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ABSTRACT

A computer assisted instruction system for drilling educationally handicapped children in word decoding skills is described. A theoretical rationale for the objectives and design of the system, based on research from the psychology of reading literature, is discussed. In addition, certain system design constraints, applied in order to accommodate the possibility of future conversion of the system to an inexpensive, hand held device, are discussed. Results of a controlled field test of the system with 12 educationally handicapped elementary school children indicated significant word decoding improvement accompanied by high learner motivation which did not significantly decline during the 2 month training period. (DB)

Computer-Assisted-Instruction In Word-Decoding for Educationally-Handicapped Children

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Computer-Assisted Instruction

In-Word-Decoding for Educationally-Handicapped Children

A computer-assisted-instruction system for drilling educationally-handicapped children in word-decoding skills is described. A theoretical rationale for the objectives and design of the system based on research from the psychology-of-reading literature is discussed. In addition, certain system design constraints, applied in order to accommodate the possibility of the conversion of the system to an inexpensive, hand-held device, are discussed. Results of a controlled field test of the system with educationally handicapped children are presented.

Computer-Assisted-Instruction

In Word-Decoding for Educationally-Handicapped Children

This paper describes the rationale for the design of a computer-assisted instruction (CAI) system for drilling educationally-handicapped children on word-decoding skills. Results of a field test of the system with children in special-education classes are also reported. For the field test the system was implemented on a Commodore PET general-purpose microcomputer. This computer, which is dedicated to a single user-terminal, is about the size of a typewriter with a small television screen. The system was designed, however, so that later implementation would be feasible with microprocessor technology in an even smaller special-purpose device about the size and cost of a hand-held calculator.

The choice of word-decoding as the focus of this instructional system was based in part on correlational evidence suggesting that poor readers are penalized by especially weak word-identification skills, and that they need much more practice than other children to develop these skills. Investigators have reported large correlations between word-identification accuracy and paragraph-reading ability (Shankweiler & Liberman, 1972; Crache, 1963). This evidence led Shankweiler and Liberman ([illegible]) to discount claims that there are many children who can read individual words well, yet are unable to comprehend connected discourse, concluding instead that poor reading of text with little comprehension is largely a consequence of reading words inaccurately or with excessive difficulty.

Correlational evidence also suggests that poor readers are especially deficient in applying grapheme-phoneme [illegible]ation and blending skills to the task of identifying unfamiliar words (word-decoding). Firth has shown that

good and poor readers matched on IQ are almost perfectly discriminated by the ability to decode pronounceable nonsense words. The same groups, however, performed virtually identically on a comprehension task requiring plausible completions for orally-presented incomplete sentences (reported by Rozin & Gleitman, 1977). As Rozin and Gleitman (1977) comment, however, the oral comprehension task might also have discriminated between good and poor readers if the capacity to process high-level meaning hadn't been partialed out by matching the groups on IQ. In any event, these results clearly point to a decoding deficiency in poor readers.

Further correlational evidence for a decoding deficiency is provided by studies measuring latency of reading responses. Perfetti and Hogaboam (1975) found that children who are poor at comprehending text are also significantly slower than normal readers in identifying single words, even though they are able to identify and define the words accurately. The difference between poor and normal readers, however, was much larger for pronounceable nonsense words and low-frequency real words than it was for high-frequency real words. The investigators interpreted these results as evidence that poor readers are especially slow in identifying words which have not been learned as high-frequency sight words, and which therefore must be decoded.

In addition, there is a considerable body of research to support the view that poor readers are impaired on the ability to segment spoken words into their constituent phonemes (Golinkoff, 1978; Liberman & Shankweiler, 1979). Since phoneme-segmentation is a skill closely associated with decoding, this may be regarded as additional evidence that poor readers need more practice in decoding.

