

Processing of Visual Syntax in a Globally Aphasic Patient

MICHAEL WEINRICH, RICHARD D. STEELE, GLORIA S. CARLSON, AND
MARIA KLECZEWSKA

*Department of Neurology, Palo Alto VA Medical Center and Stanford University and the
Rehabilitation Research and Development Center, Palo Alto VA Medical Center*

ROBERT T. WERTZ

Department of Audiology and Speech Pathology, Martinez VA Medical Center

AND

ERROL BAKER

Psychology Service, Boston VA Medical Center

A globally aphasic patient was trained on a computerized visual communication system. His ability to comprehend reversible locative prepositional phrases after training was studied and compared with the performance of Broca's aphasics on a similar task. This patient's ability to generalize symbols for actions was also investigated. The results demonstrate our patient's capacity to master a formal visual syntax in the absence of natural language and illustrate how this capacity may be used successfully in a visual communication system. A problem in generalizing symbols for actions is demonstrated, suggesting that certain heuristic and cueing capabilities in the approach may be helpful. © 1989 Academic Press, Inc.

INTRODUCTION

Agrammatic speech in patients with Broca's aphasia has attracted considerable clinical and theoretical interest. Clinically, effective remediation of these patients' communicative deficits requires retraining in forming whole sentences (Luria, 1970; Kertesz, 1979). Theoretically,

This work was supported by grants from the Rehabilitation Research and Development Service of the Veterans Administration, and by the Instruction and Research Information Systems of Academic Computing, Stanford University. Address correspondence and reprint requests to Dr. Michael Weinrich, Department of Neurology (127), Palo Alto VA Medical Center, 3801 Miranda Blvd., Palo Alto, CA 94304.

agrammatic speech may present a window into the generation of normal speech, for example, “. . . the set of language mechanisms available to aphasics are subtractive—that is, the aphasic is simply lacking some of the components available to normal language speakers, rather than inventing new ones” (Saffran, 1982). This assumption figures prominently in most contemporary theoretical discussions of agrammatism (Lapointe, 1985) and indeed has been a cornerstone of the syntactic deficit theory of agrammatism (Goodglass & Menn, 1985; Kolk, Van Grunsven, & Keyser, 1985).

Recently there has been some withdrawal from viewing agrammatism as a pure syntactic deficit. Linebarger, Schwartz, and Saffran (1983) demonstrated that agrammatic patients can correctly determine whether sentences are grammatical even though they do not comprehend them. They have now moved away from their earlier claim that “. . . agrammatic subjects have a syntactic deficit such that they are unable to utilize a fixed and principled set of procedures to recover the relational structure of spoken sentences” (Schwartz, Saffran, & Marin, 1980) and take the position that “. . . the Syntactic Deficit Theory is untenable” (Schwartz, Linebarger, & Saffran, 1985). Goodglass and Menn (1985) conclude that “. . . the failure to comprehend morphologically and syntactically encoded relationships between nouns is the same phenomenon in both fluent and nonfluent aphasics and is due to cognitive problems in dealing with decoding the linguistic expression of those relationships.”

In reviewing the evidence that meaningfulness plays a major role in verbal memory, especially in the language processing function of the right hemisphere, Goodglass and Menn (1985) suggest that “. . . it is quite conceivable that attributes like meaningfulness, concreteness, and imageability interact with diverse neural mechanisms involved in the production and comprehension of language through the several intake and output modalities. . . .” In this context it becomes important to ask what syntax-like operations are available to patients who show no natural language function due to severe global aphasia. Examining compensatory syntactic ability in these patients is important in its own right and may also shed some light on patterns of natural language use in less severely afflicted patients.

Baker, Berry, Gardner, Zurif, Davis, and Veroff (1975) trained a severely global aphasic patient with a nonverbal visual communication system (VIC). They noted that “. . . certain cognitive capacities entailed in natural language can be preserved in its absence.” Further studies extended these findings to five severe aphasic patients (Gardner, Zurif, Berry, & Baker, 1976), but many questions regarding the extent of their syntactic processing remained unanswered. We have been developing C-VIC, a microcomputer-based extended version of VIC (Steele & Weinrich, 1986). In the course of treating a chronic globally aphasic patient with this

system, we have tested his ability to discriminate between reversible locative prepositional phrases. This task was chosen to compare our patient's performance with the performance of the agrammatic Broca's aphasia patients reported in Schwartz et al.'s (1980) study using reversible locative prepositional phrases in natural language. The purpose of this comparison is to illustrate the capacity of a globally aphasic patient, who possesses essentially no useful language function, to decode the meaning of symbol strings analogous to words in prepositional phrases. We suggest that a useful term for the rules which govern the encoding and decoding of iconic symbol strings is "visual syntax." If globally aphasic patients can utilize visual syntax to perform operations which are analogous to the comprehension of prepositional phrases in natural language, then previous theories regarding the nature of the intellectual deficits in aphasia may need revision.

