Journal of Speech and Hearing Disorders, Volume 54, 233–248, May 1989

TABLETOP VERSUS MICROCOMPUTER-ASSISTED SPEECH MANAGEMENT: STABILIZATION PHASE

LAWRENCE D. SHRIBERG JOAN KWIATKOWSKI TEREZA SNYDER
Department of Communicative Disorders and Waisman Center on Mental Retardation and Human Development
University of Wisconsin-Madison

Few controlled data are available on the efficacy of microcomputers for speech management with children. The focus of this second report in a study series using microcomputers with speech-delayed children (Shriberg, Kwiatkowski, & Snyder, 1986) is on the response stabilization stage of speech management. Two repeated-measures designs were conducted with two samples of preschool children ($n = 18$) to compare tabletop management with comparable computer-assisted activities. Findings indicate that response stabilization tasks in the two intervention modes were equally effective, efficient, and engaging. Additional analyses suggest that the two modes engage the children in different ways, however, and that children may have individual needs for mode-specific features.

The much heralded entry of microcomputers into the speech-language clinic has been notably lacking a correlative efficacy literature. Surveys of national and international journals in clinical speech pathology attest to the paucity of well controlled studies. Useful review and tutorial materials (e.g., Palin & Cohen, 1986; Rushakoff, 1984a, 1984b; Rushakoff & Lombardino, 1986; Schwartz, 1984) focus on the concept of *informed use*, which stresses the need for users to understand and critically evaluate hardware and software. Lacking experimental data, particularly on the use of clinical software with young speech-language involved children, *informed use* must be restricted to concerns about operating features and evident face and content validity. Potential users of clinical software can rely only on a form of consensual validity, involving published software reviews and perhaps local field tests by colleagues and user groups. The situation reflects the general case that in most areas of communicative disorders there is a continuing lack of clinical challenge studies on which to build an applied science (cf. Miller, Yoder, & Schiefelbusch, 1983).

Experimental efficacy studies of computer-assisted speech management might begin with the premise that this technology introduces a new *form* for treatment, with

0022-4677/89/5402-0233$01.00/0

form having potential to enable different types of *content*. Form variables may be defined as content-free elements of the learning environment, including all instructional and interpersonal aspects of client-clinician interaction (Shriberg & Kwiatkowski, 1982b). The content of management, in contrast, may be defined as the linguistic intent that follows from detailed analyses of the communicative deficit (i.e., the selection and sequencing of what is to be taught). In the present context *form* features that might be exploited in computer-assisted instruction include (a) instructional features (e.g., the potential for presenting precise and timely stimuli and knowledge of results), (b) motivational features (e.g., the potential for presenting arresting graphic displays and auditory elements), and (c) quantitative features (e.g., the potential for presenting item- and summative-level information for monitoring progress). Potential areas for microcomputers to expand *content* of speech-language management include their ability to process time-varying signals in the segmental and suprasegmental domains, such as realized in paradigms using speech-recognition and analog signal displays for modifying rate and stress. By giving clinicians immediate control of instructional, motivational, and accountability displays, computer software would seem to have significant promise to impact both form and content alternatives in the daily practice of clinical speech pathology.

What is known, to date, about the efficacy of computer-assisted instruction? The bulk of the literature is found in general education where dependent variables typically concern learning across various elements of the curricula. Representative recent syntheses include those of Kulik and associates (Kulik, Kulik, & Bangert-Drowns, 1985; Kulik, Kulik, & Cohen, 1980), Clark (1985a, 1985b), and more recently, Niemiec and Walberg (1987). The latter authors synthesized 16 literature reviews spanning approximately 250 efficacy studies. The usual caveats about lack of experimental rigor in many of the research designs notwithstanding, these literatures uniformly conclude that (a) computer-assisted instruction has been associated with positive educational outcomes in a significant percentage of the better designed studies, but (b) when both the form and content of computer-assisted instruction are equated with those used in traditional instruction (i.e., novelty effects and instructional content are well controlled), the advantage of computer-assisted instruction over traditional instruction remains only moderate. Meta-analytic metrics such as *effect size* (Glass, 1976; Glass, McGaw, & Smith, 1981) place gains at approximately 0.42 standard deviation units. Such findings speak to the general conclusion that good teaching is good teaching, regardless of the modality in which it is delivered. A comment by Clark (1985b) summarizes this view: "It is the teaching methods which influence the achievement gains, not the 'computer' *per se*." Educational researchers encourage software developers to place primary focus on the quality of the instructional content and presentation and rely less on the power of the computer as a motivational medium (e.g., Johnston, 1987; Taylor, 1987; Yang, 1987).

