Artificial Language Learning in Brain Damaged Adults Using a Matrix-Training Procedure

Anthony P. Salvatore
Arizona Speech, Language, and Learning Clinic
Veterans Administration Medical Center, Phoenix, Arizona

Matrix-training is a procedure and a conceptualization employed successfully in the areas of mental retardation, disordered child language and language acquisition. Its application to brain damaged adults is an empirical question. The results reported today are from an ongoing clinical research project. Our purpose is to investigate the acquisition and generalization of rules and symbols of an artificial language by brain-damaged adults. The work is directed toward the following questions:

1. Can effective retraining procedures be developed to teach brain damaged adults the rules and symbols of an artificial language?
2. Does the brain-damaged individual have the ability to generalize to untrained symbols?
3. Does the brain-damaged individual have the potential for retraining?

The assumption of potential is basic to our retraining efforts. While the aphasic individual has been shown to be capable of learning nonverbal tasks (Brookshire, 1969; Edwards, 1965; Carson, Carson and Tikofsky, 1968), the question of potential to learn language tasks is still unclear. Tikofsky and Reynolds (1963) have shown that aphasic adults can learn word lists, Smith (1974) trained two aphasic adults to use prepositions and word order to convey the nature and direction of spatial relations using printed words. Rahbar (1980) reports that apraxic-aphasic adults can acquire the use of Bliss symbols. However a report by Horner and LaPointe (1979) raises doubts as to the aphasic adults' potential to learn novel symbols. Glass et al. (1973) reported the successful acquisition of a novel language system by global aphasics.

These latter studies did not specifically deal with the process of acquisition and generalization of training. While these reports provide an optimistic view of the procedures used, the nature of the acquisition process and process of generalization have not been presented adequately.

Esper (1925) investigated how one could "reproduce artificially" an individual's ability to produce new utterances and generalize to untrained stimuli based on previously trained sequence and class relationships. His work has implications for language retraining in the brain damaged adult. For example:

> Training of artificial language systems may help us understand how best to maximize the recovery of language rules and symbols during retraining efforts.
>
> Training may provide information about how to retrain brain damaged adults to use nonvocal communication systems.

Others have suggested that symbol systems like Esper's may not be uniquely linguistic and that the acquisition of these systems may "reflect only general human cognitive capacities" (Franklin and Klima, 1980). These systems have also been criticized for not approaching the richness of natural language. That is, artificial language has a one-to-one mapping between units of meaning and units of output, while natural language uses conventional and extrasystemic knowledge in the mapping process.

An artificial language embodies the characteristics of discreteness, arbitrariness, and generativeness, all suggested by Hockett (1966) as characteristics of a natural language. The rationale for the use of an artificial language system in this present work is based on two premises. First, there is no reason to believe that the behavioral processes involved in the acquisition of an artificial language do not also operate during language retraining. Second, an artificial language offers a control for the confounding effects of the individual's native language when addressing the issue of generalization.

METHOD

Subjects. Six adults with brain damage secondary to lesions ranging in etiology from multiple CVAs, CVA plus bilateral atrophy, to closed and open head trauma served as subjects (Table 1). Their performance on the Porch Index of Communicative Ability (PICA) ranged from the 72nd percentile to the 97th percentile. Time post-onset ranged from seven months to two years. All subjects were labeled aphasic by a neurologist and a speech and language pathologist. Site of lesion was verified by cranial axial tomography.

Table 1. Description of aphasic subjects.

SUBJECT	ETIOLOGY	AGE	PICA PERCENTILE			
			OVERALL	GESTURAL	VERBAL	GRAPHIC
MR	Closed Head	29	81	97	32	96
JB	Open Head	27	85	90	63	90
CH	CVA Bilateral Atrophy	62	73	78	77	68
NW	CVAs, Bilateral	71	97	99	85	97
JD	CVA & Bilateral Endarterectomy	59	72	78	72	68
ER	CVA & Bilateral Endarterectomy	63	79	56	66	92

(A range of etiologies and levels of communication deficits were used to determine the generality of the matrix-training procedure presented in this paper.)