REPORT OF CASE

J.S. is a 57-year-old right-handed man who was in good health except for adult onset diabetes. He was attending extension courses at a junior college for a career change until April 1985 when he suffered the acute onset of global aphasia and a mild right hemiparesis. A CT scan on admission revealed an extensive low density lesion of the left frontal, temporal, and parietal areas consistent with infarction in the left middle cerebral artery distribution. An old cystic lesion of the right temporal horn was also apparent, yet neither the patient nor his family related any history of a prior neurologic deficit. A subsequent scan 15 months later (Fig. 1) shows cavitation of the entire infarcted region. His hemiparesis resolved rapidly, but his aphasia did not. From April through December of 1985, he received speech therapy. His gestural abilities improved somewhat, as measured by improvement from the 4th to the 29th percentile on the Porch Index of Communicative Abilities (PICA) (Porch, 1967). However, there was no improvement in his verbal PICA scores. The Western Aphasia Battery (WAB) (Kertesz, 1982) showed minimal change from April (AQ = 7.3) to December (AQ = 10.4) in language abilities.

On examination, J.S. is a robust man with no evident difficulties in walking, dressing, or feeding himself. He is sociable and takes considerable interest in the activities on the ward. With the exception of the mental status examination, his neurological examination is normal. There is no residual hemiparesis, no evidence of apraxia or neglect in either hand, and no discernible visual field deficit. This relatively uncommon syndrome, the acute onset of global aphasia without hemiparesis, is primarily caused by embolic infarction, but may have other etiologies (Legatt, Rubin, Kaplan, Heaton, & Brust, 1987).

J.S.'s spontaneous speech is limited to a recurring stereotypy /ti ain/. He is not particularly skilled in inflecting this utterance to indicate his

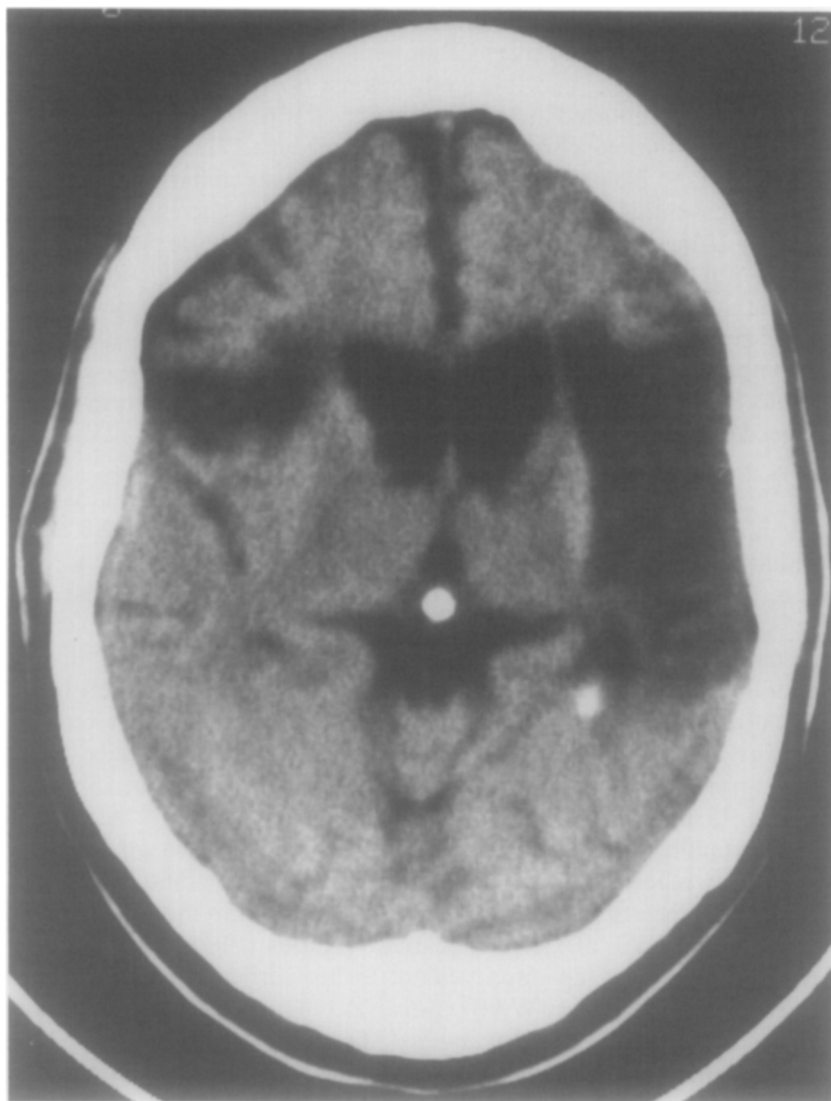


FIG. 1. CT scan of patient J.S. demonstrating an extensive lesion in the distribution of the left middle cerebral artery with cavitary infarction of the left frontal, temporal, and parietal areas, as well as a smaller right frontal lesion.

