J. psychiat. Res., 1971, Vol. 8, pp. 413–422. Pergamon Press. Printed in Great Britain.

THE BEHAVIORAL ANALYSIS OF APHASIA*

MURRAY SIDMAN

Department of Neurology, Massachusetts General Hospital, Boston, Massachusetts

MANY disciplines claim language as their domain, and each approaches language with its own concepts and methods—behavioral, linguistic, cultural, logical, etc. Since central-nervous-system lesions do not constitute the empirical operations upon which these disciplines base their theories, the effects of such lesions provide an independent test of the theoretical formulations. All disciplines seem to accept the notion that aphasia is a major theoretical testing ground. Even if CNS lesions do not appear in the theoretical statements, such lesions must cause language to 'fracture' along lines that are consistent with the theoretical classifications.

Two major problems, however, have hindered the integration of aphasic deficits with theoretical formulations of language: The definition of language, itself; and the methods of examining and classifying aphasic deficits. The first problem has been an unnecessary hindrance, not because language is easy to define but because it need not be defined in order to study the phenomena of aphasia. Such definition has been a problem only because it has influenced the way we examine aphasic behavior, and has determined the kinds of observations we are willing to accept. The phenomena of aphasia can be classified empirically, without biasing the observations by preconceptions of what language 'really' is. The data will then be available to any theory.

The methodological problems are more serious. Few aphasiologists have felt it necessary to describe their test conditions, procedures, materials, or even the behavior of the patients. For example, we often find the patient's deficits classified as 'expressive' or 'receptive', as 'recognition' or 'comprehension' disorders, etc., without any specification of the actual task or of the responses required of him; we find the writing of one set of words from dictation compared with the reading of another set of words from text, and, added to these confusions, no indication of the behavior that was required to demonstrate 'reading'; we find responses to spoken sentences compared with responses to single printed words; some examiners tell the patient that he responded correctly, and others give the patient no feedback at all. The list could go on indefinitely; anyone who has attempted seriously to survey the literature on aphasia is familiar with the inevitable frustration.

* This research was supported by Grant NS 03535 from the National Institute of Neurological Diseases and Stroke, and by the Joseph P. Kennedy, Jr., Laboratories of the Neurology Service, Massachusetts General Hospital. Colleagues in these studies have been J. Leicester, J. P. Mohr, P. B. Rosenberger and L. T. Stoddard.

Rather than add yet another set of theoretical suppositions and concepts, we have attempted in our studies of aphasia to provide the kind of operational specificity that would make our data useful to anyone. We have used the characteristic stimulus materials and responses of traditional aphasiology, so that we might avoid refining out of existence the very phenomena that give this field much of its fascination, and have simply added a few elementary considerations of scientific common sense. The methods are not, of course, free of preconceptions, but these are quite simple and explicit. Their justification, or lack of it, can be judged by their analytic power and consistency.

STIMULUS–RESPONSE RELATIONS

Let us start with the word, 'hat', a simple stimulus that has at least the potential of being language. Some of the many forms the stimulus, 'hat', may take are listed on the left side of Table 1. It may be a word in visual text; an auditory word, pronounced or spelled; a tactile word, felt but not seen; or an object or picture in any of several varieties or forms.

TABLE 1. SEVERAL FORMS OF THE STIMULUS, 'HAT' AND SEVERAL TYPES OF APPROPRIATE RESPONSES

Stimulus: *Hat*	Responses
Visual word, upper case	Oral pronunciation
Visual word, lower case	Oral spelling
Visual word, script	Oral synonym
Visual objects	
Visual pictures	Written naming, upper case
	Written naming, lower case
Auditory word, pronounced	Written naming, script
Auditory word, spelled	Written synonym
Tactile word, upper case	Matching to visual or tactile word, u.c.
Tactile word, lower case	Matching to visual or tactile word, l.c.
Tactile word, script	Matching to visual or tactile word, script
Tactile object	Matching to auditory word, pronounced
	Matching to auditory word, spelled
	Matching to visual or tactile objects
	Matching to visual pictures

Appropriate responses to these stimuli are listed on the right side of Table 1—various types of naming, writing, and matching. No single one of these stimulus–response relations can be taken as evidence for language: A parrot can repeat pronounced words; a dog can be taught to do many of the matching tasks; a person who speaks only French can copy the printed English word. But when one of the stimuli, for example, the pronounced word, can give rise appropriately to all of the listed responses, and when all varieties of the stimulus can give rise to the same response, for example, oral pronunciation, we approach language more closely. An additional step is taken when each of the listed stimuli can be shown to control all the listed responses. Finally, when corresponding forms of other stimuli, for example, cat, hay, hut, etc., can be shown to control a corresponding list of responses, it is difficult not to conclude that we are dealing with some aspect of language.

