An Intelligent Computer-based Spelling Task for Chronic Aphasic Patients

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The microcomputer is developing into a significant clinical tool for treatment of language and cognitive problems in brain-injured patients. Studies by Colby et al. (1981), Katz and Nagy (1982, 1983), Mills (1982), Seron et al. (1980), Vaughn (1980) and others have shown how large, mainframe computers and small microcomputers can be used to diagnose, treat, and compensate for language impairment resulting from brain damage.

Our initial study (Katz and Nagy, 1982) demonstrated that mildly- and moderately-impaired aphasic adults had the physical and cognitive skills necessary to independently select, load, and run specially designed reading treatment programs on a microcomputer. We reported that the availability of computerized treatment increased the amount of time patients received structured reading stimulation. In addition, we found that the microcomputer enabled patients to take more active roles in their treatment by encouraging independent behavior, judgment and decision-making.

Last year we reported on a computerized tachistiscopic reading program designed to improve word recognition for aphasic adults (Katz and Nagy, 1983). Graphics and rapid rates of stimulus presentation were used to stimulate increased attention and memory. Results suggested that stimulus material should be modified frequently to the performance level of each patient to maximize learning. It was concluded that computer programs can be made more effective by incorporating decision-making algorithms, called artificial intelligence, or AI features.

The goal of the present study was to develop and evaluate a computerized treatment program that used AI functions to make routine treatment decisions. The computerized treatment program written for this study helped patients learn to remember and spell commonly-used nouns. Drawings of the target words were displayed on the computer monitor and patients were asked to type the names of the displayed objects. AI features evaluated the patient's responses, provided appropriate feedback, selected interventions geared to the performance level of the patient, and generated suitable writing exercises for the patient at the end of the session.

The computerized treatment program, "Speller," was written in Applesoft Basic for an Apple II microcomputer, one disk drive, a monitor, and a printer. Seven nouns were used in Speller for most of the patients. The one global aphasic patient was given only three words. In each treatment session, high resolution line drawings were presented one at a time on the monitor, and the patient was prompted by the computer to type the name of the object displayed. If the patient spelled the word correctly, auditory tones and a printed message were provided to acknowledge the correct response. If the response was incorrect, feedback was given, and treatment intervention was provided. The intervention was a series of discrete linguistic cues, arranged hierarchically according to increasing amount of information contained in the cue (Table 1). Which cue was selected by the computer depended on the number of previous attempts by the patient to type the word correctly. When the patient correctly spelled the word, repetition at the successful level and again at the level just failed was used to reinforce the response. A score from 0 to 7 was assigned to each word based on the level of intervention necessary before the word was spelled correctly.

Table 1. Interventions and scores corresponding to number of attempts to spell target word.

ATTEMPT	SCORE IF CORRECT	INTERVENTION IF ERROR
1st	7	Repeat stimulus
2nd	6	Anagram w/o feedback
3rd	5	Delayed response after modeling
4th	4	Anagram w/feedback
5th	3	Multiple-choice cue
6th	2	Immediate response w/modeling
7th	1	Flag stimulus / score = 0 / next

At the end of each session, scores and descriptions of the successful intervention for each word were displayed for the patient. Also, the average score and a statement describing overall performance on the task for the session were displayed. All scores were automatically stored on disk, and the patient was asked if he would like "homework." If he did, the computer printed the error words on the printer to be copied for homework. Instructions on the homework sheet asked the patient to copy each word 10 times. Speller also included a results program for the clinician which presented each patient's scores in table and graph form for all words and for all completed sessions.

The treatment phase consisted of up to 15 computer sessions averaging 30 minutes each for two to five times each week. A clinician initially supervised each patient on the computer until the patient was familiar with its operation. Following this period, patients were able to work with the computer independently, although sessions continued to be monitored. These sessions were in addition to the patient's routine speech and language treatment. During the study, regular speech and language treatment did not focus on reading or writing activites. Patients continued the computer sessions until (a) criterion was reached -- three consecutive sessions where the patient spells at least 6 of 7 words correctly on the first attempt with the remaining word correct after only one additional attempt, or (b) 15 sessions were completed, whichever came first. Fifteen sessions took about five weeks to complete.

Because of the exploratory nature of the project and limited computer resources, only a small number of patients were evaluated. To ascertain the usefulness of the program for patients with various language deficits, aphasic patients with a range of severity and a variety of types were included. Subjects were eight adult men, with an average age of 52 years, suffering from unilateral left hemispheric damage of at least 11 months duration, resulting in aphasia (Table 2). All subjects had completed high school and none had a history of premorbid reading or writing problems. Visual acuity was normal or corrected to normal. Two other patients who began the study did not complete treatment due to illness and family problems.

Table 2. Patient description: language variables.