mood. He produces many hand gestures, but few of them are interpretable. They appear to be "jargon" gestures and are typically repetitive rectilinear outlines. He appears only somewhat aware that his utterances are incomprehensible. He is unable to repeat any words aloud and he cannot read printed material. He can copy letters and words moderately well but has no comprehension for what he has written. He does not write spontaneously, but when asked, he will generate long strings of well formed letters segmented into completely unrecognizable jargon words. His comprehension on the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972) gave him a Z score worse than -2.0 . He was able to match only a few spoken words with pictures, but he was quite adept at picking out objects in the embedded images of the Luria-Nebraska battery (Golden, Hammecke, & Purisch, 1980). While no evidence of right hemisphere dysfunction was evident on clinical examination, we were unable to assay for the presence of more subtle deficits of right hemisphere function because of the patient's profound comprehension deficit.

THE C-VIC INTERFACE

The technical aspects of the microcomputer implementation of C-VIC, and our experience training several patients with it, have been described (Steele, Weinrich, Wertz, & Carlson, 1986; Carlson, Kleczewska, Steele, & Weinrich, 1987). Essentially, the interface represents a computer implementation of an index card system that was developed by Baker et al. (1975) and Gardner et al. (1976). On the screen of a Macintosh computer, "stacks" of cards are displayed which represent parts of speech: interjections, proper and animate nouns, common nouns, verbs, modifiers, prepositions, and conjunctions. The user operates the interface solely through the use of a "mouse" pointing device, which is operable by one hand. A stack of cards can be "exploded" to reveal its contents, and a single card can be selected from this assortment. Cards consist of icons—pictorial representations—and associated English translations. The cards selected are arranged serially by the trainer and patient in separate communication spaces to form strings of symbols, as shown in Fig. 2. A complete C-VIC communication in this system must contain a punctuation marker at the beginning and end of the string. This ensures that patients continue to decode a string until they match markers and do not fail to perceive the meaning of a string due to visual neglect. Proper nouns for people are represented by digitized photographs. Common nouns and modifiers are drawn as representationally as possible. Prepositions are represented by juxtaposed geometric shapes, while verbs are a hybrid category, comprising concrete, inferentially composite, or semiabstract symbols constructed to represent either change of state, motion trajectories,

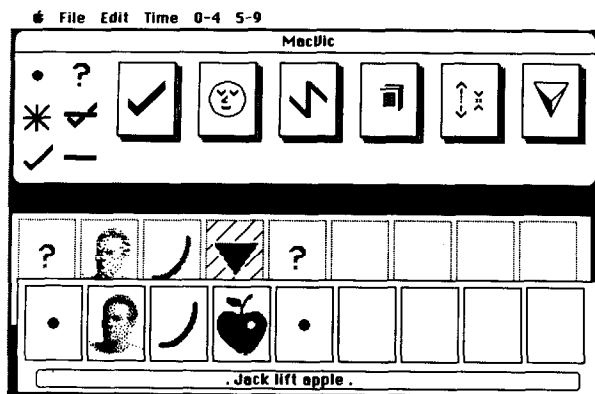


FIG. 2. The C-VIC interface screen. The screen is organized around a flashcard metaphor. Each of the stacks in the upper portion can be "exploded" to reveal its contents. A clock, a calculator, and editing functions can be accessed from the menu bar at the top of the screen. A sample communication, "Jack lifts what?" is illustrated, along with an appropriate response.

or tool usage. Figure 3 shows representative symbols of each type and a sample C-VIC communication.