The main point of this analysis is to show that we can specify a large segment of language behavior simply in terms of a set of stimulus–response relations. The approach does not necessarily encompass everything that might be called language. Yet to deny that the specified set of stimulus–response relations constitutes language, on the ground that it fails to deal with concepts, grammatical or syntactical relations, memory, learning, or development, etc., would be to ignore a large and important, if limited, class of language behavior. The appropriate question is whether the stimulus–response classification is meaningful; in the present context, does it permit us to chart lines along which behavior fractures in aphasia?

That the answer turns out to be, 'yes' should not surprise us, for many basic observations in aphasia are of deficient stimulus–response relations. A single stimulus controls many responses; a single response is controlled by many stimuli; and CNS disease need not break down all relations in which a particular stimulus or response participates. In Fig. 1, for example, S is a written word that controls reading aloud (S–R_1), copying on paper (S–R_2), and pointing to a picture (S–R_3). A cerebral lesion that leaves S–R_1 and S–R_2 intact but destroys S–R_3 is often said to leave the patient with the ability to read the word without knowing its significance. If the lesion leaves S–R_3 intact but destroys the other S–R relations, we have the condition of Broca's aphasia.

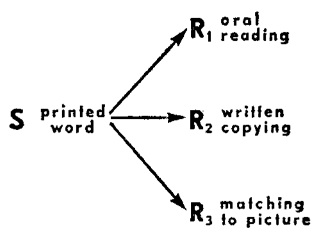

FIG. 1. Schematic representation of three stimulus–response relations, each of which shares the same stimulus.

The following scheme for testing utilizes a manageable number of elements from Table 1. Sample stimuli, at the left, provide initial input to the patient in any of three modalities, vision, hearing, or touch; he processes the samples according to the demands of each task. In simultaneous matching (top line), pressing the sample exposes a second set of input stimuli, the choices; the final response in the sequence is to press a choice that corresponds to the sample. Delayed matching has the same initial input and final output as simultaneous matching, but a time delay intervenes between sample press and appearance of choices; choices appear without the sample, which the patient must remember. Naming and writing have the same initial input as matching; the output differs. A complete description of the procedures and their automation may be found elsewhere.[1] This scheme permits us to evaluate four types of response to a single stimulus, for example, to a printed 3-letter word;

or a single response to several different stimuli, for example, oral naming of visual, auditory, and tactile words. It is possible, then, to observe the elementary but vital precautions of maintaining input constancy while varying the responses required of the patient, and maintaining response constancy while varying the input.

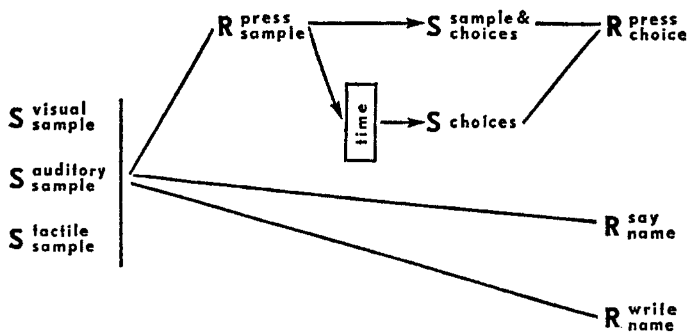

FIG. 2. Summary of test procedures as described in text.

IDENTITY VS. NONIDENTITY TASKS

Figure 3 shows the nearly complete test profile of a single patient whose deficits had become relatively stable after a severe head injury 5 yr earlier. He had undergone a left temporal craniotomy and evacuation of a subdural hematoma, and also had a right temporal burr hole placed.* The patient had a permanent right hemiplegia, hemianopia, severe aphasia, and amnesia. His test profile is arranged to facilitate two types of analysis. First, each of the four types of response, simultaneous matching, oral naming, writing, and delayed matching, can be examined individually as a function of different stimulus materials and sample stimuli. Second, specific sample stimuli, for example, visual, tactile, or auditory letters can be examined as a function of the type of response that was required of the patient.