Research findings from over two decades of studies of computer-assisted instruction in general education have only limited implications for the children, tasks, and personnel involved in speech-language services. In contrast to children in general education, children with communicative disorders have specific cognitive and affective needs associated with their deficit areas and their histories of communicative interactions with significant adults and peers. Differences in instructional form and content, especially for speech targets, contrast the comprehension tasks that typically are the focus of curriculum-centered software with the fine-gained instructional forms needed for computer-assisted speech habilitation or rehabilitation. Finally, the type of one-on-one or small group ecologies that typify speech services with preschool or school-aged children may require different sorts of interactive and technical skills from persons who do the instructing in special versus general education. To the degree that such child, task, and personnel differences may be valid, computer-assisted instruction for the purposes of speech-language services must be viewed as a special subset of the empirical literature.

Results to date from two investigations that have studied computer-assisted approaches with young, speech-language involved children are essentially consistent with findings in the general education literature. O'Connor and Schery (1986) and Shriberg, Kwiatkowski, and Snyder (1986) each report no significant differences in *effectiveness* between microcomputer and traditional modes. In the latter study, which involved booklet versus computer-assisted articulation testing, traditional modes were found to be more efficient. More time was required for the microcomputer to present over 70 graphic test stimuli, and children engaged in more off-task behaviors when they could not identify the stimuli. Such software and hardware issues reflect current constraints in the microcomputers available to school personnel. Although better graphics resolution and simpler and faster operational modes are available in alternative and typically more expensive microcomputer environments, the large installed base of lower-end microcomputers in schools currently dictates that software be developed for a relatively old microprocessor technology.

Evident in all descriptive accounts of computer-assisted speech management, as well as in the few experimental data, is the observation that neither effectiveness nor efficiency variables adequately tap the affective level of children's involvement with the computer. Shriberg et al. (1986) indicated that the computer mode was associated with "better attention and task persistence, particularly for difficult to test children." Hence, in addition to measures of effectiveness and efficiency in this literature, a third dependent variable might be required. To assess potential differences between modes that have not, to date, been studied quantitatively, this variable should be sensitive to behaviors presumed to reflect children's motivational status.

Many discussions of computer-assisted instruction in communicative disorders press for creative use of computers beyond established intervention paradigms (e.g., Larson & Steiner, 1985; Lasky, 1984; Minifie, 1984; Mullendore, 1984; Schwartz, 1984). It would seem that such an enterprise must be based on a firm foundation of experimental data describing exactly how this discipline's traditional paradigms fare when maximally implemented in microcomputer modes. The purpose of the two studies to be described is to compare "tabletop" speech management with a computer-assisted analog of the same activity. Among the three stages of speech management—*response development, response stabilization*, and *generalization*—response stabilization is viewed as the best context for this purpose. The two studies reported here test the null hypothesis of no differences between tabletop and computer-assisted modes on the dependent variables of *effectiveness, efficiency*, and a motivational construct termed *engagement.*

METHOD

Subjects and Speech Targets

Table 1 includes demographic and speech-language characteristics for the 18 subjects in Studies 1 and 2. Three children participated in both studies. In each of the studies, 1 of an original group of 10 subjects needed to be excluded due to missing data occasioned by technical problems or child illness affecting one of the experimental conditions. The 10 original subjects constituted all the children attending a university speech clinic for speech delays of both known and unknown origins during the fall and spring semesters for Studies 1 and 2, respectively. All children received services from the beginning of the semester during which they were included in the study.