PATIENT TRAINING

J.S. received ten 1-hr C-VIC training sessions a week. The data included in this report were gathered when he had completed approximately 200 hours of training. Training of symbols and their use was done by demonstration and drill. Nouns were introduced by showing the new symbol with the associated object. These were learned rapidly, usually within one or two presentations. J.S. rarely made errors using C-VIC nouns. Therefore, formal testing of noun comprehension was infrequent. Testing 10 objects in a matrix of 29 indicated that J.S. was 30% correct in selecting an object after it was spoken by the examiner and only 70% correct in matching objects to the written word. However, he matched objects with C-VIC symbols with 100% accuracy. The level of comprehension of written nouns on this test far exceeded his comprehension as measured on formal language evaluations probably because the C-VIC program displays the English words together with the icons so that, at the time of this test, the patient had seen these symbols and nouns myriad times. His ability to comprehend other parts of speech or simple commands in written form remained nonfunctional. Indeed, serial formal language evaluations (BDAE) showed no change in his written or auditory comprehension over the period of C-VIC training.

Verbs were taught by demonstrating the action and associating it with a C-VIC verb. Generally verbs were more difficult to teach and required

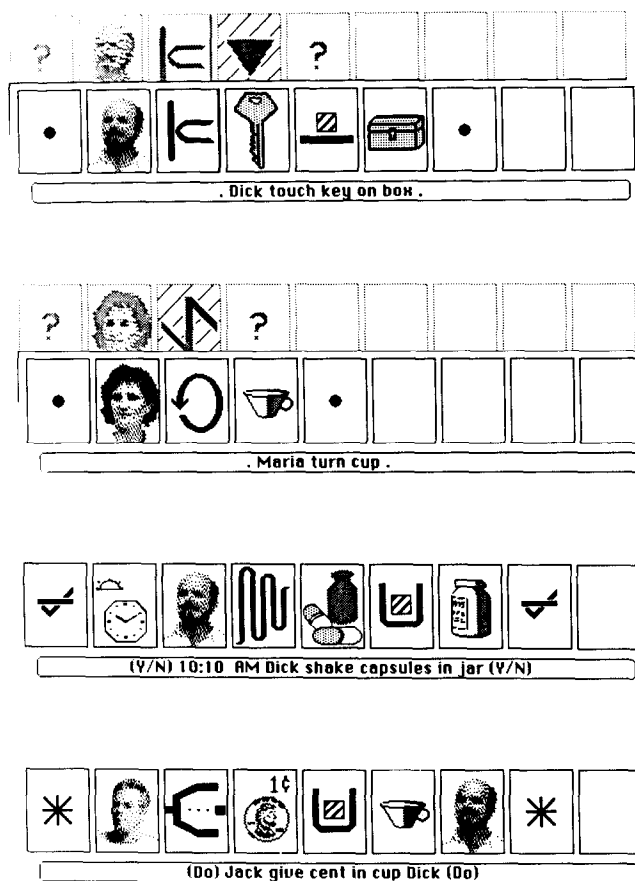


FIG. 3. Sample C-VIC constructions: "Dick touches what?" and response—"Dick touches the key on the box." "Maria does what?" and response—"Maria turns the cup." "Dick shook the capsules in the jar at 10:10 A.M.?" (question requiring a yes/no response). "Jack, give Dick a cent in the cup" (command). (Translations are not yet available in well-formed English.)

one or two warm-up trials during each session. Further, performance using verbs overall was more likely to decline temporarily as new verbs were added. J.S. was better at performing an action in response to a C-VIC command, 90% correct, than he was at selecting the correct C-VIC verb to describe an action, 60%. However, this exceeded his ability to perform, 40%, and describe, 20% when printed stimuli were used.

Introduction of prepositions "in," "on," and "by" was monitored in a multiple baseline design study. Performance was measured in response to simple commands utilizing two well-trained verbs, "give" and "take" and prepositional phrases using two objects. In each testing session, J.S.

Prepositions:

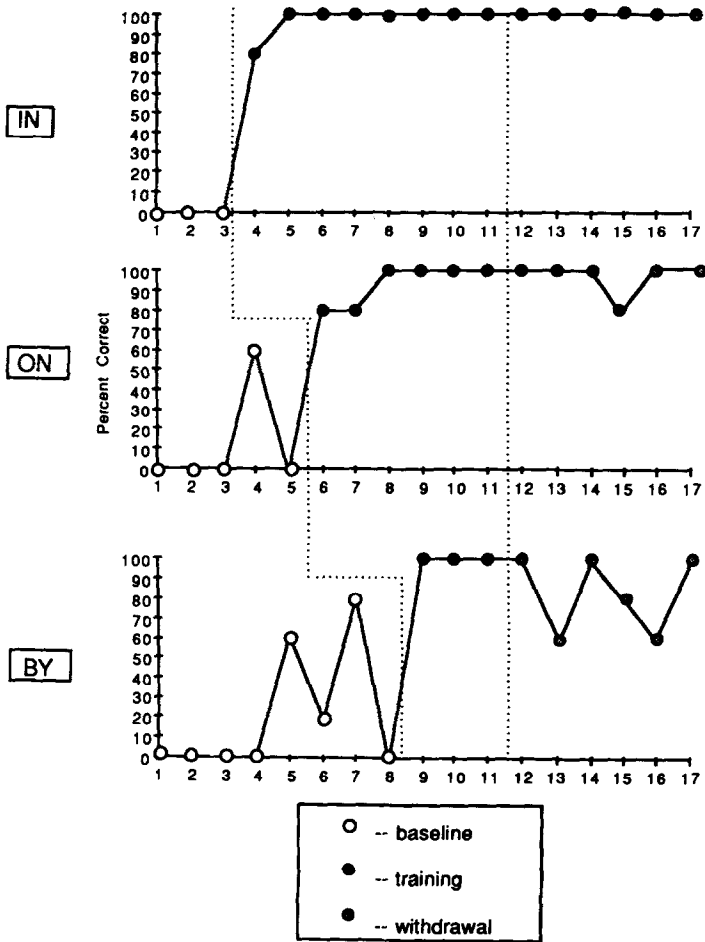


FIG. 4. Receptive learning of prepositions for subject J.S. (June 1986). Multiple baseline study. Abscissa shows treatment sessions.

was given 15 commands, 5 with each preposition. To complete a command successfully, he had to perform the appropriate action, placing the two objects in the correct juxtaposition within 20 sec. Responses were scored as either correct or incorrect. Baseline performance was obtained in the initial three sessions. J.S. was then trained in the use of "in," and performance on all three prepositions was tested. Subsequently, J.S. was then trained on "on" and then "by," and performance on each preposition was obtained in each session. Training was by demonstration and drill with correction of incorrect responses. Both reversible and nonreversible object pairs were used for training. Figure 4 illustrates the results obtained

^a THE JAR IS IN THE BAG.

THE JAR IS ON THE BAG.

THE BAG IS ON THE JAR.

THE BAG IS IN THE JAR.

THE BAG IS BY THE JAR.

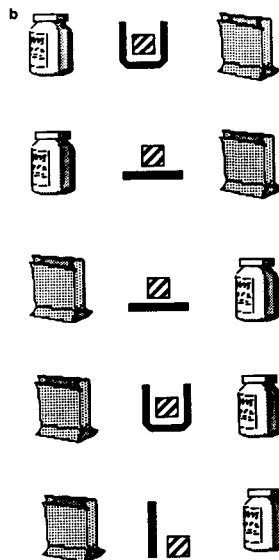


FIG. 5. Sample matrices of reversible prepositional constructions used.

during training and demonstrates the efficacy of C-VIC training in this task.

EXPERIMENT 1

After 2 weeks of training on prepositions, J.S. was tested on reversible prepositional phrases. Twelve sets of two objects were presented serially. The objects were either in, on, or next to each other. Each preposition was used four times in the set of 12, and the order of presentation was randomized. For each set, J.S. was required to select the correct printed sentence from a matrix of five sentences that described the relationship between the two objects. He was then presented with the same sets in random order and required to pick out the correct C-VIC phrase that described the relationship between the objects. He was given 30 sec in each trial to make a decision. Figure 5 shows an example of the printed

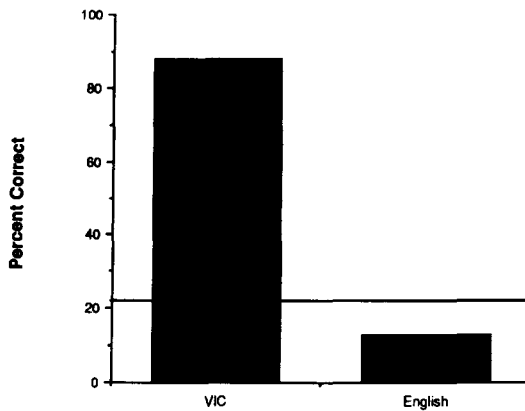


FIG. 6. J.S.'s performance on the reversible locative preposition task using printed English or C-VIC stimuli. The solid line indicates chance performance.

and C-VIC constructions used. Note that C-VIC phrases differ, somewhat, from the complete syntactic printed sentences. Two of the 12 pairs were logically completely reversible for all three prepositions, for example, "the bag is in the cup," or "the cup is in the bag." All pairs were reversible for "on," and the order using "by" was immaterial. The experiment was performed twice, on 2 days, separated by 10 days.