Before examining the test scores in any detail, it will be advantageous to take account of the differences emphasized by the solid black and the gray bars. Solid black indicates 'identity' tasks; gray indicates 'nonidentity' tasks. The distinction is as follows:

Take simultaneous visual–visual matching of letters. This is an identity task because the sample letter and the correct choice are exactly the same. The patient can match a letter without recognizing it as a letter, even without having seen it before. Tactile–visual matching may be a second type of identity task. Having learned that tactile and visual stimuli, although physically different, may be equivalent, the patient can match a tactile to a visual letter without having experienced the letter before in either modality.

The same considerations apply to trigrams, 3-letter words, pictures, colors, and digits, the identity matching tasks for these materials being indicated by solid black bars. Note that in simultaneous matching, the patient performed all the identity tasks nearly perfectly.

* The study of this patient was made possible through the cooperation of Dr. D. Frank Benson, Boston Veterans Administration Hospital.

So long as the patient can discriminate and match any physical stimulus aspect, for example, shape, area, color, or angularity, he need have no behavior that is uniquely common to a particular sample and choice. He cannot, however, match a letter seen to a letter heard without having learned a name or some other response that is uniquely common to that particular visual letter and to its auditory counterpart; auditory–visual matching is 'nonidentity'. Similarly, each of the following is a nonidentity matching task: matching of words with pictures, and *vice-versa*; color names with colors and vice versa, digit names with digits, and vice versa; and digits with dots. The patient was not deficient in all of these simultaneous matching tasks, but all of his serious deficits were in nonidentity matching (gray bars).

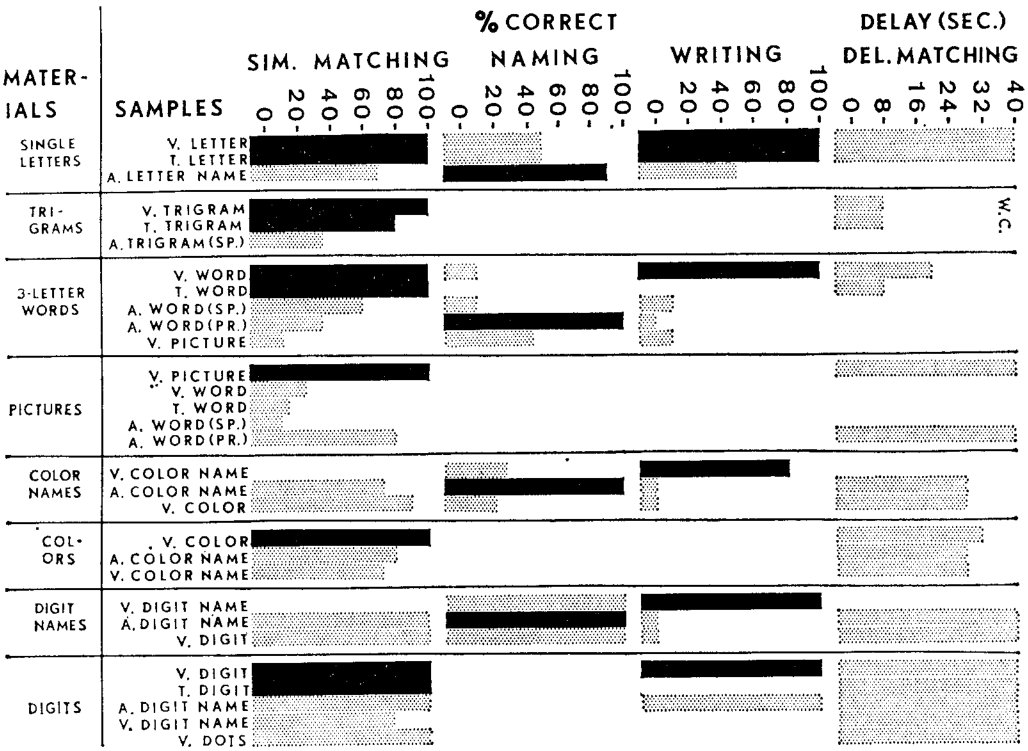

FIG. 3. Example of a test profile. '*Materials*' indicates the choice stimuli in the matching tasks, as well as the product of the naming and writing tasks, in response to each of the indicated sample stimuli. *V.*—visual; *T.*—tactile; *A.*—auditory.

Certain naming and writing tasks constitute additional identity classes. For example, auditory–naming may involve only repetition. A patient who can imitate sounds will be able to name a dictated letter even if he has neither heard nor spoken it before. He may also copy a visual letter without having seen or written it before. Tactile–writing may also be an identity task; a patient who can draw tactile samples may copy a tactile letter he has never felt or written before.