Finally, there is evidence that, at least through the age of eight,

children rely heavily on word-decoding skills in reading sentences for meaning (Doctor & Coltheart, 1980). Thus, the evidence points to two conclusion: (1) poor readers need additional drill on identifying words; and (2) the additional drill should include work on decoding. These conclusions, although based on recent research, were anticipated long ago in the development of remedial reading curricula. As early as 1936 when whole-word reading programs were used almost exclusively in regular classrooms, two phonics reading programs were independently published by workers in special education (Gillingham, 1970; Hegge, Kirk, & Kirk, 1970). More recently, newer phonics programs such as DISTAR (Engelmann & Bruner, 1969) have been used widely in special education.

In discussing the relevance of decoding skill to reading, Fries stated that learning to use grapheme-phoneme associations is not only necessary for those learning to read an alphabetic orthography, but that these associations must become habits so automatic that the graphic shapes themselves sink below the threshold of attention (Fries, 1963; p. 132). A problem for any reading program, therefore, is providing enough drill to develop grapheme-phoneme association and blending skills that are not only accurate but also automatic.

To meet this need, two CAI systems, each providing drill on a variety of word-decoding skills, were developed by a Stanford University team (Atkinson, 1968; Fletcher, 1979). The development of these systems was completed in 1968 and 1975. Although the systems were instructionally effective, their acceptance in the educational community was limited, probably due to the high cost of installing a large computer with many terminals. Perfetti and Lesgold (1979) have pointed out, however, that with the advent of inexpensive microcomputers dedicated to a single terminal, CAI may now be an economically

viable method fo[illegible] drilling w[illegible] [illegible]ding skills.

We fe[illegible] that [illegible] might [illegible] more economica[illegible]y viable fo[illegible] drilling word-decoding s[illegible]lls [illegible] [illegible] system could be implemented in [illegible]ecial-purpose, hand[illegible]d [illegible] [illegible] cost. Accordingly, while the [illegible]esent system was [illegible] [illegible]ral-purpose microcomputer, its design was considerabl[illegible] constra[illegible] [illegible]ate the possibility of future [illegible] a hand-held [illegible]ice. [illegible] the design incorporates severa[illegible] [illegible] strategies.

System Desi[illegible]

The usual flash-[illegible] [illegible] of instruction, in which a limited l[illegible] f words is pres[illegible]ted re[illegible] [illegible]ntil the learner responds correctly to each word, was not used [illegible] [illegible]nvites the learner to adopt a whole-word strategy rather tha[illegible] [illegible] strategy. Instead, the computer presents different nonsense wor[illegible] on [illegible]h trial. Within a lesson, however, [illegible]e nonsense words share a common pa[illegible]tern and the learner is required to decode these different w[illegible] unt[illegible] he pas[illegible] the mastery criterion for that pattern. The nature of t[illegible] learn[illegible] decoding response is discussed later in this section.

For exa[illegible], at one skill level the computer might present a [illegible]ngle consonant-vowe[illegible] [illegible]sonant (CVC) word such as nil, san, or tum on eac[illegible] trial. Words are [illegible] in lower-case letters on the computer's telev[illegible]ion screen. At [illegible] [illegible]ghtly more difficult level, the computer might present CVC words in whi[illegible] [illegible]e confusable grapheme-phoneme correspondences b an[illegible] d are represented with higher-than-usual frequencies, such as fid, bam, or [illegible]ub.

At more advanced levels, consonant blends and digraphs may be introduced, resulting in [illegible]atte[illegible]s such as neld, grat, or shab, or more complex patterns such as grast or b[illegible]th. Thus, two parameters of the basic task that may be

varied are the complexity of word patterns and the frequency with which specific graphemes are represented.

In principle, this approach co... have been implemented with real words rather than nonsense words. Nonsense words were preferred, however, for several reasons. An economic reason is that computers can be programmed to generate nonsense words, thus eliminating the cost of entering and storing real words. ... consideration ... not particularly critical in implementing the ... system on the Commodore PET microcomputer, it would be important in a future effort to reduce the system to the size and cost of a special-purpose hand-held device such as Texas Instruments' Little Professor, which generates its own arithmetic problems. In the present system, therefore, the computer generates nonsense words that match patterns that are specified by the teacher. The coding system used by teachers to specify patterns was designed to facilitate rapid lesson changes and to require no previous computer experience.