Results

The difference between J.S.'s performance with printed stimuli and with C-VIC to describe the location of two objects was striking. Figure 6 illustrates the results on the 24 pairs tested. Performance with printed stimuli was less than chance—he frequently threw up his hands and made no response at all. In contrast, he selected the correct VIC prepositional phrase with 88% accuracy. Errors choosing the wrong preposition were rare, and he never made errors of word order in C-VIC. The pairs which were logically reversible for "in" and "on" produced no greater error rate than other pairs.

EXPERIMENT 2

J.S. was tested on four verbs: "turn," "lift," "touch," and "shake." He had already received extensive drill using these verbs with small objects. In this task, the examiner performed one of the actions with one of two objects. J.S. was required to point to the correct C-VIC symbol or printed verb that described the action out of an array of 11 symbols or printed verbs. He was given 20 sec to make his selection. Performance was measured twice, once with the examiner using familiar, small objects and once with the examiner performing the actions with

two large objects not usually associated with the actions (table and chair). Four trials on each printed verb and C-VIC symbol for each size object—16 trials for each size—were administered in random order in two sessions 2 weeks apart.

Results

J.S.'s performance on this task paralleled his performance on other tasks testing the selection of single lexical items in C-VIC and English. He chose the correct printed verb to describe an action with 22% accuracy—essentially, at chance level. His C-VIC performance was 100% correct when the examiner used small objects. However, when larger objects were used his performance dropped to 69% correct. Further, his performance with larger objects was slower and more labored. He would observe the action, imitate it with his hands, and then imitate the action with the small objects before making his selection.

While the difference between his performance using C-VIC to describe actions with small and large objects is not as great as the difference between his performance using C-VIC and written English, our clinical impressions from the C-VIC training sessions are nonetheless confirmed. J.S. was first introduced to these verbs with small objects and trained to perform commands with them. When first presented with the same commands on large objects, he was confused, made the hand motions that would apply to the small objects, and had difficulty generalizing to the larger objects.

DISCUSSION

A critical issue in the rehabilitation of the aphasic patient is the extent to which "the grammar of his thinking" (Crichtley, 1970) is disturbed. Head (1926) agreed with Jackson's (1915) belief that "the speechless patient . . . cannot propositionize in any fashion." This contention has been difficult to refute because performance on traditional tests of cognitive function by severely global aphasics is difficult to interpret. This difficulty arises from the verbal instructions and labeling used in many tests (Kertesz, 1979) and from associated apraxias and deficits in nonverbal comprehension, and the severe expressive deficits in these patients (Feyereisen & Seron, 1982a, 1982b). However, our results suggest that globally aphasic patients may be able to perform syntactic-like operations on nonverbal representations of information.

Our patient's performance on the locative preposition task can be compared with performance by agrammatic Broca's aphasic patients on a similar task. Schwartz, Saffran, and Marin (1980) tested five Broca's patients on a reversible locative preposition task. The best performance by any of their patients in selecting the correct arrangement of objects in response to a verbal request was 42%. "Lexical" errors accounted

for only 12% of the errors in their patients. The remaining errors were reversal errors, i.e., failure to decode the meaning of word order. Our patient placed objects in the correct spatial arrangement with 96% accuracy in response to C-VIC commands. On the converse task, selecting the correct prepositional construction to describe the arrangement of two objects, he did nearly as well.

We do not argue here that our patient's superior performance in C-VIC indicates that it is superior to natural language for rehabilitating globally aphasic patients. We suspect this may be true, because J.S. and the other globally aphasic patients were accepted into our project only after having received no significant benefit from traditional speech therapy. Nonetheless, we have not spent comparable time training our patients in natural language. We do argue that our patient demonstrates the ability to perform a syntactic-like operation with C-VIC symbols at a level far exceeding the capacity of some Broca's aphasic patients to perform a similar operation using natural language.

It should be noted that we have not shown the existence of an extensive abstract syntactic ability in our patient. Prepositions are represented quite iconically, and the vocabulary of prepositions taught was limited. Thus, the rule utilized by the patient to make use of symbol order in C-VIC prepositional phrases may be a very limited one, far less abstract than the rules used by normal individual to decode prepositional phrases in natural language.

The extent to which globally or agrammatic aphasic patients can learn to use abstract syntactic rules is unknown. The present data suggest that they can utilize some simple rules with visual symbols. This result is not without precedent: prior investigations of nonverbal processing in agrammatic aphasic patients, for example, Deloche and Seron's (1985) report of an agrammatic aphasic patient's ability to transcode Roman and Arabic numerals, have suggested some preserved syntactic abilities in these patients. Thus, Caramazza and Zurif's (1976) contention, "... the anterior language area of the brain is necessary for syntactic-like cognitive operations," may need to be tempered. This area may be necessary for syntactic-like cognitive operations which operate on natural language, but alternative representations may be able to access analogous operations in other cortical areas.