	PICA %-ILE			BDAE		TPO
PATIENTS	OA	RDG	WRT	TYPE	S.R.	(YEARS)
CB	74	84	64	Broca	3	7.2
JR	68	80	65	Anomic	4	0.9
DG	61	75	64	Broca	2	23.2
WB	58	61	43	Anomic	4	1.0
DF	44	41	59	Broca	2	2.4
RH	36	42	52	Broca	1	3.0
CM	34	18	20	Global	0	3.9
HG	26	15	35	Wernicke	1	1.5
AVERAGE	50.7	50.0	50.3		2.0	5.4

The effectiveness of the AI features in Speller was evaluated by single-case design. Two sets of scores were used. The first set was scores from a written confrontation naming task taken at the beginning and end of the study. For this measurement, the computer drawings were presented, and each patient wrote on paper the names of the objects displayed. Comparison of the written responses with the target words was determined by a similarity index based on letter selection, sequencing, and the intelligibility of each written response (Table 3). This index is similar to one used by Seron, Deloche, Moulard and Rousselle (1980). The second set were simply the performance scores on the computerized spelling task obtained from the computer sessions. These scores were examined to see if criterion was achieved, and to identify the learning patterns for each word for each patient.

Table 3. Similarity index based on letter selection, sequencing and intelligibility of response. (Adapted from Seron et al., 1980).

$$C = (P1 + P2 + P3)/3$$

C = Compatibility Index between target and response
(1 = identical spelling   0 = no similarities)

P1 = Percentage of letters common to both stimulus and response. (Extra letters are subtracted from total.)

P2 = Percentage of letters common to both stimulus and response, and appearing in the same order in both words. (If only one letter is in common, P2 = 0.)

P3 = Functionality/readability of response. (If the word can be identified correctly by readers, P3 = 1. If readers can not identify the response, then P3 = 0.)

Results

The results of this study are very encouraging. Table 4 shows scores on the pre-treatment and post-treatment written confrontation naming task. All patients improved writing the target words. Six of seven patients demonstrated considerable change. Patient HG, a Wernicke's aphasic patient, changed the least. He dropped out of the study after four sessions. Patient CM, the global aphasic patient, suffered a new stroke at the end of the study, and post-treatment measurements were not obtained from him.

Table 4. Pre- and post-treatment test scores for writing words in response to pictures for seven aphasic patients ($t = 5.92$, $df = 6$, one-tailed, $p < .01$).

PATIENTS	PRE-TEST	POST-TEST	CHANGE
CB	.56	1.00	.44
JR	.37	.90	.63
DG	.21	.98	.77
WB	.50	1.00	.50
DF	.23	1.00	.77
RH	.35	.85	.50
HG	.14	.23	.09
AVERAGE	.34	.85	.51

Table 5 displays each patient's scores on the treatment task. Seven of eight patients substantially improved when baseline and final session scores were compared. The final three scores are shown to demonstrate consistency. Only the Wernicke's aphasic patient who dropped out of the study showed no improvement.

Table 5. Performance on computerized treatment task in response to pictures for eight aphasic patients.

PATIENTS	SESSIONS	BASELINE	LAST 3 SESSIONS		
CB	15	3.28	6.57	7.00	7.00
DG	15	2.14	7.00	7.00	6.71
DF	11	4.14	6.57	6.85	6.71
HG	4	1.28	1.85	1.00	1.00
JR	15	1.85	6.57	6.14	6.57
RH	7	3.00	7.00	7.00	7.00
WB	7	2.28	6.85	7.00	7.00
CM	10	3.33	5.33	7.00	6.66
AVERAGE	10.4	2.66	5.97	6.00	6.00

Discussion

Writing the target words improved for most of the patients. Changes in the written confrontation task are particularly significant because they represent improvement in the ability to write the target words correctly, not simply type the words. Changes for six of the aphasic patients were dramatic in both the writing task and in computer performance. However, the Wernicke's patient showed no improvement at the time he dropped out of the study. The global aphasic patient also showed no improvement in performance initially, although he made progress when several short and personally relevant stimulus words were used.

The AI or artificial intelligence features built into the Speller program create considerable flexibility in the treatment task. The computer adapts the treatment material to the current needs of the patient by presenting spelling cues based on his previous spelling performance. The study demonstrates that the computer can make effective, rudimentary treatment decisions about whether an intervention is needed and, if so, which one should be selected. The resulting process more closely approximates the procedure a speech clincian would use to present the task to different patients with different abilities or to the same patient at different times in the course of treatment. This ability to shape treatment material using information from the previous performance of the patient is crucial if we intend to augment individual treatment with quality computerized tasks.

The flexibility of Speller produces a more rewarding experience for the patient. The task is constantly changing -- from order of presentation of stimulus objects to the spelling cues provided when errors are made. We believe this dynamic state of treatment increases attention, interest, and motivation in the patient.