In addition, there are pedagogical reasons for avoiding real words. It is more difficult for young children, especially poor readers, to think about the sounds that make up language if the sounds form real words than if they form nonsense words. This is probably because the semantic structure of real words is so salient to young children and poor readers that it tends to detract from the more difficult task of becoming aware of phonological structure (Byrne & Shea, 1979; McNeil & Stone, 1965). Since awareness of phonological structure is a prerequisite for decoding, nonsense words were preferred.

In addition, using nonsense words made it practical to instantly individualize lessons. For example, in associating graphemes to phonemes, some children confuse the short sounds of e and i. For these children, a lesson with

nonsense words including only e and i would be useful and could be instantly set up. While this would be relatively simple on a computer which generates nonsense words, it would be more difficult if lists of real words had to be prepared and entered into the computer by teachers.

As we have described, a lesson is composed of a series of trials. On each trial nonsense words, which the learner is expected to decode, are presented in lower-case letters on the computer's television screen. This is continued until the learner responds correctly for a specified number of consecutive trials. Designing a type of response that could be evaluated by a computer was, of course, a major problem. We would have liked to allow the learner to respond by simply saying aloud his response. Unfortunately, speech-recognition technology is not sufficiently advanced for this to be practical solution. We were forced, therefore, to a more oblique technique.

This problem has usually been dealt with by substituting spelling instruction for reading instruction. For example, in one of the Stanford CAI systems, a pre-recorded word is presented by a speech output device. The child is then required to spell the word on the keyboard, and the keyboard response is evaluated by the computer (Fletcher, 1979). This solution, however, has the objectionable feature of drilling the learner on phoneme segmentation and phoneme-to-grapheme encoding rather than grapheme-to-phoneme decoding and phoneme blending. While segmentation and encoding skills may transfer positively to the development of decoding accuracy, the authors believe that if automaticity is the goal, decoding and blending must be practiced.

To illustrate our approach to the response problem, consider a trial in which the word mek is displayed on the television screen for one second, and the learner is simply required to respond by keying it from memory after it

has been erased from the screen. In this example, there is no way to guarantee that the learner has decoded the display into the phonemic sequence /mek/. Instead, the learner may have merely remembered and keyed the separate names of the graphemes m, e, and k. Thus, verifying that the learner has depressed correct keys in a correct sequence is not the same as checking that the learner has actually decoded the word correctly.

Now suppose that instead of one nonsense word, the following three words are simultaneously displayed for three seconds: mek bam dup. The learner is then required to respond by keying only one of the words from memory. The word to be keyed is randomly chosen by the computer, and indicated to the learner by displacing the stimulus display with a response display, such as mek --- dup. With this task, the memory load is too great for a young learner to adopt the strategy of remembering the grapheme names in sequence. Instead, to master the task the child must decode the nine graphemes into three CVC words, and remember the sounds of the words. If, on this task, the child is consistently correct, one may be reasonably certain that he is (1) decoding all three words on each trial, and (2) keying in his response by spelling back the required word.

Thus, a third parameter of the basic task that can be specified by the teacher is the number of words displayed on each trial. For a child at a low skill level, the teacher might specify a single CVC word. It is possible, at this level, that when only one word is presented a child might adopt a grapheme-naming strategy. To discourage this, in the field test we instructed the children to sound out each word aloud. Under this condition, we seldom found that a child who incorrectly sounded out a word was able to key it correctly. Moreover, although some supervision was required, it is precisely

at this level of instruction that supervision is needed to diagnose decoding problems and design individualized lessons. At higher skill levels, the teacher might specify two or three words on each trial. With this increased memory load, our response evaluation technique is reliable with considerably less supervision.