In their extensive report on the original VIC system Gardner et al. (1976) considered the possibility that their patients might have been participating in a game, one which followed a set of rules but one which was devoid of semantic meaning and communicative intent for them. Gardner likened such a game to the activities of pigeons operantly conditioned to play "ping-pong", whose outward activity resembled the familiar game, but whose rewards and purposes were not at all the same. The distinction between a fully generative syntax and an arbitrary set

of operantly conditioned rules is easy to make in extreme cases (e.g., where pigeon behavior is contrasted with human behavior), but in the work reported, we are most likely dealing with a continuum rather than with mutually exclusive alternatives. (Consider, for example, the linguistic performance of a student beginning to learn a foreign language.)

What evidence would support the hypothesis that C-VIC performance is more than slavishly copied responses? One would like to see generalization occur, one would like to see spontaneity in the generalization, and one would expect to see some relationship between the ease of generalization and the degree of abstraction. At the easiest end of the spectrum, one would like to see patients generalize to apply rules to novel instantiations of a learned type of object. For example, having learned to perform transactions using the preposition "in" with any given cup, they should not have to relearn the vocabulary and syntax each time a different style of cup is introduced into the training room. Second, patients should generalize syntactic constructions to include objects of the same class, but a different type (for example, a milkshake glass or demitasse should not require new learning of constructions already established for "cup," since they are all members of the class "containers for drinking"). Third, patients should be able to generalize the use of syntax to new classes (e.g., "ovens" and "cupboards" as opposed to "drinking containers." Finally, patients should be able to utilize the vocabulary and syntactic rules to respond to and generate communications in entirely novel contexts (e.g., for persons inside structures such as houses, rather than inanimate objects inside cups). In training work with our patients in the clinic and at home, we see performance which suggests communicative intent, generative performance, and generalization in accord with the outline above. The greater the degree of abstraction or distance from the exemplar, the less certain and less frequent are the innovative communications. The errors that do occur typically pertain to symbol selection, rather than to symbol order.

Our patient's performance using C-VIC symbols for verbs points to a deficit other than a purely syntactic one (see Miceli, Silveri, Villa, & Caramazza, 1984, for a similar conclusion in studies of agrammatic patients). J.S. was 100% accurate recognizing the correct verb when the examiner performed an action with a frequently used object. Performance fell to 69% when less familiar objects were used. Unlike nouns, each new application of a verb appears to require separate training. J.S. imitated the examiner's motions with his hands, then imitated the motion for performing the action on a small object, as if he were trying to match a template. His difficulty in applying a verb symbol to a novel situation was perhaps an example of what Goldstein (1948) called a failure of "abstract attitude." Goodglass and Baker (1976) noted that aphasic patients with mild to moderate comprehension deficits had "a disproportionate

increase in the difficulty of recognizing Function Associates (verbs).” Specifically, our patient fails to generalize the meaning of verbs in C-VIC to encompass the meaning of equivalent English verbs from his prior experience. Thus, the equivalence of “turn” when applied to large objects and small objects, for which different hand motions are required, must be learned. J.S.’s behavior on the ward suggests that his conceptual base (Schank, 1972) is intact, but the rules linking C-VIC verb symbols and conceptual structures must be learned. Generalization of verbs to novel situations is not automatic and appears to require additional cues or in some cases even explicit teaching.

Clearly, an effective alternative communication system for aphasics must enable them to spontaneously express their thoughts and desires. They must be able to identify not only objects, but also the actions which they wish performed. Luria (1970) observed that “it is these dynamic schemata of propositioning, however, which suffer most in efferent forms of motor aphasia” and the “restoration of expressive speech may be achieved by substituting external aids for the missing dynamic schema.” Prescott, Selinger, and Loverso (1985) suggest treating aphasic patients by utilizing verbs as “pivots.” We agree that the utilization of verbs is pivotal for the success of this alternative communication system, and much of our current work is directed toward exploring visual presentations of verbs which may enhance patients’ comprehension and generalization.

