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THE NATURE OF APHASIC RESPONSES*

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Abstract—The errors of patients with aphasia and other related disorders were studied quantitatively. Some errors were related to the sample by relevant aspects of the stimuli, either physical parameters or language parameters. Some errors were related to the sample by irrelevant aspects of the stimuli; these responses often appeared as perseveration. Some perseverated errors were repetitions of a response that had been correct and reinforced on a previous trial. The mechanisms that sometimes produced perseveration also produced responses that were not perseverative. The consequences for the patient of his perseverated responses may be an important factor in some types of perseveration.

INTRODUCTION

THE ERROR responses of aphasic patients were analysed by several of the classical writers on aphasia. These workers classified each error simply by examining it and making a judgement about it. They concluded that some errors bore a relation to the correct response, that some were due to perseveration, and that others were apparently random responses. The early analysis by Jackson and the remarkable one by Lissauer may illustrate this method. JACKSON [1] stated: "In defects of speech we may find that the patient utters instead of the word intended a word of the same class in meaning as 'worm-powder' for 'cough-medicine;' or in sound, as 'parasol' for 'castor oil,' " (*Selected Writings*, Vol. 2, p. 158). He described what is now called perseveration: "The patient ... may get out a word, right or wrong, such as 'very well,' and go on uttering that in rejoinder to further questions to which it is irrelevant, ... " (p. 198). He acknowledged random errors and suggested they might be lawful, that "many of the apparently random mistakes in words are not real exceptions to the principle of Dissolution," (p. 158). LISSAUER [2] ,in mind-blindness, found that some error responses were related to the correct object, either by a similarity in physical shape (candle for pencil) or by a partial physical similarity (giraffe for swan) or by an "inner relation" without any physical similarity (pear for bunch of grapes). Some error responses, now called perseveration, had an entirely different basis. He noted that perseveration often concerned an object name that had initially been used correctly.

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Other responses seemed arbitrary and incomprehensible. He suggested that some of these errors were related to the correct object by a hidden similarity. Some responses were simply vague (e.g. "a figure").

We have re-examined the nature of error responses in aphasia and related disorders, with methods that enable one to demonstrate the non-random nature of many of these responses with much greater precision and power than was once possible. This report will illustrate the methods we have used and present some of our results. Matching-to-sample tasks were used extensively because they regularly provide data suitable for analysis. Some results with naming and writing responses will be presented.

METHODS

The patients were tested in a quiet, softly lit room. They sat before a panel of 9 translucent windows, each 2 in. square, arranged in a 3 × 3 matrix. In matching tests each trial began by presenting the sample stimulus. Visual samples were projected from the rear onto the center-window of the matrix. Auditory samples were dictated from tapes over a speaker, and tactile samples were presented for palpation inside a screening box. The patient pressed the center window to bring the choice stimuli onto the outer windows of the matrix. One choice, the correct one, corresponded to the sample; the others did not. The patient selected and pressed one of the choice windows. Correct selections were rewarded by chimes ringing and delivery of a nickel (5c.). After incorrect choices there were no chimes or nickels. In some tests the sample remained after the choices appeared (simultaneous matching); in others the sample disappeared with the center key press and the choices appeared 0–40 seconds later (delayed matching). The sample stimulus was presented in the same way for writing and naming tests. For writing tests the patient had a new sheet of paper for each trial. Correct responses were rewarded by chimes ringing and payment of a nickel.

The patient was given many trials with each type of task, the trials differing in the specific stimuli presented and in the arrangement of the stimuli on the windows. This was essential to avoid pitfalls of window-pressing preferences, learning of trial sequences, imperfectly designed sets of trials, etc. The methods are described in greater detail in [4].

RESULTS

Error responses controlled by numerical sequence in tests with digits

In matching-to-sample tests involving the digits 1 through 9 some patients made error responses that were related to the sample by proximity in the numerical sequence. This was demonstrated by using generalization gradients. For this, the choice digits on each trial were designated by their deviations from the correct or sample digit. For example, when digit-7 was correct digit-8 had deviation from sample +1; digit-9, +2; digit-6, −1; digit-1, −6. Correct choices had a deviation of zero. There were fewer opportunities to select large deviations, e.g. deviation +8 could only occur when digit-1 was correct, on one trial in nine. Therefore, the number of times the patient selected each deviation was adjusted to account for the different opportunities. This gave the generalization gradient.

In one type of test digits and dots had to be matched. When the sample was a digit the choices were dots, and vice versa. The appearance of a trial from one of these tests is shown in Fig. 1. The generalization gradients of five patients are shown in Fig. 2, as semi-logarithmic plots for easy viewing. The gradients all show a preponderance of errors with small deviations from the sample, reflecting the fact that these patients' errors were related to the sample by proximity in the numerical sequence. This was a common finding in a variety of clinical states, and is possibly but not always necessarily due simply to imprecise counting of dots. The actual errors of one of the patients (A.E.F.) were:

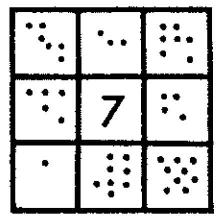

FIG. 1. Tests with digits and dots. Illustrative trial, simultaneous matching, visual digit sample, dot choices. Digits 1-9 tested, 2-dots omitted from this trial. Different patterns of dots were used on other trials.