Increasing the memory load serves an additional purpose. There is evidence that when learners must remember as well as decode a verbal sequence, decoding responses must be more automatic than if only decoding were required. This is inferred from data indicating a relationship between the speed with which subjects can name visually-presented items and their memory spans for those items. This positive correlation between naming speed and memory span has been reported when naming speed varies due to individual differences among subjects (Spring & Capps, 1974), and also for single subjects when naming speed is varied by using different materials (Mackworth, 1963). A general explanation of this relation is that more information-processing capacity can be assigned to mnemonic processing if less is needed to identify incoming items. This relationship has been hypothesized to explain the difference between memory spans of adequate and poor readers (Spring & Capps, 1974) as well as to explain the increase of memory span with age (Chi, 1976; Huttenlocher & Burke, 1976). In addition, Baddeley (1979) has used this notion to explain the difficulty beginning readers often experience, while attempting to sound out words, of decoding graphemes to phonemes while attempting to retain previously-identified phonemes in short-term memory. If this general hypothesis is correct, the learner's success as the memory load is increased in the present CAI system depends on his word-decoding becoming more automatic.

We have identified three parameters which the teacher may control: (1) the complexity of word patterns; (2) the frequency with which specific graphemes are represented in words; and (3) the number of words that must be decoded and remembered on each trial. In addition, the teacher may modify the difficulty of the task by controlling a fourth parameter: the amount of time that a stimulus is displayed. For example, in the field study it was common to start learners on one-word CVC displays presented for 10 seconds. Gradually, as decoding became more automatic, the display time was reduced to only 1 second. When the learner progressed to two-word CVC displays, however, the display time inevitably had to be increased temporarily to 7 or 8 seconds. Increasing the display time presumably gives learners extra time for mnemonic processing (Mackworth, 1962). As the learner's decoding continued to become more automatic with two-word displays, however, we were able to gradually decrease the display time again.

Thus, by continuously balancing the task-difficulty parameters, a teacher is able to fine-tune the task to match or slightly excede a learner's decoding ability at any point during the learner's training. In the field test we found that we could continuously challenge and maintain the interest of our learners in this way.

In addition to this intrinsic motivational technique, a somewhat more extrinsic motivational technique was used. During a lesson, a score-keeping horizontal bar is displayed at the bottom of the screen. On the first trial, if the learner responds correctly the horizontal bar is extended one position to the right. This continues on subsequent trials until the bar reaches a pre-specified target position, at which point the lesson is terminated with an appropriate congratulatory message. If, however, the child responds incor-

rectly, or fails to respond within a period which may also be specified by the teacher, the horizontal bar is reset to its starting position. Thus, the teacher may establish the criterion for passing a lesson by specifying the number of required consecutive correct responses and by specifying a time limit for keying responses. Informal observations during the field test convinced us that this technique successfully focused the learner's attention on the task, with concentration especially high as the horizontal bar neared its target.

System Use

The present system was designed to augment the regular reading program with about 10 minutes of decoding practice each day. In this respect it is similar to the Stanford systems (Atkinson, 1968; Fletcher, 1979). The scope of the present system, however, is considerably less than the scope of the Stanford systems. The Stanford systems are self-contained, requiring practically no teacher involvement. In both Stanford systems, the computer keeps records of each learner's progress, and decision algorithms are used to advance learners through a comprehensive set of exercises. In discussing the Stanford systems, Fletcher (1979) states: "Despite extensive workshops, individual conferences, and daily reports on the progress of individual students, very few changes in the practices of classroom teachers were observed that could be attributed to CAI."

The present system, on the other hand, is not self-contained. Use of the system must be preceded by rudimentary instruction in grapheme-phoneme correspondences and in blending. Following this initial instruction, the system may be used to develop and refine these skills by providing individualized practice. Student records are not kept by the computer, and the system does not

include decision algorithms to control a child's advancement to more difficult tasks. Instead, these functions are performed by teachers. The computer is used only to generate and present individualized decoding tasks, the parameters of which must be specified by teachers. It is this economy which makes it feasible to implement the present system in an inexpensive, special-purpose, hand-held device.

In addition to the systematic use of the present system by teachers, the system may be used as a game in the classroom or home. As previously described, it is possible to vary the difficulty of the basic task across a broad range. In fact, the range may be extended to include adult players. We have found that even college students can be severely challenged by the decoding and memory requirements of an appropriately specified decoding task. Given this range, the possibilities for inventing impromptu games with handicapping or bonus-point options are obvious.