By contrast, the patient could not do nonidentity naming and writing tasks by imitation, copying, or form equivalence, but only by virtue of learned mediating responses. The patient's scores on the naming and writing tasks, like simultaneous matching, reflect the identity–non–identity distinction. Those naming tasks that could be done by mere oral repetition, and those writing tasks that could be done by copying the samples, were nearly perfect; all deficits were in the nonidentity tasks.

Delayed matching must be regarded as a nonidentity task, even with identity materials. Sample and choice are never available for simultaneous comparison, and the patient must respond to the sample with some behavior that permits him to bridge the delay. In support of this, we may note that even some of the identity matching tasks broke down when changed from simultaneous to delay (trigrams, 3-letter words, colors).

The identity–nonidentity distinction, reflected in the patient's test scores, provides a necessary control in the study of aphasic deficits. For example, even while the patient had trouble naming visual and tactile letters, he matched and copied those same letters perfectly. Even while he had trouble matching and writing dictated letters, he was able to repeat them orally. Each input, visual, tactile and auditory letters, was involved in at least one intact stimulus–response relation. Therefore, none of his problems with letters could be classified as input deficits. Similarly, output deficit with letters could be ruled out because there was at least one adequate performance with each of the three types of response: matching, naming, and writing.

The identity performances provide the same type of control for each of the test materials. The patient's deficits, therefore, cannot be classed as input or output and must, by exclusion, fall into a relational category; they indicate deficient input–output relations. These relational deficits were not confined to any particular stimulus modality, stimulus material, or response. The patient's naming and writing deficits were not simply expressive; his matching deficits were not simply receptive. Inputs were deficient only when related to certain types of output, and outputs only when related to certain input stimuli.

Without going into all the interesting details of the patient's test profile, we can summarize the following major characteristics. Eliminating the identity tasks (solid black bars) from consideration, since they have served their control function, we see, with the exception of certain tasks involving numbers: relational writing deficits that cut across stimulus materials and modalities; relational naming deficits that cut across stimulus materials and modalities; and relational matching deficits that appear largely confined to tasks that involve visual letters and words as samples or choices. Delayed matching requires further clarification, and has been discussed elsewhere.[1]

The classification along the lines of empirical stimulus–response relations does reveal orderly categories of behavioral deficit in aphasia. The case presented here is not unique, nor is this the only deficit constellation the methods are capable of revealing. Some additional findings, and their implications for the study of language, will now be discussed.

LETTERS AND WORDS

The separate analysis of performances on identity tasks serves as a control for input and output deficits, and permits the identification of relational deficits. Relational deficits are a unique product of a stimulus–response analysis. Language, too, is a relational process. It is neither a particular type of input nor is it merely speech or any other single output, but is a process that includes many types of input, output, and their interrelations. But it would not be profitable to equate language deficit with the relational category, for this deficit category is not a unitary entity. Different nonidentity performance profiles among stimulus materials, input modalities, and output responses illustrate its multifaceted nature.

A particularly interesting example is the difference some patients show when analogous performances with letters and words are compared. Relational deficits that involve either letters or words might, with some justification, be considered language deficits. Yet not only may a patient's performances with these two materials differ, but the simpler-appearing materials, letters, may actually be associated with the more severe deficits. Because words are longer than letters, contain several letters as elements, and come from a larger stimulus population, one might reasonably expect more severe deficits with words than with letters; this expectation justifies the comparison of absolute test scores across the two different stimulus materials, a practice that is otherwise likely to lead to misleading conclusions.