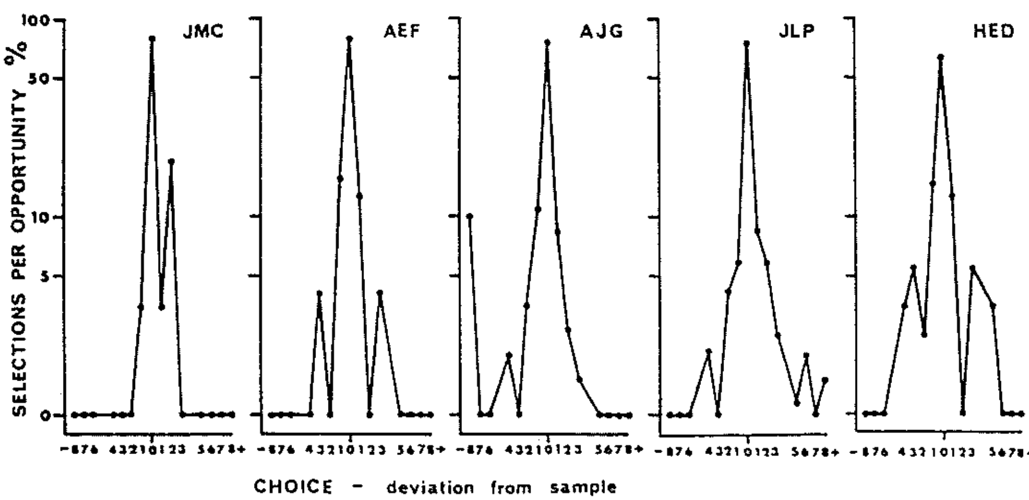

FIG. 2. Tests with digits and dots. Generalization gradients, relations of subjects' responses to samples by numerical sequence parameter. (No +4, −5 deviation because of omitted choice stimulus).

Visual Samples						
Sample	7	8	6	7	4	8
Error	6-dots	5-dots	7-dots	6-dots	5-dots	7-dots

Auditory Samples					
Sample	"three"	"seven"	"seven"	"four"	"eight"
Error	4-dots	8-dots	6-dots	7-dots	7-dots

In another type of test digits and digit names had to be matched. When the sample was a digit the choices were digit names, and vice versa. A typical trial is shown in Fig. 3. Generalization gradients from three patients are shown in Fig. 4. Consider first Case M. McL.

M. McL., female, 50, rheumatic mitral stenosis. Left middle cerebral embolus. Transient right hemiplegia. Apraxia of left hand mimicking, handling unfamiliar objects. Transient partial right field defect. Persistent severe global aphasia with marked auditory word deafness. Aphasia examination 1 week after

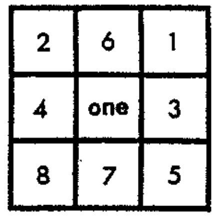

FIG. 3. Tests with digits and digit names. Illustrative trial, visual digit-name sample, digit choices. Digits 1–9 tested, 9 omitted from this trial.

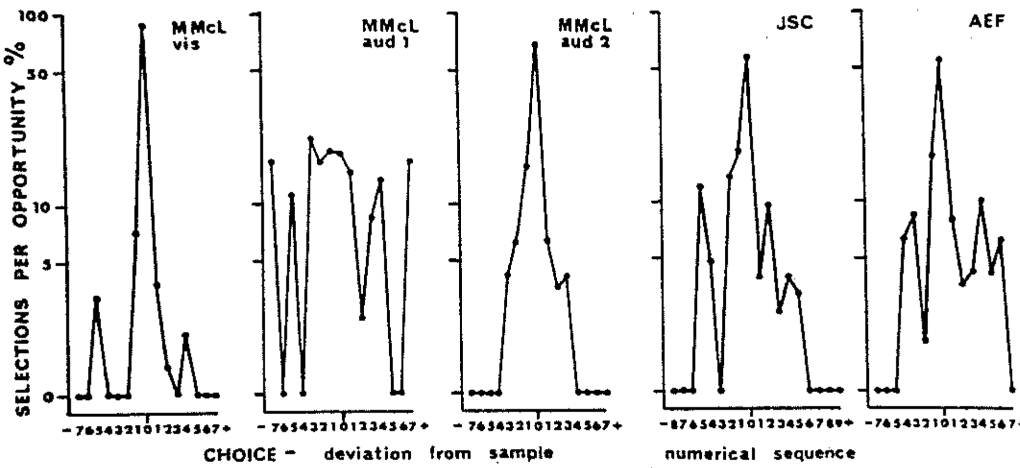

FIG. 4. Tests with digits and digit names. Generalization gradients, relationships of subjects' responses to samples by numerical sequence parameter. (No +8, −8 deviations because of omitted choice stimulus, except J. S. C. tested with digits 0–9).

stroke: No conversation. Most spoken responses inappropriate perseverated words—"vegetable", "finger" "cucumber," "there." Occasional appropriate phrases—"No, it wasn't like that." Prosody, pronunciation normal. Alphabet, numerical, weekday sequences recited with some omissions. Repeated familiar words well, failed nonsense words. Very poor naming of visually presented letters, digits, words, pictures. Gray 1 paragraph reading a few amorphous sounds. No writing. Matching visual samples to visual choices: capital to small letters 15/20, words to colors 9/9, digits to digit names 44/54. Matching auditory samples to visual choices: letters 4/30, words 19/30, words to pictures 15/18, digits 10/45, digit names 0/9.

