THE SPIRAL AFTER-EFFECT AS A TEST OF BRAIN DAMAGE*

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A NUMBER of studies have been recently concerned with the clinical application of the Archimedes spiral, an illusory negative after-effect of apparent movement, which requires no description here. Freeman and Josey (3) reported a relationship between the presence or absence of this after-effect and a clinical judgment of memory function, while a cross-validation study by Standlee (11) failed to confirm this observation when an objective measure of memory impairment was used.

More recently three contributions have appeared in the literature which suggest that inability to perceive the negative after-effect of the spiral is related to brain damage. The first of these studies (9) produced results indicating that the spiral might be an extremely useful instrument in the diagnosis of brain damage, 60 per cent. of organic patients failing to perceive the after-effect at all, while approximately 95 per cent. of functional patients and normal controls obtained the after-effect on all occasions.

Gallese (4), using a slightly modified procedure to that employed by Price and Deabler (9), attempted to validate the latter's findings. Five groups were tested: Normals; schizophrenics without organic involvement; organics having acute or chronic brain syndrome associated with alcoholic intoxication or idiopathic convulsive disorder; organics comprising C.N.S. syphilitics, encephalitics, circulatory disturbances, etc., and a group of lobotomized schizophrenics.

Gallese found that where a group of brain-damaged subjects similar to those used by Price and Deabler were employed, the number of identifications made were very similar in the two studies. However, 5 per cent. of his functionals failed to obtain the negative after-effect on any occasion. Even more striking was his finding that lobotomized schizophrenics, and those subjects whose brain damage was associated with alcoholism or convulsive disorder, tended to behave somewhat like normal controls.

A further validation study was conducted by Page *et al.* (7), who in addition to obtaining all-or-none reports from their subjects also measured the duration of the after-effect. As they give no quantitative data on the latter measure it is not possible to evaluate their reported finding that the measure did not discriminate between their brain damage and non-brain-damage groups. Their results on the all-or-none measure (i.e. occurrence or non-occurrence of the negative after-effect) were less striking than those cited by earlier investigators. Their data "... would suggest that 40 per cent. of the organic group would not be so identified. Conversely, some 15 per cent. of the non-organic patients would be inaccurately described as suffering cranial damage."

The study to be reported here represents an attempt to establish further the connection between organicity and failure to perceive the spiral after-effect.

As will be pointed out in the discussion, it is also possible to make predictions concerning the duration of the after-effect in brain-damaged subjects, and to this end this measure was added to the all-or-none measure which formed the basis of previous studies.

The Experiment

(a) *The Groups:* Twenty-one brain-damaged, and 17 normal control subjects were used. The former comprised mainly patients whose history and symptomotology were associated with G.P.I., temporal lobectomy, convulsive disorder, cerebral atrophy, leucotomy, and traumatic brain injury. Seven of this group were female patients, while the control group was entirely male in composition. This male/female discrepancy between the two groups is probably unimportant for it has been shown that sex differences do not influence the results (7).

It has also been shown that age is not a significant variable (7) in the perception of the spiral after-effect, so that the difference between the mean ages of the organic and normal groups is unimportant. This conclusion is confirmed by the rank correlations between age and duration of after-effect for the two groups which were $-0 \cdot 29$ for organics, and $0 \cdot 05$ for normal controls.

A further difference between the groups is probably in intellectual capacity. No data are available for the normal controls, but it is most likely that they were significantly brighter than the organic group for the former were all university students. Supporting the notion that intelligence probably plays little or no part in determining the spiral after-effect is the rank order correlation of $0 \cdot 18$ between the intelligence test score and after-effect duration for the brain-damaged group.

The relevant statistical data on the variables age and intelligence are given in Table I.

Table I

Age		Sum Weighted Score	
Mean	S.D.	Mean	S.D.
Brain-Damaged Group			
33·14	12·60	26·29	9·73
Normal Controls			
29·47	6·87	—	—

It should be noted that intelligence was measured, in the organic group, by the sum of the weighted scores on three Wechsler subtests, Vocabulary, Similarities, and Block Design. This combination of subtest scores has been found to be a good estimate of scores obtained on the total of 10 Wechsler subtests (5).

(b) *Procedure:* The technical details of the administration and apparatus were very similar to those used by Price and Deabler (9) and it is not proposed to detail them here but merely to record the differences between their procedure and ours. These were as follows:

1. If and when the spiral after-effect was obtained the subject was simply asked to tell the experimenter when the after-effect ceased. The duration of this after-effect was measured in seconds.

2. The organic group received four trials, two with a clockwise motion of the spiral and two with an anti-clockwise motion. The controls, on the other hand, received only two trials, the first being a stimulation period of 15 seconds, and the second one of 30 seconds duration. Having determined that no significant differences existed between the duration of after-effect for the four 30-second stimulation periods for the organics ($F=1 \cdot 253$), it was decided to compare the two groups on trial two where both had received a stimulation period of 30 seconds.

3. Certain minor changes in the physical conditions of stimulation were also introduced in testing control subjects (e.g. use of chinrest), but these changes have been shown not to influence the duration of the after-effect.

Results: The results do not fully confirm previous findings, for only one patient out of the 21 organics failed to perceive the after-effect on all four trials. One other organic failed to perceive the after-effect on three out of the four trials, but otherwise perfect scores were returned by other members of this group. No control subject failed to report the after-effect on each of the two trials given to this group.

However, a difference was found between the two groups on the duration of the perceived after-effect on trial 2. The relevant statistical data are shown in Table II.