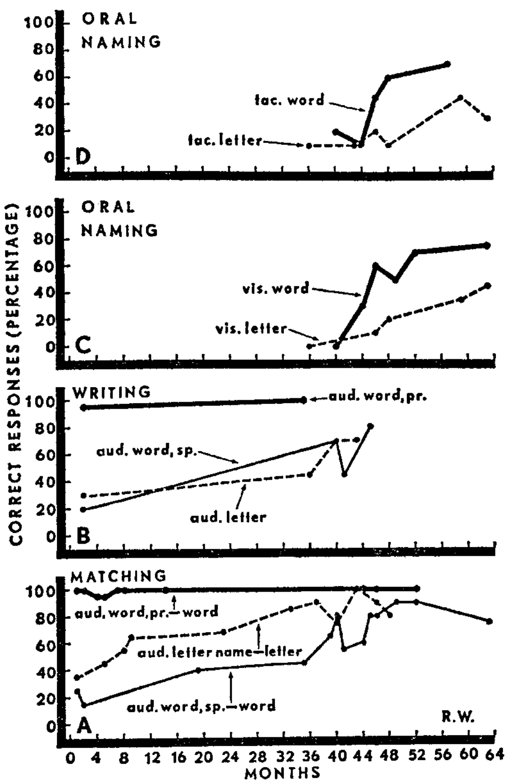

FIG. 4. Test scores as a function of time. Each frame shows the patient's scores for a given response: matching, writing, or naming; each curve is labelled with the type of stimulus to which the patient responded. The curves in frame *A*, *Matching*, show the sample and choice stimuli, the latter always visual.

An illustrative patient is a boy who suffered an occlusion of the left middle cerebral artery, with right hemiparesis and complete loss of oral speech.[2] Tested frequently over the next five years, his deficits evolved in a most interesting way. The heavy black curve in Fig. 4 shows his nearly perfect performance in matching auditory-pronounced 3-letter words (dictated) to visual-word choices (printed). The same task with single letters, dictated samples to be matched to visual choices (broken-line), was, however, severely deficient at first, and improved only slowly over the next four years. When the samples were the dictated words, spelled rather than pronounced, to be matched to the same visual words, the patient's performance was also grossly deficient, and improved only slowly.

Comparable deficits were observed in writing. The patient was able from the beginning to write the dictated-pronounced words, but had great difficulty writing dictated single letters and dictated-spelled words (Fig. 4).

During the first 3 yr, before the patient was capable of any oral speech, the selective matching and writing deficits with letters were assumed to be specific auditory–visual intermodality deficits (the patient performed well on the identity tasks, visual and tactile matching and writing of letters, and auditory–auditory matching). But this assumption was premature, as was demonstrated when oral naming began to appear during the fourth year. With both visual (Fig. 4C) and tactile (Fig. 4D) samples, the patient improved more rapidly in naming words than in naming single letters.

Thus the distinction between word and letter deficits generalized across the three input modalities, vision, hearing and touch, and across the three output responses, matching, naming and writing.

One might have been tempted to classify responses to words and letters both as language, with, perhaps, words being more prone to deficit because of their greater complexity. But this patient's generally more severe deficits in response to letters than to words indicate clearly that the category, language, is too gross. The stimulus–response analysis, unprejudiced by preconceptions of what language 'really' is, can uncover types of deficit specificity for which any theory of language must find a place.

THE PRESUMED PREREQUISITES FOR SPELLING

In the literature on aphasia, one often finds statements about ancillary mental or internal processes that are presumed to underlie the observed performances. The type of analysis proposed here, because of its operational specificity, can often be useful in checking the adequacy of such formulations.

For example, spelling is sometimes characterized as a performance that requires mental transformations of spelled words into written form, and then the 'reading' of these written words (images). Such a view is subscribed to by NIELSEN[3] and has been most explicitly stated by GESCHWIND,[4] whose writings are otherwise noteworthy for their empirical specification: "In order to comprehend a word spelled out loud, the listener must transform it into written form and then 'read' it. Conversely, to spell orally one must transform the spoken word into its written form and then 'read' the letters one by one." (p. 278).

This conception was checked by examining certain relevant test scores of a patient who has been extensively described elsewhere[1]. The data are from weeks 7 and 8 post-stroke. Figure 5 deals with the comprehension of dictated-spelled words. We see first (Bar *A*) that the patient was relatively proficient at pronouncing dictated-spelled words; Bar *B* shows equal proficiency in matching the spelled words to pictures, demonstrating that the patient comprehended the spelled words; Bar *C* shows that he could match dictated-spelled words to printed words. He could respond in several appropriate ways to the spelled words.

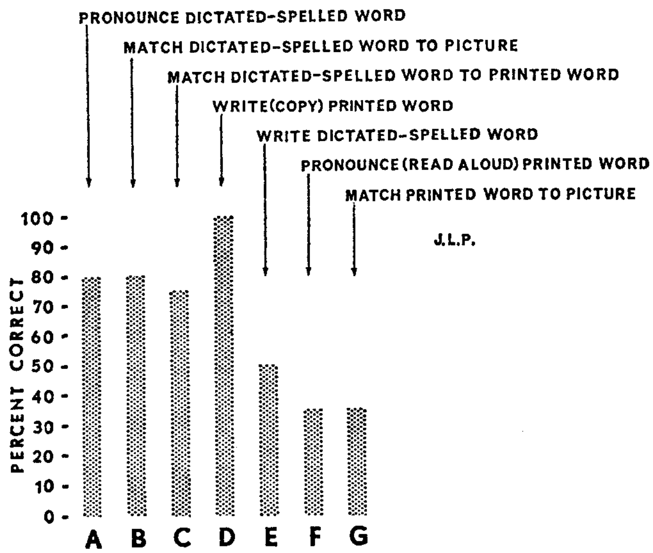

FIG. 5. Test scores on spelling comprehension and presumed related tasks.