One week after the stroke simultaneous matching from visual samples between digits and digit names was fairly accurate (88 %), and there was a definite relation of proximity in the numerical sequence between errors and correct responses (Fig. 4, left). The errors, in order of occurrence, were:

Sample	4	5	6	9	3	2	3	6	2	five	7
Error	three	four	seven	four	two	six	two	eight	three	6	six

Simultaneous matching from auditory samples to visual choices was grossly inaccurate (18 %), and the generalization gradient (Fig. 4, second from left) showed that the errors were not related to the correct response by proximity in the numerical sequence. These were nevertheless not all random responses. On one test they were related to choice window position; 16 of the 18 responses were selections of the middle window on the left side of the matrix. The patient was seen again three weeks later. Her aphasia was slightly improved When the digit tests with auditory samples were repeated a remarkable change was seen. The patient had improved (accuracy 67%) and her errors were related to the correct response by proximity in the numerical sequence (Fig. 4, third from left). The performances were similar whether the choices were visual words or visual digits. The errors were:

Sample	"five"	"seven"	"five"	"four"	"seven"	"five"
Error	three	six	seven	five	six	3

Sample	"six"	"four"	"seven"	"five"	"two"	"three"
Error	3	3	6	8	3	2

Similar findings were seen in several other cases of global aphasia. The generalization gradients of the combined results from several tests in two other patients are shown (Fig. 4, right). In these tests between digits and digit-names the error responses were related to the correct response by an "inner relation" of LISSAUER [2] without any physical similarity; an "inner relation" that depended on language.

Error responses controlled by alphabetical sequence in tests with letters

The alphabet sequence is a parameter of letters, perhaps analogous to the numerical sequence of numbers. CRITCHLEY ([3], p. 358) stated that errors in tests with letters were sometimes related to the correct response by proximity in the alphabet. We have done extensive testing of many patients with a variety of single letter tests. The appearance of a trial from one of these tests is shown in Fig. 5. The method of generalization gradients was applied to test whether the patients' errors were related to the correct response by proximity in the alphabet sequence. Rank–order deviations from the sample were assigned to the choices by their relative positions in the alphabet. For example, in the trial of Fig. 5 the deviation from the sample of the choices was: f, −5; i, −4; j, −3; l, −2; p, −1; t, 0; v, +1; y, +2. Other trials having different samples and choices were ranked similarly. The generalization gradients of three patients are shown in Fig. 6. Consider first Case V. C. C.

l	f	y
t	T	i
p	v	j

FIG. 5. Tests with letters. Illustrative trial, visual upper case sample, lower case choices.

V. C. C., female, 60, hypertension. Cerebral infarction of abrupt onset, transient right hemiplegia, hemianopia. Apraxia of left hand on command, mimicking. More persistent posterior aphasia. Aphasia examination 1 week after stroke:

Many sentence responses—"Why do I have to know so much?" Good prosody, clear pronunciation of most words. Recited numerical, weekday sequences, alphabet to J with occasional omissions. Unable to read paragraphs, or write from dictation. Very poor naming of visually presented letters, words, pictures, objects. Matching visual samples to visual choices; letters, simultaneous 20/20, delayed 10/35, capital to small 2/5; words to pictures 8/20, color-names to colors 1/5, digits to digit-names 1/5. Matching auditory samples to visual choices: letters 5/20, words to pictures 14/15, words to colors 3/5.

The patient was studied 11–13 days after the stroke. She was to match visual upper-case samples to upper-case choices and lower-case samples to lower-case choices. Simultaneous matching was errorless. Delayed matching (delays 0–2 sec) was poor (30% accuracy). The alphabet sequence was important, affecting her errors not by relation to the sample but by relation to the choice display (generalization gradient, Fig. 6, left). The patient tended to choose letters early in the alphabet (negative deviations), regardless of which letter was the sample. On 16 of the 35 trials she chose the earliest letter possible. These delayed matching tests were repeated one and six months later, when her aphasia was considerably improved. The patient then performed accurately and her errors were related to the correct response by proximity in the alphabet (Fig. 6, second from left).

Eleven days after the stroke the patient was asked to name letters from visual samples. She declined to attempt some letters, and the responses she did make were related to the correct response by the alphabet sequence. They were:

Sample	D	G	A	E	N	S	e	s	c	b
Response	"C"	"H"	"A"	"five"	"I"	"O"	"six"	"q"	'three'	"two"