Four children ranging in age from 7-12 years of age were used for comparison purposes. All of the children had unremarkable medical histories and all were attending public school programs for the gifted.

Stimuli. Subjects were required to match printed nonsense words to colored geometric forms that were printed on individual 2"x 3" cards. The nonsense words were derived from the matrix shown in Figure 1. The 2 x 2, 3 x 3, and finally 4 x 4 matrices are identified by outline. The T's indicate those cells trained, while the G's indicate generalization cells.

Since the purpose was to teach and not test, the matrix was reduced in complexity for training purposes. Subjects proceeded from simple to complex discriminations. Training proceeded from word-to-color, to word-to-shape, to word-to-color + shape combined.

Color / Shape	○ TEP	△ FUB	+ GOM	□ PIV
ZIN (red)	T	T	G	G
JOR (yel)	G	T	T	G
KES (blue)	T	G	T	T
NID (grn)	T	G	G	T

Figure 1. The training matrix was divided into 2X2, 3X3, and 4X4 matrices for training purposes. (T) = cells trained. (G) = untrained generalization cells.

Procedure. Subjects were trained to point to the printed word and then point to the correct colored geometric form. For example, Figure 2 shows that the correct response is the triangle. In Figure 3 (y) yellow is correct. No verbalization was required. Each subject was initially presented with a two-choice discrimination (Figure 4). After he showed stable performance, he was given a three choice discrimination (Figure 5). Correct responses were followed by verbal praise. Error responses were followed by the verbal comment "No," the correct response was modeled by the examiner, and the subject was required to model the examiner's response before the next trial was presented. If a subject began making errors when the words were combined, a backup step (cued) was introduced (Figure 6). After completing the cued step the subject was returned to the combinational step.

A training block consisted of three presentations of each stimulus to be learned at a particular level. For example, during the 2 x 2 matrix training (Figure 7) there were three training words. Each word was presented randomly three times for a total of nine trials per training block. Performance was calculated in percentages. Successful performance was defined as 80 percent correct or better per training block. Untrained words were presented at the end of each session. Correct responses to untrained words were reinforced, but there were no consequences for an error.

RESULTS

Summarized acquisition and generalization data are presented for each subject. Figure 8 presents the performance of the first subject trained (MR). Successful performance is indicated by movement from the bottom to the top of the graph. The levels of complexity progress from simple (color + shape) to complex (4 x 4). Sessions are marked at the bottom of the graph. Each data point indicates successful completion of the corresponding level of complexity. At the top of the graph is shown the results of performance on untrained words.

MR was a 29-year-old male who two years prior to training suffered a closed head injury secondary to a motorcycle accident. His PICA overall percentile was 80, he had severe dysarthria, right hemiparesis of arm and

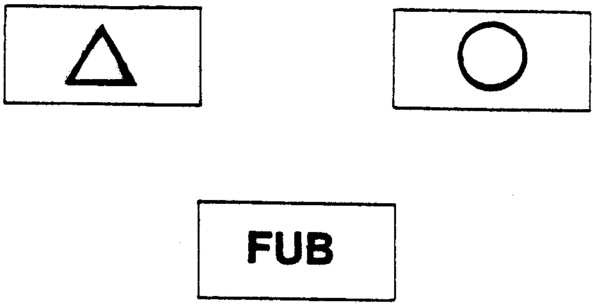

Figure 2. Two-choice shape discrimination.

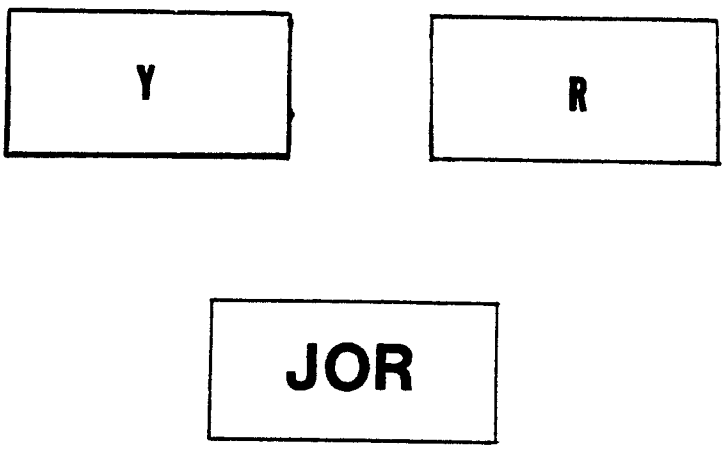

Figure 3. Two choice color discrimination. Because color is not reproduced, the colors are coded: (R)=red, (Y)=yellow, (G)=green. (These letters were not on stimuli during training.)