AI functions also relay detailed information to the clinician about the patient's spelling ability. Because each performance score is based on the amount of information in the spelling cue, the score reflects the patient's knowledge of the word (e.g., recognition, memory, letter sequence). The Speller program can thus quantify the patient's spelling ability more precisely than just "right" or "wrong." By examining performance scores, the clinician knows which words the patient can spell correctly, which give him some difficulty, and which words he has little idea how to spell. Performance scores for all words can then be used as the basis for deciding whether the task should be continued, terminated, or changed in future sessions.

The copying homework for words spelled incorrectly seemed to have an important role. At the end of each computer session, when errors had been made, the patient was asked by the computer if he wanted homework for mispelled words. Patients always chose the homework option, and they consistently handed in completed homework to the clinician before the next computer session. The fact that they conscientiously completed homework indicates that they recognized that doing the writing homework could improve their scores.

The fact that no homework was given for words spelled correctly during a computer session may have had a negative impact on spelling performance in later sessions. Without homework, correct spelling was not practiced and reinforced from one session to the next. Examination of performance trends for all patients showed that they often made isolated errors on words they had spelled correctly in the previous sessions. Without copying homework for these words, the correct spelling was not reinforced, and spelling scores for these words dropped. (Dysnomia is a second possible explanation contributing to these errors.) Reinforcement is an important component in learning for all persons and appears to be particularly important for maintaining newly-learned words.

This study further supports the contention that the computer motivates patients to become more actively involved in their own treatment. Compared to traditional treatment sessions in which some of the patients refuse to accept or finish homework, all patients in this study requested and completed computer-generated homework. The behavior of the patients who improved their spelling suggests that they perceived the computer task as a challenge to be met rather than a drill to be endured. After each computer session, they expected verbal reward from the clinician if their performance was good and expressed disappointment or determination when they made errors.

While the results of this study are encouraging, various modifications, including greater variety of language cues, program control of word difficulty and additional tasks to aid in maintenance and generalization could improve the program's effectiveness. It appears quite possible that computerized treatment using AI features can become a valuable therapeutic approach in the rehabilitation of reading and writing problems in aphasia.

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DISCUSSION

Q: Could you give a more detailed description of the nature, extent and consistency of the homework packet? Also, could you comment on how you separated the treatment effect of the homework from the treatment effect of the computer task?

A: The homework was simply a printout generated by the program through the printer. On the paper, the patient's name was printed at the top, followed by the lesson number, and the instructions to "COPY THE WORDS BELOW TEN TIMES." The error words were then printed along the left margin with sufficient space to allow for copying. We did not attempt to separately measure the effects of the homework and task intervention.

Q: Once a successful cue was found for a word, could the program go directly to that cue the next time instead of presenting all the previous, unsuccessful cues?

A: We did not program our treatment task to do that. We felt that as the patient learned to spell the word, he required less information on how the word was spelled. The cues were arranged hierarchically more or less according to the increasing amount of spelling information contained within each cue. Therefore, it seemed appropriate to give the patient only as much information as he needed to spell the word correctly.

Q: What does a patient have to be like to use the software? It seems to me that if the instructions are more complicated than the task, it is going to take something more for the task to work.

A: From our CATS study (Katz and Nagy, 1982), we found that when clinicians sat with the patient and showed him what to do, provided feedback when appropriate and so on, mildly- and moderately-impaired aphasic patients were able to learn procedures necessary to run the computer program. We feel most of the instructions displayed on the screen become redundant once the patient becomes familiar with the task. For example, when the message, "PRESS SB TO CONTINUE...[ ]," is printed at the bottom of the screen, the patient (and most of the rest of us) respond without actually reading the message once we are familiar with the task. Also, by anticipating potential mistakes, error-trapping routines are programmed to cue the patient accordingly, e.g., when the patient erroneously types his name in response to the prompt, "DO YOU WANT INSTRUCTIONS? (Y/N)," the program recognizes that the multi-letter response is inappropriate and responds with auditory and visual feedback.

Q: There have been some clinical psychology reports stating that when you compare interaction of treatment approaches using a clinician versus a mechanical means, treatment works better when there is clinician interaction. Did you compare the same program using a clinician?

A: No.

Q: How long did it take you to write the program?

A: On and off, about three months.

Q: Did you have a pre-treatment baseline and if not, do you think that familiarity with the computer and program made a difference?

A: During the pre- and post-treatment writing measurements, the patients did not use the computer at all, so we felt it would be highly unlikely that familiarity with operating the computer and program would influence writing performance. As for actual, session-to-session task performance, familiarity with the program could have affected their early performance, and a better design would have been to demonstrate a stable baseline before providing the cues.

Q: Did verbalization increase or did they employ spelling as a way of communicating?

A: We did not see the patients using spelling to compensate for verbal problems. I feel certain that spelling would have to be trained specifically as a compensatory technique for these patients to use it that way. That is one of our long term goals for this project, along with improving their ability to write letters and cards.