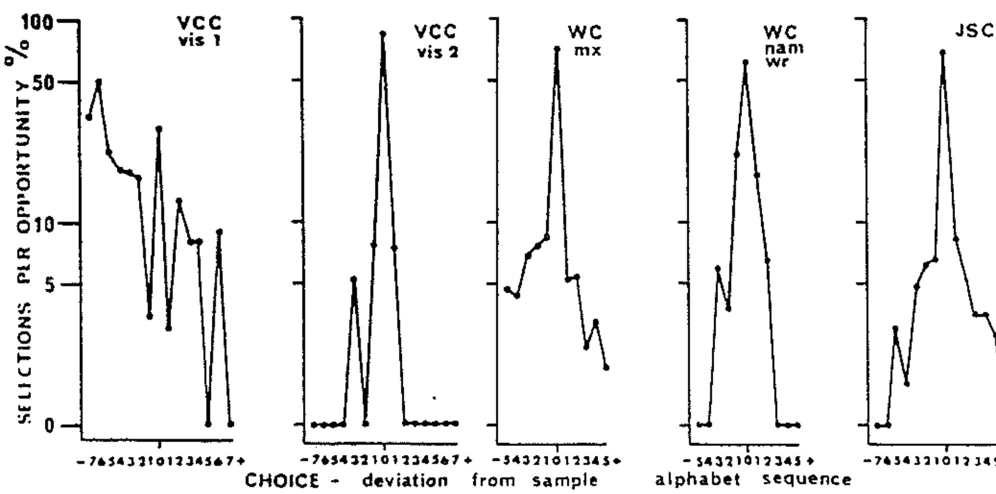

FIG. 6. Tests with letters. Generalization gradients, relationships of subjects' responses to samples by alphabet parameter. (W. C. matching tests 6 choices and 2 blank keys each trial.)

W. C., male, 28, severe head injury 5 years before, left temporal craniotomy, subdural haematoma. Permanent right hemiplegia, hemianopia, severe aphasia, Living in an institution. Aphasia examination: made sentence responses, prosody and pronunciation fair except for verbal paraphasias. Repetition familiar words intact. Numerical, alphabet sequences recited correctly. Paragraph reading, writing to dictation poor. Digits correct, other naming defective: letter, objects fair, words, colours, body parts poor. Matching from visual samples to visual choices: letters, simultaneous 9/9, delayed poor; words to pictures 5/20, color names to colors 13/18, digits to digit names 10/10. Matching from auditory samples to visual choices: letters 14/20, words 7/20, words to pictures 16/20, color-names to colors 8/10, digit names to digits 10/10.

The patient was given matching tasks with single letters, and he made errors related to the correct responses by proximity in the alphabet (Fig. 6, third from left, combined result of all matching tests). On naming and writing tests the patient always produced an unambiguous single letter response. These unusually "clean" responses allowed us to study the effect of the alphabet sequence when all 26 letters were available for responses on every trial. Only lower case consonants were tested. A generalization gradient was made by designating deviations from the sample to the letters in blocks of 5. For example, sample letter f: a–e, −1; g–k, +1; l–p, +2; q–v, +3; v–z, +4. This gradient showed a strong relation by alphabet sequence between samples and errors (Fig. 6, second from right). Closer analysis showed that several other factors also influenced the responses. The naming errors were:

	aud.	visual										tactile samples									
Sample	v	h	t	q	s	y	d	p	k	j	x	j	s	p	d	h	y	q	x	t	k
Error	z	j	p	b	r	v	b	b	i	l	z	l	r	o	b	i	v	j	z	r	o

There was confusion, based on a physical parameter of letter shape, between the isomeric b, d, p, q, with a bias to response "b". This influence produced the two errors with large deviations from sample by alphabet sequence.

His writing responses were:

	auditory sample																			
Sample	m	c	k	r	h	w	s	x	t	q	z	j	f	b	l	v	y	p	d	n
Response	M	C	L	P	P	W	P	P	P	P	Z	P	P	B	P	V	Y	P	D	N

There was an interaction between two influences: alphabet sequence and perseveration with response P. The 10 P responses were predominantly with samples close to P in the alphabet (r, h, s, x, t, q, j, f, l, p); the sum of their absolute deviations from P was 46. The 10 other responses were predominantly with letters distant from P (m, c, k, w, z, b, v, y, d, n); the sum of their absolute deviations from P was 81.

The alphabet sequence was important in the performance of several other aphasic patients who were thought clinically to have involvement of the posterior speech areas (Fig. 6, right, combined matching tests, Case J. S. C.).

Error responses controlled by unknown parameters of colors or color-names

Extensive testing with colors and color-names was carried out. The same six colors—red, orange, yellow, white, green and blue—were used for every trial. We could not apply the usual methods of analysis to these tests, because we had not quantified, rank-ordered or even specified the stimulus parameters likely to be important. Instead, errors were analysed by a "scattergram method" that demonstrated lawfulness in the patient's responses by showing that particular errors occurred more frequently than could be due to chance. For example, non-random behavior might produce the particular error of repeatedly responding to the red sample by selecting the orange choice.

The results with four patients will be presented. The subjects all succeeded in matching from color samples to color choices. They made errors on other tests with colors: matching color samples to delayed color choices, color samples to color-name choices, visual color-name samples to color choices, and auditory color-name samples to color choices. The resulting scattergrams are shown in Fig. 7.