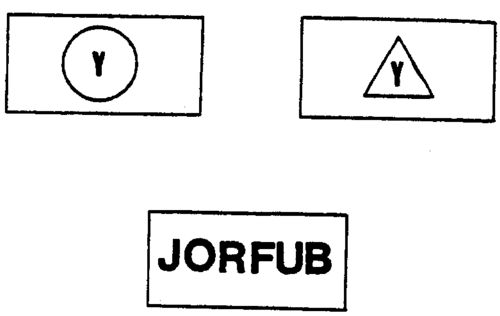

Figure 4. Two choice discrimination with a nonsense word made up of color (JOR) and shape (FUB).

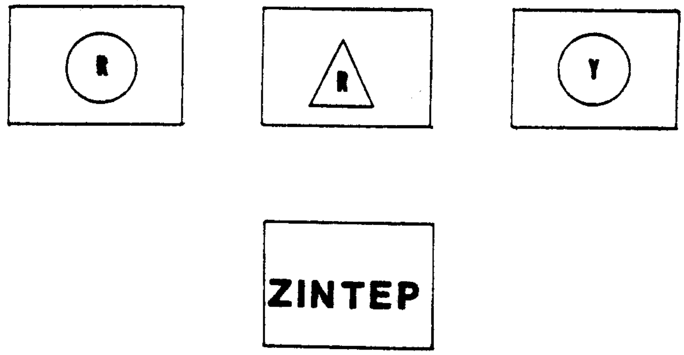

Figure 5. Three choice discrimination.

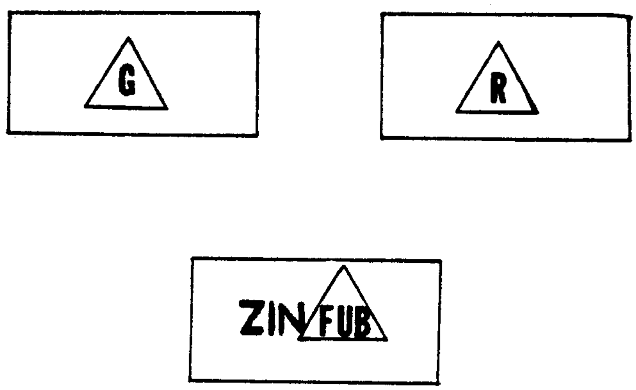

Figure 6. An example of a trial in the Cued setup. (ZIN) is printed in red and (FUB) is placed with the triangle. The correct response is RED TRIANGLE.

Training Stimuli 2x2 Matrix	Generalization
JORFUB	JORTEP
ZINFUB	
ZINTEP	

Figure 7. Training and generalization words from 2X2 matrix.

leg and moderate memory problems. He lived in a Veterans Administration nursing care unit.

After hundreds of trials over two months he has reached successful performance on the 3 x 3 matrix and has been trained but has not met success criterion on the 4 x 4 matrix. He shows some evidence of generalization to untrained words. Note the heavy slashed vertical line on the graph. To the left of the line the subject was training with two-choice discrimination, to the right with a three-choice discrimination.

Figure 9 shows the performance of the second subject (CH) trained on the procedure. He was a 60-year-old ambulating male, with a history of multiple CVAs (probably embolic), and bilateral central atrophy. His PICA overall was 57th percentile. He had severe memory problems. He, like the first subject, ran into difficulty when the discrimination tasks were shifted from two choices to three choices. He also showed evidence of generalization to untrained words.

Based on the performance of these first two subjects the training procedure was modified in the following ways.