Field Test

The effectiveness of the system was tested with educationally-handicapped children selected from special-education classrooms in several elementary schools. These children were given training on the system in daily 10-minute individual sessions. A control group of comparably handicapped children was not given CAI training. For administrative and logistic reasons, training had to be limited to about two months.

Given this limited training period, we felt that it would be unrealistic to expect the children to successively pass both accuracy and automaticity criteria. We were faced with the choice, therefore, of working with inaccurate decoders and testing the system's effectiveness in developing their accuracy, or of working with accurate but slow decoders and testing the

system's effectiveness in developing their automaticity. We decided, for this initial field test, to work with inaccurate decoders. Our objective was to significantly increase their decoding accuracy, compared to the control children. Accordingly, we selected EH children for both the training and control groups who had already received instruction in grapheme-phoneme correspondences, but who were inconsistent in using these correspondences in the context of word identification. This was determined by a pre-test of decoding ability.

Method

Subjects

Three age-matched groups of public elementary-school children were formed. Two of the groups contained educationally-handicapped (EH) children from special classes in six schools. One of these EH groups, designated the training group, contained 12 EH children (10 boys and 2 girls). The other, designated the control group, contained 10 EH children (6 boys and 4 girls) after losing 2 children who moved out of the school district during the study. The third group, designated the normal group, contained 12 average readers (10 boys and 2 girls, selected from regular classes. The mean age for the training group was 9.1 years (*SD* = 1.0); for the control group it was 9.7 years (*SD* = 1.3); and for the normal group it was 9.2 years (*SD* = 1.0). WISC-R intelligence scores were available for all but two of the children in the training group, and for all of the children in the control group. The mean WISC-R total IQ of the training group was 83.5 (*SD* = 9.1). The remaining two children in the training group had Stanford-Binet IQ scores of 85 and 106. The mean WISC-R total IQ of the control group was 89.2 (*SD* = 7.0). Although intelligence scores were not available for children in the normal

group, their mean reading comprehension score was 0.4 years above their mean expected grade level (SD = 0.3) on the Iowa Test of Basic Skills.

Instruments

Three word-reading tests were given to all subjects as pre-tests and as post-tests immediately preceding and following the CAI training period. The first of these tests required subjects to read aloud three lists, each containing 10 CVC nonsense or real words (List 1: baf, fap, nip, tid, fed, bet, rud, pub, nos, don; List 2: sab, ped, dif, ron, dut, rap, bes, rib, top, sub; List 3: lac, meg, hik, vol, jum, huc, kog, wek, gil, wam). For a response to be judged correct, these words had to be read with short vowels. The score was the percentage of the 30 words read correctly.

The second pre and post-test required subjects to read aloud a single list of 10 real CCVC/CVCC words, each containing a beginning or ending consonant blend (List 4: step, flop, plus, crop, frog, sled, drip, bump, sand, mask). The score was the percentage of the 10 words read correctly. The third pre and post-test required subjects to read aloud a single list of 10 real CVC words, each containing a beginning or ending consonant digraph (List 5: back, wish, path, chin, ship, whip, sick, when, this, such). The score was the percentage of the 10 words read correctly.

In addition to accuracy scores, under certain conditions word-reading times were measured during post-testing with a stopwatch to the nearest second. If a subject made no more than one error while reading any of the five lists, the subject was asked to read it again and the time was measured during the repeated reading. This time was used in later analyses, however, only if the repeated reading also contained no more than one error.

During CAI training sessions, a daily log was kept for each child in the

training group by one of the experimenters who monitored the sessions. This log included a record of decoding tasks successfully completed, as well as notes describing each child's learning problems. The log also included a record of learner's daily spontaneous comments and behaviors which reflected positive or negative motivation.

Procedure

Pre and post-tests were adminstered individually to all subjects. Instructions preceding pre and post-tests alerted subjects to expect nonsense words as well as real words. CAI training, given only to the 12 subjects in the training group, was scheduled in daily 10-minute sessions for about 2 months. This training was given in addition to the regular classroom instruction all subjects received. Training was conducted individually in a corner of the child's classroom. Results of each child's pre-test were analyzed before training was begun. Based on these analyses an appropriate entry-level training task was specified for each child. Children who started at about the same level were not necessarily taken through identical sequences of decoding tasks, for although their pre-test scores may have been identical, specific problems may have differed. Subsequent training tasks for each child were specified to remediate specific problems encountered on preceding tasks.