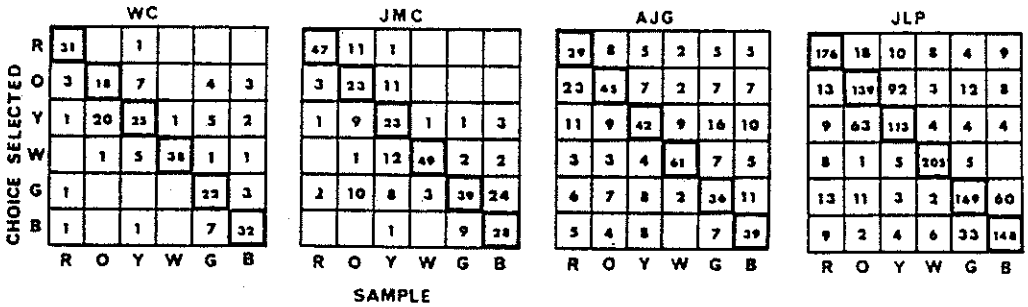

FIG. 7. Tests with colors and color names. Colors red, orange, yellow, white, green, blue indicated by first letter. Scattergrams of responses.

Consider first Case W. C., the patient with severe aphasia due to a head injury five years before. The scattergram is read as follows: When red was the sample he was correct 31 times, he selected the orange choice 3 times, the yellow, green and blue choices each once and the white choice never. When orange was the sample he was correct 18 times, he selected the yellow choice 20 times, the white choice once, and never chose the red, green, or blue choices; and so on for each sample color. He chose the red choice 32 times, 31 times correctly and once in response to a yellow sample; and so on for his choices of each color. This was not a random performance. The commonest errors were between yellow and orange, with a bias to select yellow. Errors between blue and green were frequent, with a bias to select blue. The yellow samples and the white choices were related. With white samples he made only one error, a yellow choice.

The other scattergrams of Fig. 7 also show the effects of response biases and of relationships of errors to samples. Case J. M. C. was not aphasic. He had memory loss and difficulty with certain tasks involving colors, due to infarction involving the left hippocampus and left lingual gyrus. He had a response bias for green choices (particularly with delayed matching of colors to color choices). The commonest errors were between green and blue, with a bias to select green. Errors between yellow and orange, between red and orange, and white responses to yellow samples were common. He was most accurate with white.

With Case A. J. G. the frequent occurrence of particular errors was less striking. He had right hemiplegia and severe aphasia caused by left middle cerebral artery embolism. The relation of error to sample was greatest between red and orange, with a bias to select orange. There was a modest response bias to select yellow. He was most accurate with white.

Case J. L. P. had right hemiplegia and severe aphasia with left internal carotid artery occlusion [4]. He showed clear relations of errors to samples, greatest between yellow and orange, and also between blue and green, red and orange. He was most accurate with white.

Overall, the commonest mistakes were errors involving the pairs red and orange, orange and yellow, and blue and green. Evidently, the colors were not arranged in a smooth continuum along the unknown parameters that controlled the errors. Rather, there was a red-orange-yellow cluster, white, and a blue-green pair. Yellow and white were related, but less closely. These relations may have been determined by one parameter or by several parameters. Some erors (e.g. between blue and white) were very rare, presumably because these colors were not at all similar in any controlling parameter. Their occasional occurrence may have been due to the intrusion of another factor. It seems likely that physical parameters of the colors were important in determining the errors. This is especially probable in Case J. M. C., who was not aphasic and could read color names and write them for dictation.

There is special interest in the performance of two of these patients with another task, that of matching auditory color-name samples to visual color-name choices. These results are shown in Fig. 8. Although the test involved only the color-names, these patients showed some of the same errors that were frequent in tests between colors and colour names, in which tests they were attributed to physical parameters of the colors. Compare Figs. 7 and 8, especially the common yellow-orange and blue-green confusions. The interpretation of this finding will be considered in the Discussion.

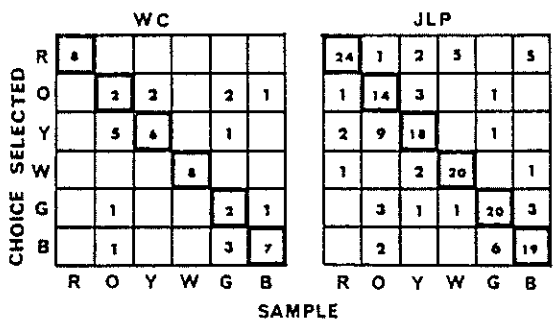

FIG. 8. Tests with color names. Auditory color-name sample, visual color-name choices. Scattergrams of responses.

Errors producing perseveration

In matching-to-sample tasks with a number of patients there were 81 instances of perseveration for 3 responses or longer. Of these, 55 were 3 trials long, 18 were 4 trials long, and 8 lasted longer than 4 trials. Two mechanisms seemed to produce perseveration. Sometimes the patient continued to make a response that had been correct and reinforced as an earlier trial. In other instances, the patient used irrelevant parameters of the stimuli, such as the white background on which color-names were printed. The eight longest runs of perseveration were all explained by these mechanisms, and so were many of the short runs. The long runs of perseveration are itemized in Table 1.