REFERENCES

- Baker, E., Berry, T., Gardner, H., Zurif, E., Davis, L., & Veroff, A. 1975. Can linguistic competence be dissociated from natural language functions? *Nature (London)* **254**, 609–619.
- Caramazza, A., & Zurif, E. B. 1976. Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, **3**, 572–582.
- Carlson, G. S., Kleczewska, M., Steele, R., & Weinrich, M. 1987. Designing a computerized visual communication system for aphasics. *Rehabilitation Society of North America Proceedings*, 1987.
- Critchley, M. 1970. *Aphasiology and other aspects of language*. London: Arnold.
- Deloche, G., & Seron, X. 1985. Syntactical knowledge in a case of agrammatism: Evidence from transcoding Roman and Arabic numerals. *Brain and Language*, **25**, 234–235.
- Feyerseisen, P., & Seron, X. 1982a. Nonverbal communication and aphasia: A review. I. Comprehension. *Brain and Language*, **16**, 191–212.
- Feyerseisen, P., & Seron, X. 1982b. Nonverbal communication and aphasia: A review. II. Expression. *Brain and Language*, **16**, 213–236.
- Gardner, H., Zurif, E. G., Berry, T., & Baker, E. 1976. Visual communication in aphasia. *Neuropsychologia*, **14**, 275–292.
- Golden, C. J., Hammecke, T. A., & Purisch, A. B. 1980. *The Luria-Nebraska Neuropsychological Battery*. Los Angeles: Western Psychological Services.
- Goldstein, K. 1948. *Language and language disturbances*. New York: Grune & Stratton.
- Goodglass, H., Baker, E. 1976. Semantic field, naming and auditory comprehension in aphasia. *Brain and Language*, **3**, 359–374.
- Goodglass, H., & Kaplan, E. 1972. *The assessment of aphasia and related disorders*. Philadelphia: Lea & Febiger.

- Goodglass, H. & Menn, L. 1985. Is agrammatism a unitary phenomenon? In M. L. Kean, (Ed.), *Agrammatism*. Orlando, FL: Academic Press.
- Head, H. 1926. *Aphasia and kindred disorders of speech*. Cambridge: University Press.
- Jackson, H. 1915. Hughlings Jackson on aphasia and kindred affections of speech, together with a complete bibliography of his publications on speech and a reprint of some of the more important papers. *Brain*, **381**, 1-190.
- Kertesz, A. 1979. *Aphasia and associated disorders*. New York: Grune & Stratton.
- Kertesz, A. 1982. *Western Aphasia Battery*. New York: Grune & Stratton.
- Kolk, H. J., Grumsvén, M. J. F., & Keyser, A. 1985. On parallelism between production and comprehension in agrammatism. In M. L. Kean, (Ed.), *Agrammatism*. Orlando, FL: Academic Press.
- Lapointe, S. G. 1985. A theory of verb from use in the speech of agrammatic aphasics. *Brain and Language*, **24**, 100-155.
- Legatt, A. D., Rubin, M. J., Kaplan, L. R., Healton, E. B., & Brust, J. C. M. 1987. Global aphasia without hemiparesis: Multiple etiologies. *Neurology*, **37**, 201-205.
- Linebarger, M., Schwartz, M. F., & Saffran, E. M. 1983. Sensitivity to grammatical structure in so-called agrammatic aphasics. *Cognition*, **13**, 361-392.
- Luria, A. 1970. *Traumatic aphasia*. The Hague: Mouton.
- Miceli, G., Silveri, M. C., Villa, G., & Caramazza, A. 1984. On the basis for the agrammatic's difficulty in producing main verbs. *Cortex*, **20**, 207-220.
- Porch, B. E. 1967. *Porch index of communicative ability*. Palo Alto: Consulting Psychologists Press.
- Prescott, T. E., Selinger, M., & Loverso, F. L. 1982. An analysis of learning, generalization and maintenance of verbs by an aphasic patient. In R. H. Brookshire (Ed.), *Clinical Aphasiology: Conference Proceedings, 1982*. Minneapolis: BRK. Pp. 178-182.
- Saffran, E. M. 1982. Neuropsychological approaches to the study of language. *British Journal of Psychiatry*, **73**, 317-337.
- Schank, R. C. 1972. Conceptual dependency: A theory of natural language understanding. *Cognitive Psychology*, **3**, 552-631.
- Schwartz, M. F., Linebarger, M. C., & Saffran, E. M. 1985. The status of the syntactic deficit theory of agrammatism. In M. L. Kean, (Ed.), *Agrammatism*. Orlando, FL: Academic Press.
- Schwartz, M. F., Saffran, E. M., & Marin, O. S. M. 1980. The word order problem in agrammatism. *Brain and Language*, **10**, 249-262.
- Steele, R. D., & Weinrich, M. 1986. Training severely impaired aphasics on a computerized visual communication system. *Rehabilitation Society of North America Conference Proceedings 1986*.
- Steele, R. D., Weinrich, M., Wertz, R. T., & Carlson, G. S. 1986. A microcomputer-based visual communication system for treating severe aphasia. *Academy of Aphasia Abstracts 1986*.