Results and Discussion

Pre-test

Mean scores on each of the three pre-tests are shown in Figure 1. Although the training group scored slightly lower than the control group on each test, none of the differences were significant by F tests ($F < 1$ for each comparison). Mean scores of the normal group on each of the tests, however, were significantly higher, as determined by F tests, than corresponding mean

scores of the training and the control groups ($p < .001$ for all comparisons).

Insert Figure 1 about here

Training

From the daily logs kept for each subject in the training group, we abstracted six milestone training tasks in ascending order of difficulty. These six milestones, shown in Table 1, range from the lowest to highest difficulty levels mastered by our subjects by the end of their training. Also shown in Table 1 are the number of subjects who mastered each training milestone. This is shown for all subjects at the end of the regular 2-month training period, and also for two subjects who were given, at the request of their teacher, an additional two months of training. It may be seen from Table 1 that each successive milestone was reached by fewer subjects. For example, the first milestone, passed by all 12 subjects, required subjects to decode and retain one CVC nonsense word displayed for 4 seconds and composed from any of 5 vowels and 17 consonants. The sixth milestone, passed by only one subject, required subjects to decode and retain three CVC nonsense words presented for 4 seconds and composed from the same 5 vowels and 17 consonants.

Further analysis of the daily logs revealed that, although subjects in the EH training group initially failed to attend to the television screen at critical moments and had trouble locating letters on the computer keyboard, these procedural problems disappeared very rapidly. Three decoding problems, however, were relatively more intractable. The children were often inaccurate in associating graphemes with phonemes. The graphemes b and d were frequently confused, and confusions of voiced-voiceless phoneme pairs such as b and p, d

and t, f and v, and s and z were common. Even when grapheme-phoneme associations were accurate, they were often slow; thus, after correctly but torturously sounding out each separate letter in a CVC sequence, the children were often unable to recall the phoneme sequence and thus could not blend the sounds or key in the correct letters after the display had been erased from the screen. These observations agree with Baddeley's (1979) hypothesis that decoding problems arise as a result of conflicting phoneme-identification and phoneme-retention demands on a system of limited processing capacity. A related and especially troublesome problem was experienced by children who progressed to two-word displays. While these children learned to sound out single words with consistent accuracy, they required much more practice to reach the point where they could remember the first word after sounding out the second word. Without exception, this was a problem for subjects who failed to progress beyond a multi-step process for decoding single CVC words: dividing them into two or three letter segments, sounding aloud the separate letter segments, and finally blending the resulting phonological segments into a single word. On the other hand, two-word displays were considerably less of a problem for those few subjects who learned to decode CVC words in only one step. Thus, as expected, only after achieving some decoding fluency were subjects able to deal effectively with an increased memory load.

Insert Table 1 about here

Post-test

Mean scores of each of the three post-tests are shown in Figure 1. In examining these data, our interest was primarily focused on the comparison

between the training and control groups. Accordingly, we compared the scores of these two groups on each of the three post-tests with three separate analyses-of-covariance. The three pre-tests were used as covariates in the corresponding covariance analyses. For CVC words, it was found that the post-test scores of training subjects were significantly higher than the scores of control subjects, $\underline{F}$ (1,19) = 15.1 $\underline{p}$ < .001. Similarly, for CCVC/CVCC words, the post-test scores of training subjects were significantly higher than the scores of control subjects, $\underline{F}$ (1,19) = 6.76, $\underline{p}$ < .025. For CVC words containing digraphs, although training subjects scored higher than control subjects, the difference was not significant, F (1,19) = 2.9, $\underline{p}$ < .25. We conclude that decoding ability, measured by an accuracy criterion, was significantly improved by CAI training.