Consider first perseveration due to a previously correct and reinforced response. This may be illustrated by some responses of patient R. J. M., a 42 year old man who had recent myocardial infarction, left middle cerebral embolus, right hemiparesis, transient hemianopia, unintelligible speech, and profound posterior aphasia all aspects of language. His performances during tests, matching auditory digit-name samples to visual digit choices and auditory color-name samples to color choices were:

Sample	"nine"	"four"	"eight"	"three"	"seven"	"five"	"onc"	"nine"	"two"
Response	7	2	7	3	3	3	3	3	3

Sample	"ora"	"yel"	"whi"	"red"	"gre"	"blu"	"ora"	"whi"	"blu"	"yel"
Response	ora	ora	ora	red	gre	gre	ora	ora	ora	ora

Note that each perseveration began with a correct response. It was the short runs of perseveration that often began with a correct response. An elegant example was seen when patient A. J. G. attempted to write the names of pictures of simple objects (Fig. 9).

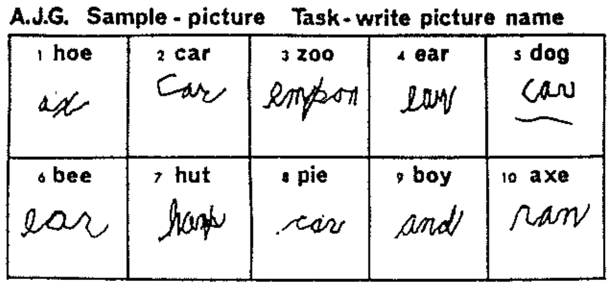

FIG. 9. Responses related to previous correct and rewarded responses. Perseveration. 10 trials, order of presentation shown by numbers.

We suggest that the correct response led to the perseveration, and that the consequences of responses were important in this regard. After correct responses the chimes rang, and made it clear to the patient that the response was correct. The patient was rewarded, or reinforced, by payment, and probably by implicit approval and the satisfaction of knowing he was correct. After incorrect responses the chimes did not ring and there were no rewards or reinforcements. We believe that with our arrangements of tests, patients, and consequences of responses some perseveration was produced by the reinforcing consequences of a correct response, and may have been terminated by the absence of rewards for perseverated responses.

Table 1. Perseveration for more than four trials

Patient	No. of perseverated trials	Task	Perseverated choice	Origin of perseveration
H.E.D.	5	sample: auditory color-name choices: visual color-names simultaneous matching	blank window	irrelevant parameter
M.M.	5	sample: auditory color-name choices: visual colors simultaneous matching	white	irrelevant parameter
R.J.M.	6	sample: auditory digit-name choices: visual digits simultaneous matching	3	correct response
M.McL.	6	sample: auditory letter choices: visual letters simultaneous matching	blank window	irrelevant parameter
J.A.C.	9*	sample: auditory digit-name choices: visual digit simultaneous matching	3	correct response
R.E.R.	12*	sample: auditory color-name choices: visual colors simultaneous matching	white	irrelevant parameter
R.E.R.	18*	sample: auditory color-name choices: visual colors simultaneous matching	white	irrelevant parameter
R.E.R.	18*	sample: visual color-name choices: visual colors simultaneous matching	white	irrelevant parameter

* Continued to end of test.

Perseveration due to using irrelevant stimulus parameters may be illustrated by some results with Patient R. E. R.

R. E. R., male, 25 obscure dementing illness. Slow deterioration for 8 years. Unable to keep any job because he failed to benefit from instruction, had a poor memory, and was apathetic. Now quite apathetic, living in a nursing home, On examination, memory span less than 5 minutes, poor fund of knowledge, no plans. Clinical picture like simple schizophrenia. No color agnosia or aphasia. CSF protein 100–150 mg/100 ml repeatedly. No specific diagnosis after full investigation.

The circumstances of R. E. R.'s remarkable perseveration with white were: First, color samples were matched to color choices. In this test the center sample window color was the relevant parameter. The test was done correctly. Then auditory color-name samples with color choices were given. In this test the center window was off-white while the auditory color-name was presented. He selected the white choice on every trial, apparently because of the irrelevant off-white color of the sample window. The test with color samples was repeated and he was again accurate. Then visual color-name samples with color choices were given. In this test the sample window showed the printed color-name on a white background identical in color to the white choice. The patient selected the white choice on every trial. He then read the color names aloud and named the colors without error. The test with auditory color-name samples was repeated and he again selected white on every trial. After this, the tasks were repeated while the patient was given verbal instructions with every step of every trial. He performed better, although there were five short runs of perseverated white responses, three of which began with a correct white response.

Three other patients (M. M., A. J. G., J. L. P.) began the tests with color-name samples with erroneous perseveration of white choices. In their cases the perseveration was soon terminated, probably by lack of reinforcement. The examples of perseveration of blank key choices (Table 1) were analogous, as the center window and the blank choice windows looked similar in these tests. Another instance of perseveration occurred when Case W. C., aphasic after head injury, was to write the names of colors. Each sample appeared on the center window as a bright, colored square. The patient drew the outline of the square (Fig. 10). His response was related to an irrelevant parameter of the sample, its shape. This response was perseverated for eight trials.