1. Based on the difficulty both these subjects experienced shifting from two to three choice discrimination, the three choice discrimination was introduced much earlier in training at the color-shape level.
2. Error analysis of these subjects indicated that they tended to respond based on the first part of the combined word (color) and ignored the second part of the combined word (shape).
3. Both subjects also had a difficult time retaining accurate responding within and across sessions. In an attempt to reduce the influence of memory deficits, each session now began with a brief review on a level less complex than that acquired successfully in the preceding session.

Figure 10 shows the performance of JB, a 27-year-old male who one year earlier suffered an open head trauma secondary to walking into a moving airplane propeller, which damaged portions of temporal, parietal and frontal lobe. He also suffered an amputation of the left arm. His PICA overall score was at the 85th percentile. He had moderate to severe auditory comprehension deficit and nonfluent speech production. He showed no memory problems and lived by himself. As the graph shows, he acquired the 4 x 4 matrix and generalized successfully to untrained words.

The next subject, WAT, a 71-year-old male, suffered two CVA's. The first was to the right hemisphere approximately 15 years ago, and resulted in left hemiparesis of the arm and leg. The second CVA occurred approximately one year ago. His PICA overall was at the 95th percentile, he had no memory problems, but showed neglect for his personal appearance. As Figure 11 shows, he learned the 4 x 4 matrix and subsequently generalized to untrained words.

The next two subjects suffered unilateral CVAs. Subject JD was a 59-year-old male with a left hemisphere lesion, a history of TIA's and left carotid endarterectomy prior to training. His speech was fluent and paraphasic, with poor auditory phonemic discrimination and moderate deficit in carrying out spoken messages. His PICA overall was at the 72nd percentile. Figure 12 shows that he acquired the 4 x 4 matrix and successfully generalized to untrained items.

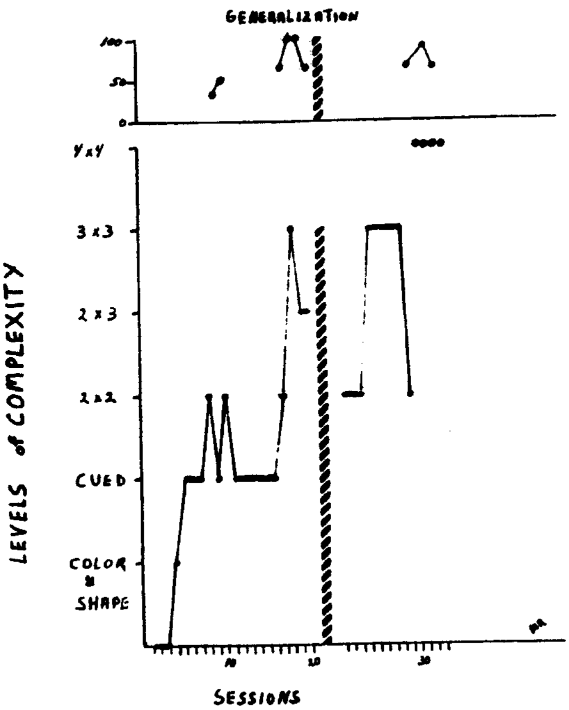

Figure 8. Subject MR

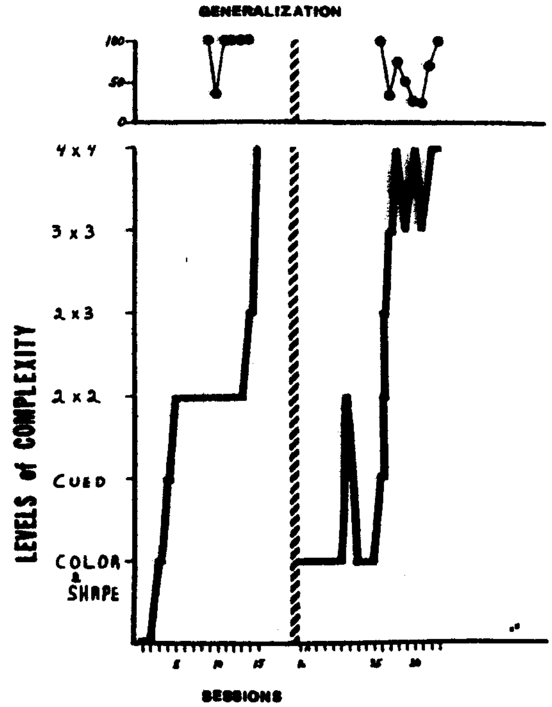

Figure 9. Subject CH.