But although his printed-word input was intact (Bar *D*), the patient was deficient in demonstrating explicitly the first of the tasks held to be necessary for spelling comprehension —writing the dictated-spelled words (Bar *E*); he was only poorly able to transform spelled words into written form.

Even if we were to suppose that his poor writing was merely apraxic or paragraphic, and that his internal writing, or imagery, was intact, the patient showed also that he could not explicitly perform the second of the presumed necessary mental tasks (Bar *F*); he was deficient at reading the written words aloud. Bar *G* shows that he was also deficient in comprehending the written words.

The patient could comprehend oral spelling, but was unable with the same words, to perform the tasks held to be necessary for spelling comprehension.

What of the converse task, oral spelling? Figure 6 shows that the patient could spell pronounced words aloud (Bar *A*), comprehend pronounced words (Bar *B*), and match pronounced to printed words (Bar *C*). But he was deficient in the first of the tasks held necessary for oral spelling, transcribing the pronounced words into written form (Bar *D*). The second of the presumed necessary tasks, reading the written letters one by one, was not tested directly with the 3-letter words, but was tested with trigrams; the patient was grossly deficient at this task (Bar *E*). He was also deficient, as we have seen before, in reading aloud and comprehending the written words (Bars *F* and *G*).

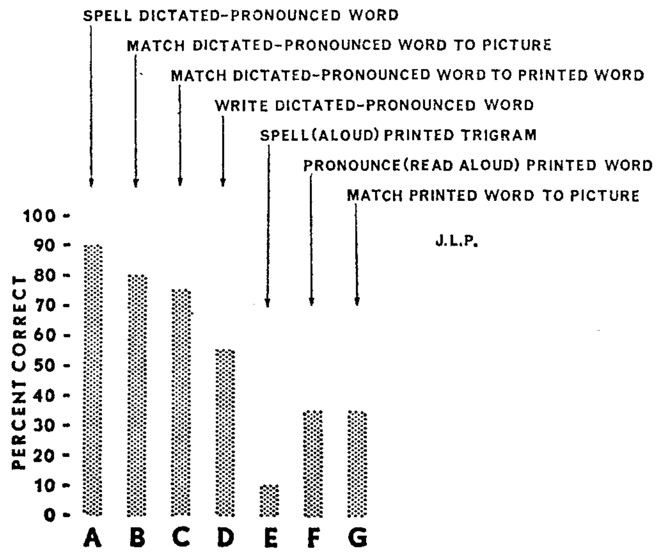

FIG. 6. Test scores on oral spelling and presumed related tasks.

The patient could comprehend spelled words and could spell orally, but was unable to demonstrate the supposedly necessary underlying processes. He was deficient in writing dictated-spelled and pronounced words, in reading aloud and spelling from text, and even in comprehending written text. It might be proposed that the overt performances described above could have been deficient while their internal counterparts were still intact. Acceptance of such a proposal would, of course, remove the study of language and aphasia from the domain of all sciences. Here, preconceived mentalistic conceptions of a language process proved amenable to specific analysis by means of relevant stimulus–response relations. An alternative proposal, therefore, is that all such mentalistic conceptions be translated into testable form and, if not translatable, that they be abandoned.

REFERENCES

1. SIDMAN, M., STODDARD, L. T., MOHR, J. P. and LEICESTER, J. Behavioral studies of aphasia: Methods of investigation and analysis, *Neuropsychologia* (in press).
2. ROSENBERGER, P. B., MOHR, J. P., STODDARD, L. T. and SIDMAN, M. Inter- and intra-modality matching deficits in a dysphasic youth. *Archs Neurol.* **18**, 549, 1968.
3. NIELSEN, J. M. *Agnosia, Apraxia, Aphasia*, 2nd ed. Hafner, New York, 1962.
4. GESCHWIND, N. Disconnexion syndromes in animals and man. *Brain* **88**, 237, 1965.