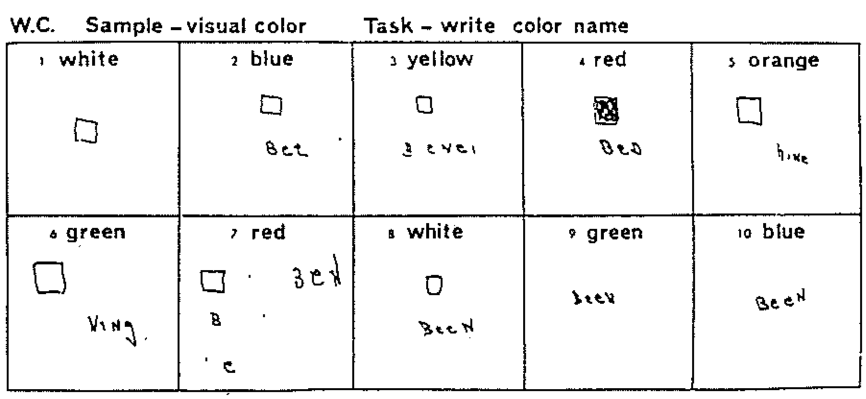

FIG. 10. Responses related to irrelevant parameters. Perseveration.

We believe that with our arrangement of instructions, tests, and reinforcements, some perseveration was produced by responses to irrelevant parameters of the samples. This type of perseveration sometimes occurred in potentially capable subjects, and instructions that were inappropriate for the particular patient appeared to be important in its genesis.

Repeating a response that was initially correct may in some circumstances produce an error pattern other than perseveration. This was demonstrated by Patient V. C. C., when she first attempted delayed matching of visual letter samples to visual letter choices. She began this task with several errors of undetermined origin. She then correctly selected C, the earliest in the alphabet of the 8 choice letters of that trial. This selection immediately initiated a general pattern of choosing the earliest letter available. This occurred despite the fact that the earliest letter was different from trial to trial. Sixteen such selections were made, comprised by letters A, B, C, D, E and K.

The use of irrelevant stimulus parameters may also produce an error pattern other than perseveration. A remarkable example of this occurred when Patient W. C. was to write the digit-names of sample digits. His responses are reproduced in Fig. 11. On the first trial (Sample 5) the patient first wrote the digit 5. He was told again to write the name of the digit and he wrote E, remarking: "The fifth one." He was told to write the word. He said, "There is no word there," and wrote Eat. This response was related to an irrelevant parameter of the sample, the corresponding letter of the alphabet. This type of response persisted, without further instructions being given, for the entire nine trials of the test, although the patient had a new sheet of paper for each trial and received no rewards.

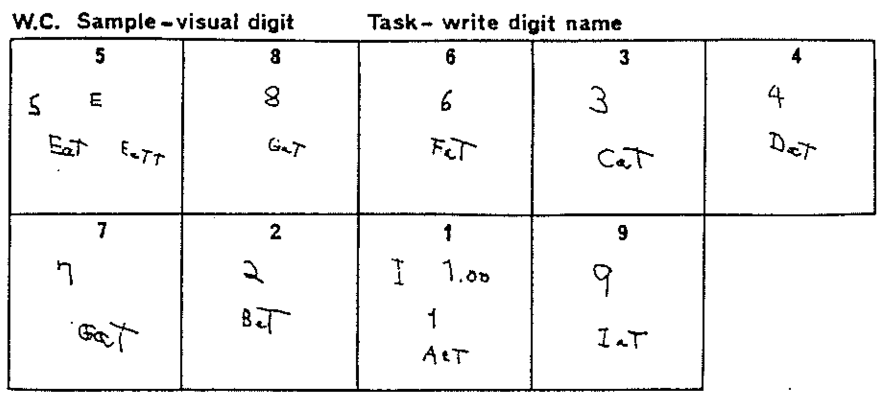

FIG. 11. Responses related to irrelevant parameters. Not perseveration.

Responses related to choice-window position

Two forms of this were seen. One was a succession of trials when the patient selected the same choice window; this was not common and often began with a correct response on that window. The other was a bias to select choice windows on the side of the matrix opposite their lesions, shown by a number of the patients whenever they were inaccurate at the task [5]. When present, this bias occurred in conjunction with the various phenomena discussed earlier.

DISCUSSION

Errors related to the sample by relevant parameters used inadequately

Relevant stimulus parameters are those parameters that relate the sample to the correct choice; by their use the task can be done correctly. In our patients the error responses were often related by relevant parameters to the sample stimuli.

The generalization gradient is the best tool for showing a relation of error responses to samples by a single measurable parameter. A sharply peaked gradient shows that there was a close relation between the responses and the parameter being studied. A flat gradient shows that there was no relation by that parameter; other explanations for the errors should be sought and can often be found. One interpretation of a gradient of intermediate form is that it shows that there was some relation to the parameter being studied, and that some other influences were also present [6, 7]. These other factors relatively often caused the subject to make errors with small deviations from the sample; occasionally, when they were particularly influential, they caused errors with larger deviations from the sample. When a gradient of intermediate form occurred, as it often did, these other factors could often be demonstrated (see naming and writing of letters by W. C., p. 146).

The "scattergram method" should be applied when the errors may be related to unknown parameters, or parameters that cannot be measured. The scattergram provides the integrated effect of all the factors influencing the performance. When the errors are related to the sample by relevant parameters the scattergram will also show which choices were closely similar to each other and which were much different. From this, the investigator may be able to discover what type of parameter was being used.