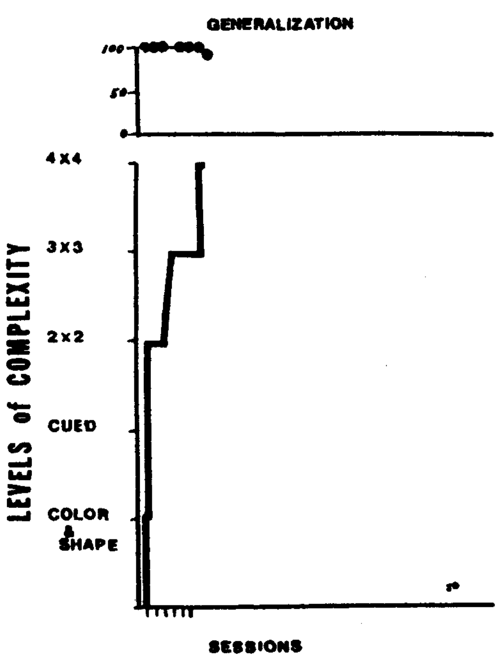

Figure 10. Subject JB

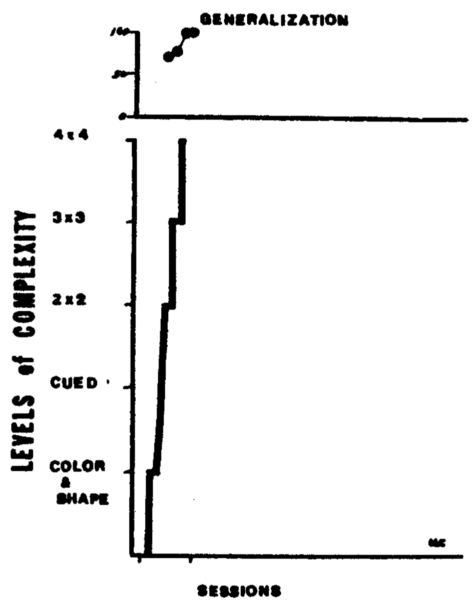

Figure 11. Subject WAT

The final subject, ER, a 63-year-old male, had a left hemisphere CVA, TIA's and bilateral carotid endarterectomy prior to training. His PICA overall was at the 79th percentile. He produced nonfluent speech, had a moderate deficit in carrying out spoken messages and had no hemiparesis. He proceeded successfully through the 4 x 4 matrix and generalized to untrained items (Figure 13).

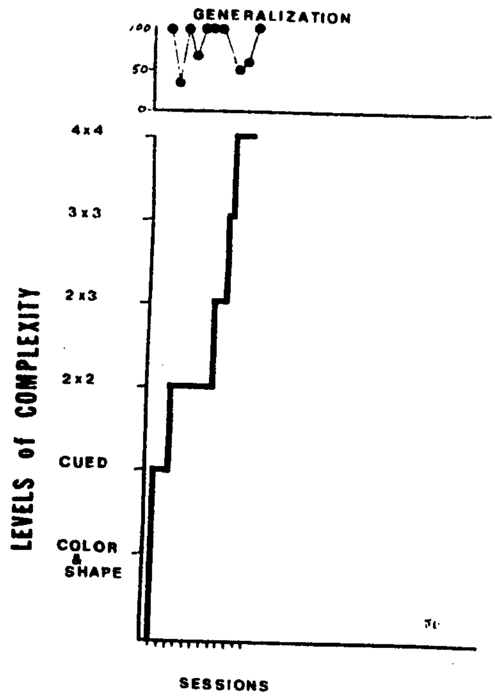

Figure 12. Subject JD.

