mean value of RT for each intensity of visual and auditory stimuli. Values are given separately for groups of responses given first or second in the testing session.

It is seen from Table I that with visual stimulation given first, after an initial drop in RT from stimuli of 16 foot candles to 135 foot candles, there is thereafter a rise in RT as stimulus intensity increases. This pattern is shown by thirteen out of sixteen subjects, a proportion significant at the ·05 level by the Sign test.

This pattern is not shown when visual stimuli appear second, a rise in RT being shown by only four out of sixteen subjects.

These results are similar to those previously obtained and indicate the phasic nature of this paradoxical phenomenon by its disappearance on a second occasion of testing.

It is thus established that the conditions and type of subject are such that significant paradoxical effects may be obtained in the visual modality; and the results obtained with auditory stimulation can now be examined.

Mean values of RT for the four intensities of auditory stimulation show no evidence of a rise in RT with increasing intensity and examination of individual figures shows that only three out of sixteen subjects show a rise in RT on the first occasion of testing, and four out of sixteen on the second.

Lack of evidence of a paradoxical effect with stimuli of 1,000 c.p.s. might possibly be due to stimulation using only a single pure frequency. A parallel with white light is provided by white noise. A second experiment was therefore carried out with sound of this nature to see if the presumed activation of a larger number of nerve endings would result in appearance of paradoxical effects.

White noise was presented by means of an amplifier and loudspeaker having a wide frequency response to give optimum reproduction of a full range of frequencies. In addition, intensities greater than had been possible with earphones were used to explore the effect of very intense stimuli. The test series used values of 60, 75, 90 and 115 db. Eight male, chronic, non-paranoid unleucotomized schizophrenics, who were not under treatment and who had not been previously tested, were tested; their mean age was 48·8 S.D. 8·4 years.

Examination of the central part of Table I (Experiment 2), shows that no evidence of lengthening of response latency, even with the high intensities employed, was given. Only two of the eight subjects showed a rise in RT with increasing auditory stimulation.

Before considering the evidence for lack of paradoxical effect as final, it was decided to perform a third experiment using a stimulus of 200 c.p.s., and with no forewarning signal. The frequency of 200 c.p.s. was adopted as being well below that of 800 c.p.s. where, as shown in an experiment by Stevens and Davis (1938, p. 395), a sudden drop in the action potential in the auditory nerve occurs. "Above this critical frequency the individual fibres cannot follow the frequency of the stimulus, but must respond to every other vibration." At 200 c.p.s., even allowing for anomalies due to possible deficits in neurone transmission and abnormal length of refractory phase in schizophrenics, it is likely that maximum potential in the auditory nerve for a particular intensity will be achieved.

The forewarning signal was omitted in this experiment because it was thought possible that the alerting of the auditory system by a warning in the same modality as the stimulus might be responsible for the non-appearance of the paradoxical effect.

Intensities of 50, 70, 90 and 98 db. were used for test trials. The practice trial employed an intensity of 80 db. The stimulus tone was presented through a loudspeaker in the same manner as the white noise. The subjects were eight male chronic non-paranoid unleucotomized schizophrenics who were not under treatment at the time of the experiment, and who had not previously been tested. Their mean age was 35·65 S.D. 8·75 years.

The bottom part of Table I (Experiment 3) shows the mean values of RT obtained. It is seen that there is no evidence of paradoxical effect and, considering individual results, not one subject showed an increase in RT with increase in stimulus intensity.

With this final negative result it must be considered as established that no paradoxical effect is to be observed in schizophrenics in responses to intense stimuli in the auditory modality.

The degree of consistency of this finding may be most conveniently illustrated by the use of Kendall's (1948) coefficient of concordance, W. If the results of each subject for each group of four auditory intensities are ranked in order of response speed the concordance of their rankings is shown by a W coefficient of ·355 which is significant by the use of the F statistic, having a value of 17·1, at well beyond the ·001 level for *dfs* of three and 91.

Lack of effects of the order of the test trials are shown by an F of 0·258 for the first, 0·398 for the second and 0·220 for the third experiment. None of these values approach significance.

Discussion

The findings reported in this paper, although negative, enable the pattern of schizophrenic dysfunction to be clarified somewhat.

One deduction which can be made concerns the site of function of the paradoxical effect, now established in the visual modality with 56 out of the 64 schizophrenics who took part in our two previous studies and the present one. As the final effector pathway is common to RT experiments testing both the visual and auditory modality it is evident that the paradoxical effect may be considered as having its origin at a point in either the receptor organ or in the cortex before the effector pathway. Much further work must be carried out to establish whether this schizophrenic anomaly of function can be considered central or peripheral.

It was established in a previous experiment (1956b) that the extent of the paradoxical phenomenon was related to the initial slowness of the subject's RT. With visual stimuli there was a correlation of $r=0\cdot74$ between RTs on the weakest stimulus and the slope of a linear regression line representing for each subject the increase in RT from the stimulus of optimum intensity to the brightest stimulus. Examination of the present data for auditory stimuli indicates that the gradient of fall of RT with increasing intensity is also related to initial level of RT and hence probably to severity of illness. A correlation between initial RT and the slope constant (negative) of the linear regression equation summarizing the subjects' performance was found to be ·45, $P<\cdot02$. It thus appears that the sensitivity of the schizophrenic to changes in stimulus intensity is related to his slowness of response and hence, in so far as the latter is related to severity of illness (King, 1954), to his pathological condition. This is contrary to what one would expect, in that the withdrawn, severely ill schizophrenic appears to be the patient who is least responsive to his environment. It may however be that it is his pathological sensitivity to changes in his environment which causes him to withdraw to a state where changes are least felt.

A third anomaly which needs further research to put it on more than a suggestive footing, is the finding that in the first experiment (cf. Table I) responses to all but the loudest intensity of auditory stimulation are longer than those to visual stimulation. This is a reversal of the usual finding with normal subjects. Teichner (1954) makes the statement that "there is no evidence available that indicates whether or not the RT varies according to the receptor system stimulated", but he goes on to say that in fourteen studies it is reported that auditory RT was found to be faster than visual RT. The data in Table I are thus suggestive of a yet further anomaly in the performance of schizophrenics.

SUMMARY

Experiments carried out have shown no evidence for the appearance in schizophrenics of paradoxical increase in reaction time with increase in auditory stimulus intensity. This phenomenon has previously been established for schizophrenics with visual stimulation, and the present experiments gave, with visual stimuli, further evidence of its existence. Implications of the difference of results between the two sensory modalities are discussed.

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