Some relevant parameters are used by normal subjects and constitute the natural method of doing the task. Other relevant parameters are redundant; they are not normally used and are alternative methods of attempting the task, by which the patient can achieve some degree of success. Although it is not certain, the alphabet sequence is probably a redundant relevant parameter in tests with letters.

Another distinction among relevant parameters is between physical parameters and language parameters. Physical parameters describe the shape, color, size, etc. of visual stimuli, the loudness, pitch, etc. of auditory stimuli, the shape, etc. of tactile stimuli. Aphasic test stimuli possess physical parameters that must be used correctly to succeed in the tests, and errors due to difficulty with these parameters were seen. Language parameters describe nonphysical parameters of language symbols. They are arbitrary, learned by convention, and transfer between auditory and visual modalities. We were surprised to find that language parameters could be studied by the same methods as physical parameters, and that responses related to language parameters were governed by similar laws to those that govern responses to physical parameters. For example, the alphabet and numerical sequences, both arbitrary learned conventions, could be studied by generalization gradients. These parameters governed aphasic errors in a manner similar to the way physical parameters govern non-aphasic errors. In another example, matching auditory color-name samples to visual color-name choices (arbitrary, learned, and transferring between auditory and visual modalities) could be studied by the "scattergram method". It was found that the same types of error were made with the language parameters of this test as were made with the physical parameters of tests with colors. This finding demonstrates another point—that language symbols apparently come to be governed by the physical parameters of the things they represent. This property of language symbols can explain the common observation that patients may make the same errors when reading object names as when naming objects. In our experience, patients who made errors related to language parameters had abnormalities that affected their posterior speech areas.

Errors related to the sample by irrelevant parameters

The relation of these errors to the sample may easily be overlooked; the examiner, attuned to the relevant aspects of the task, may be misled by the patient's low score. The errors frequently appeared as perseveration, but they could take other forms. In the circumstances of our tests they usually began with the first trial of a test, and sometimes persisted for many trials; their characteristics might change with different tests, instructions, and consequences of responses. This type of error sometimes occurred in patients who were potentially capable of doing the task correctly (e.g. R. E. R.), because the instructions were inappropriate for that patient.

Errors related to previous correct and rewarded responses

These errors frequently appeared as perseveration, but they could take other forms. In the circumstances of our tests they often intervened in the course of a test, and usually persisted for only two or three trials; these characteristics might change with different consequences of responses. The errors occurred because the previous correct response had reinforcing consequences. They are consistent with a fundamental tenet of modern behavior theory, that a response is likely to be repeated if it has certain consequences, which have been termed reinforcing.

Totally unexplained errors

Many errors remained unexplained. They included some instances of perseveration, and many apparently random errors. As so many factors have been found to be important, it is quite possible that patients' responses are always generated in some lawful way. With present-day methods it is difficult to analyze responses that are produced by a complex interaction of multiple factors, and especially so when these factors change rapidly in the course of testing. Clear examples of interaction of multiple factors and of change of method by the patient during testing did occur, and similar mechanisms probably underlay a proportion of the unexplained errors. Other errors may have been related to undiscovered parameters.

Relation to previous interpretations of error responses in aphasia

Our interpretations of errors have much in common with those of previous workers, but some differences exist. Previous workers have pointed out that some errors were related to the correct response by shape or sound. In our terminology these error responses were controlled by relevant physical parameters of the sample. Other errors were related to the correct response in meaning or by an "inner relation". These errors were also related to the sample by relevant parameters, probably language parameters.

Previous workers have believed that perseveration was caused by abnormal physiology—abnormally facilitated and persistent after-effects of ideation, memory, or motor performance [2, 8–15]. We have described perseveration due to repeating previously correct and reinforced responses and perseveration controlled by irrelevant stimulus parameters. Both these types are consistent with established principles of behavior, and neither requires any abnormal physiology. There are probably a number of different processes by which perseveration is produced.

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Résumé—On a étudié quantitativement les erreurs faites par les malades atteints d'aphasie et d'autres désordres voisins. Quelques erreurs étaient liées à l'exemple par les aspects pertinents des stimulus, soit paramètres physiques, soit paramètres linguistiques. Quelques erreurs étaient liées aux aspects non pertinents des stimulus et ces réponses apparaissaient souvent comme des persévérations. Quelques unes de ces erreurs de persévération étaient des répétitions d'une réponse antérieurement correcte et réenforcée dans un essai précédent. Les mécanismes qui produisaient parfois la persévération entrainaient aussi des réponses de caractère nonpersévératif. Les conséquences de ces réponses de persévération pour les malades peuvent être un important facteur dans quelques types de persévération.

Zusammenfassung—Die Fehler von Kranken mit Aphasien und verwandten Störungen wurden einer quantitativen Prüfung unterzogen. Einige Fehler ließen sich nach physikalischen oder sprachlichen Parametern gliedern, andere hatten keine Beziehung zu den jeweiligenReizen. Diese stellten sich oft als Perseveration dar. Manche perseverierte Fehler waren korrekte Wiederholungen einer Antwort auf eine vorherige Frage. Der Mechanismus, der zur Perseveration führt, kann auch Antworten bewirken, die nicht perseverativ sind. Der Einfluß einer perseverierten Antwort auf den Kranken ist für machne Perseverationsformen bedeutsam.