As previously noted, when a subject read one of the post-test lists with no more than one error, he was timed during a second reading of the list. If he made more than one error on the second reading, however, his time was discarded. A subject's score for CVC words was the average of whatever times were measured, if any, to read CVC lists 1, 2, and 3. This procedure enabled us to obtain post-test CVC times for all of the subjects in the normal group, 7 out of 12 subjects in the training group, and 1 out of 10 subjects in the control group. The CVC times of the EH children in the training and control groups were converted to $\underline{z}$ scores based on the distribution of times in the normal group. Of the eight EH children for whom times were obtained, seven had $\underline{z}$ scores at least 1.0 standard deviation slower than the mean of the normal group. Thus, even when the EH children were accurate on the CVC post-test, they were rarely as automatic as children in the normal group. Similar results were obtained for CCVC/CVCC words and for CVC words with digraphs.

Among the seven EH children in the training group for whom post-test CVC times were obtained, we detected a significant rank-order correlation between the time to read CVC words and the number of milestones passed during training, $r = -.78$, $p < .05$, one-tailed test. A similarly large, but non-significant rank-order correlation was obtained for the five children in the training group for whom post-test CCVC/CVCC times were obtained: $r = -.64$. Unfortunately, too few times were obtained to repeat this analysis for the post-test of CVC words with digraphs. The first of these correlations indicates that there is a relationship between progress in CAI training and the development of automaticity.

Motivation

Even though the basic decoding task used in CAI training was continuously modified to challenge the learner, we were concerned that the sameness of the task might result in loss of motivation over a training period as long as two months. To check this, we kept a daily record of positive and negative spontaneous comments and behaviors. These spontaneous responses to the task were tallied separately for the first and last months of training. A decrease of positive responses and an increase of negative responses, from the first to last month, would indicate a change toward lower motivation. Combining the responses of all subjects in the training group, we found a decrease from 49 to 37 positive responses and an increase from 14 to 18 negative responses. Although the direction of these changes suggests a slight loss of motivation, a chi-square test indicated that this shift was not significant: $\chi^2(1) =$ 1.[illegible], $p > .20$. Furthermore, even during the second month, positive responses were more frequent than negative responses by a ratio of 2 to 1. We conclude, therefore, that the motivation of subjects in the training group remained high

during the 2-month training period.

Conclusions

The design of the present CAI system was considerabl constrained in order to accomodate the possibility of future conversion to an inexpensive, hand-held device. Even so, we were able to demonstrate significant word-decoding improvement, using an accuracy criterion, by handicapped learners. This was accomplished with high learner motivation which did not significantly decrease during the 2-month training period.

Training was not of sufficient duration, unfortunately, to also facilitate the development of decoding automaticity. We found evidence, however, of a correlation between decoding speed and the progress made by children during CAI training. This relationship increases our expectation that it may be possible, in a future study of accurate but slow decoders, to also facilitate the development of decoding automaticity.

For maximum effectiveness of the present system, teacher involvement is necessary. We expect that, as teachers acquire experience in balancing the system's task parameters to match the decoding abilities of different learners, they will begin to hypothesize about, experiment with, and discover solutions to a variety of decoding problems. It is our hope that teacher acceptance of CAI will be increased when their involvement is required in this way.

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Table 1

Number of Subjects Passing

Milestone Tasks During CAI Training

Milestone Task	Subjects
1. 1 simple word[a] 4-second display	12
2. 1 simple word[a] 1-second display	7
3. 1 complex word[b] 1-second display	5 (7[c])
4. 2 simple words[a] 2-second display	2 (4[c])
5. 2 complex words[b] 2-second display	2 (3[c])
6. 3 simple words[a] 4-second display	1

[a] CVC nonsense word composed from any of 5 vowels and 17 consonant letters.

[b] CCVC/CVCC (blend) or CVC (digraph) nonsense word composed from any of 5 vowels and 13 consonant letters, and 18 consonant blends or 4 consonant digraphs.

[c] Reflects 2 additional months of training given to two subjects.

Figure Captions

Figure 1. Pre-test and post-test mean percent-correct scores of subjects in the training, control, and normal groups on three word-decoding tasks.