TABLE II

Statistical Data. Duration of Spiral After-effect

	Mean	S.D.
Brain Damaged	11·29	6·77
Controls	19·70	6·93

$t=3 \cdot 763$ (0·001 level)

So far as identifications are concerned the results were not particularly striking. Eight out of 21 organics had an after-effect duration of less than 9 seconds (i.e. lower than any normal control), while 3 control subjects had after-effect duration scores of more than 27 seconds (i.e. higher than any organic.)

In spite of the poor differentiation on the all-or-none score, and the considerable overlap between the two groups on duration of after-effect on trial 2, these results do indicate that the spiral test may be useful in the diagnosis of organicity.

It might be objected that the measure which discriminated between our groups was based upon only one trial, but it is thought that this objection is not serious. It may be that further trials would have improved the differentiation, or worsened it, but it has been shown by Holland (6) and other authors that the spiral effect is an extremely reliable one.

DISCUSSION

In their recent paper Price and Deabler (9) put forward two possible explanations of the observed differences in the perception of the spiral after-effect. One of these explanations was based upon Shapiro's theory (10) which had been developed as a result of investigating certain perceptual anomalies found among brain-damaged subjects. In order to account for his observations Shapiro postulated an intensification of cortical inhibitory processes in organic patients, and he was probably the first to make use of such a model in this connection.

A similar explanation of individual differences in the persistence of the spiral after-effect has recently been advanced by Eysenck (1). It will be remembered that he postulates as one of the main parameters of personality the dimension of Extraversion-Introversion. In its behavioural aspects this dimension is characterized by patterns of responses which are dependent upon the rate at which inhibition is aroused by the passage of neural impulses through the cortical pathways. Thus, for Eysenck, the behavioural dimension is paralleled by an inhibitory dimension whereby the introvert is characterized by low inhibitory potential and high excitation, and the extravert by high inhibition and low excitation. On this assumption he has been able to make a number of predictions concerning behavioural differences and, using a Hullian model, integrate certain facts in the fields of learning theory and personality.

Most of Eysenck's work so far has been conducted with normals and neurotics, but in the sphere of brain damage he has suggested (1) that organics, because of the intensification of their inhibitory processes, e.g. negative induction, should display patterns of behaviour and responses similar to those of the extreme extravert. A study conducted by Petrie (8), employing leucotomized psychiatric patients, gave results which support the notion that brain damage gives rise to more extraverted patterns of behaviour.

As a mainly central phenomenon, having a minor though measurable peripheral effect, the spiral after-sensation is readily testable in terms of Eysenck's theory. Two experiments have already been conducted and a third is at present under way. Of the two for which results are available the first is a drug study (2) in which the spiral test was administered to six subjects on each of three days. The experimental conditions were identical with the exception that the subjects had taken either d-amphetamine sulphate (10 mg.), sodium amylo-barbitone (4½ grains), or a placebo. The persistence times of the after-effect under these conditions differed significantly in the predicted direction, the same subject giving significantly shorter persistence times after amytal than under either placebo or the amphetamine. This strongly suggests that drugs which are cortical inhibitants enhance satiation effects and therefore affect the duration of after-effects which are a function of that process.

The second study is one in which an attempt was made to determine the relationship between a questionnaire measure of extraversion (the Rathymia scale of the Maudsley Personality Inventory), and the persistence of the spiral after-effect. The sample in this case was a group of normal university students (N 17) who were given six trials on the spiral at the following periods of stimulation: 100 secs. (one hour break), 15 secs., 30, 50, 80, 100 secs., with one and a half minute intervals between trials. In the same order, the correlation of the responses to these periods with the Rathymia score of the subjects were, 0·36, 0·28, 0·28, 0·34, 0·25, and 0·12. Although none of these correlations manage to achieve statistical significance they are, without exception, in the predicted direction.

From the evidence outlined above it would seem that there are reasonable grounds for assuming that the cortical inhibition theory offers some explanation of the individual differences which are characteristic of performance on the spiral test. However, an alternative explanation of individual differences in duration of spiral after-effect is deducible from the same theory. Too often in psychology we assume that because we have gained the "co-operation" of the subject the effectiveness of the stimuli we administer is equal in all cases. One of us has reported (6) that the persistence of the after-effect appears to be directly related to the ability to maintain fixation, and that if the fixation point is changed randomly over the surface of the disc, during a one-minute period of stimulation, no after-effect is observed. It is often stressed in the literature on brain damage that the patients are very easily distracted from any task or test. A difficulty in maintaining fixation may therefore be contributing to the shorter duration of spiral after-effect in organic patients. This fixation difficulty may itself be a function of the growth of an inhibitory process, satiation of the stimulated cortical elements necessitating a change in fixation which may serve a useful biological purpose.

(It is interesting to note here that a significant correlation has also been determined between a measure of Extraversion and the ability to fixate.)

An interesting speculation based upon empirical observation may also be relevant in discussing the clinical application of the spiral after-effect. It may be that perception of the after-effect, whether on an all-or-none basis, or its duration, depends upon the type of damage sustained. Having regard to the results of this and other studies, together with the types of brain-damaged subjects used, leads the authors to suggest that while subjects with strictly localized lesions might behave like normal controls, patients with injuries subsumed under the category heading of "multiple and diffuse" might fail to perceive the after-effect. A study comparing various classes of brain damage would be necessary in order to check on this tentative suggestion.

Summary

An attempt was made to validate certain previous observations which pointed to a relationship between brain-damage and failure to perceive the negative after-effect of the Archimedes spiral. The results of comparing scores for the duration of after-effect indicated that the length of this period was reduced in brain-damaged subjects, while scores on an all-or-none basis failed to confirm previous findings.

Two possible explanations for the results of this and other studies were put forward. First, individual differences in the degree of cortical inhibition, and differences in the type of brain damage sustained.

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