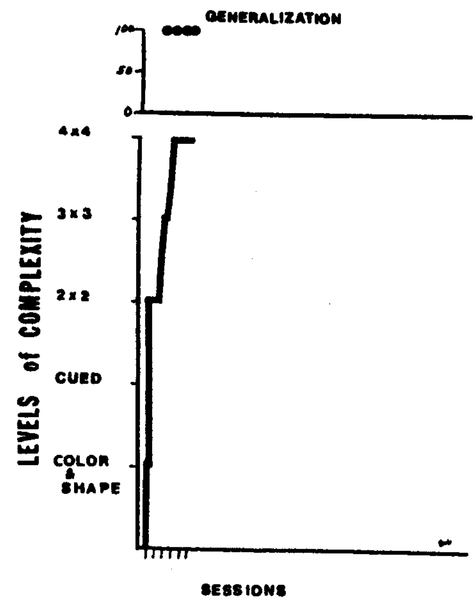

Figure 13. Subject ER.

He is now being trained on the next level of complexity (Figure 14). At this level nonsense forms were inserted between two previously learned symbols. This level was based on the work reported by Tillman and Goldstein (1980). Subject ER has shown a 90 percent correct or better performance at this level after being trained to match the new symbols to the printed nonsense word equivalents.

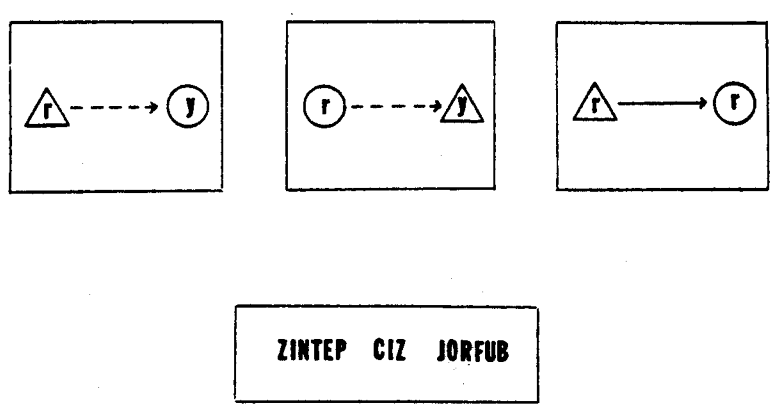

Figure 14. Nonsense sentence. ZINTEP (red circle) = subject, CIZ = verb, and JORFUB (yellow triangle = object.

Four children trained in the present study all learned the 2 x 2 matrix with very few errors. Their performance was in sharp contrast to the brain damaged adults.

Summary. The performance of these initial subjects suggests to me that the present training procedure may successfully train individuals with a variety of lesions, locations, severity and levels of communication deficits. The most exciting and optimistic result was that all six adults showed a high level of successful generalization to untrained words. Attempts to demonstrate generalization with natural language in brain-damaged adults is tenuous at best. With less complex artificial language, it appears that one can more easily measure the presence or absence of generalization.

The poor performance shown by the first two subjects may result in part from (1) memory deficits, (2) ineffectiveness of the examiner to teach, or (3) extent of bilateral damage. Bilateral damage itself is not a strong argument, given the performance of the fourth subject, who suffered multiple CVAs, one to each hemisphere, fourteen years apart. He performed as well as the unilaterally impaired subjects. However, could we be seeing evidence in this subject of the "serial lesion" effect? While serial effect of lesions is reported only in the animal literature and only with unilateral lesions, it offers an interesting hypothesis.

CONCLUSION

After a lengthy search of the literature, it appears this is the first report that clearly shows that brain damaged adults can acquire novel language symbols and rules and can generalize these rules to untrained symbols. While no general statement can be made with confidence about learning potential, the study does suggest that successful retraining may be dependent on the systematic nature of our training procedures. The matrix-training procedure offers a framework for further research in this area. It is also clear that the true test of the effectiveness of the training procedure described is its application to the severely impaired adult.

Finally, the subjects in this report learned novel symbols, learned to combine those symbols and to generalize a combinational rule to untrained words. The systematic nature of the matrix-training procedure offers a method for investigating the efficiency of retraining natural language in the brain-damaged adult.

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