As shown in Table 1, the 8 boys and 1 girl in Study 1 ranged in age from 3 years, 8 months to 8 years, 5 months, with a mean age of 4 years, 10 months. The 6 boys and 3 girls in Study 2 ranged in age from 3 years, 6 months to 8 years, 9 months, with a mean age of 5 years, 10 months. Seven of the 9 children in both studies had *mild-moderate* speech involvement and two had *moderate-severe* involvement, based on their Percentage of Consonants Correct (PCC) (Shriberg & Kwiatkowski, 1982a; Shriberg, Kwiatkowski, Best, Hengst, & Terselic-Weber, 1986). All of the children had age-level language comprehension based upon measures obtained when they first were enrolled for treatment. Eleven of the 18 children (61%) demonstrated up to a 1-year delay in language production as assessed by stage-level categorization of their use of syntactic forms in continuous speech (Miller, 1981).

All speech targets for the study were selected from among those speech sound errors that were in the stabilization phase of the child's current speech program. For each child, a candidate speech target must have shown no more than 20% generalization to spontaneous speech and be less than 80% correct on the first try during practices in the sessions preceding the first study session. Word-initial and word-final targets that met these criteria for at least one child—and hence were trained in the study—included deletion, substitution, and distortion errors on the singleton consonants /b/, /d/, /k/, /g/, /f/, /s/, /ʃ/, and /r/ and the clusters /st/, /sp/, and /sk/.

Materials

Comparable materials for tabletop and computer versions of two high-interest, clinically validated activities

TABLE 1. Descriptive data for the 18 subjects in Studies 1 and 2. See text for a description of the speech and language measures.

						Language status			
				Speech status		*Comprehension*		*Production*	
Study	*Subject*	*Gender*	*Age years:months*	*Mild-moderate*	*Moderate-severe*	*Age level*	*Below age level*	*Age level*	*Below age level*
1	1	M	3:8	X		X		X	
	2	M	3:9	X		X			X
	3[a]	M	4:0		X	X			X
	4	M	4:1	X		X			X
	5	M	4:7		X	X			X
	6	F	4:10	X		X		X	
	7[a]	M	5:0	X		X			X
	8	M	5:5	X		X			X
	9[a]	M	8:5	X		X		X	
2	1	F	3:6	X		X		X	
	2	M	4:4	X		X			X
	3[a]	M	4:4		X	X			X
	4	F	4:7		X	X		X	
	5	F	4:8	X		X			X
	6	M	5:0	X		X			X
	7[a]	M	5:4	X		X			X
	8	M	5:5	X		X		X	
	9[a]	M	8:9	X		X		X	

[a]Participated in both Studies 1 and 2.

(Kwiatkowski & Shriberg, 1986) were constructed by an artist-computer programmer. Programming was accomplished on a 128K Apple IIe microcomputer in 6502 machine language. The computer version of each activity was presented on a 128K Apple IIe microcomputer equipped with a 65C02 microprocessor, a new monitor ROMS, and an 80-column AppleColor Composite Monitor IIe, with a Koala Pad as the peripheral input device. Figure 1 includes representative materials from the two versions of the hiding-finding activity used in Study 2. Panel A is a black-and-white screened photograph of the tabletop materials, and Panel B is a black-and-white screened photograph taken directly from the colored image of the comparable computer-mode format. Each activity included the presentation of the same four pictured words, first for labeling and then for production in the context of a game. All computer versions of the activities included sound effects. In addition, the matching game contained musical celebrations following each match, and the hiding-finding game contained animated animals. These differences followed from the general goals of including microcomputer features that are fairly standard in computer-assisted instructional activities and arcade games.

Conditions and Procedures

Each tabletop and computer condition consisted of four sequential tasks. During the first two tasks pictured stimuli were presented at the word level in imitation (Task 1) and spontaneously (Task 2). During the remaining two tasks target words were practiced at the spontaneous carrier phrase level in the context of a game (Task 3 and Task 4). For both Task 3 and Task 4 in Study 1, the clinician and the child took turns finding matched word pairs. The carrier phrase, "I found <word>," was produced each time the first of two pictures was revealed. For Task 3 in Study 2 the clinician hid four animals, one at a time, for the child to try to find under a picture after producing the carrier phrase, "I want to look under <word>." When the activity was repeated, the roles were reversed (Task 4), and the child produced the carrier phrase, "Look under <word>," to tell the clinician where to look for the hidden animal. To make the latter variant of the task appealing, the child was given the option of aiding or tricking the clinician when indicating where to look. During all clinician turns the clinician actively avoided matching pictures and finding hidden animals to maximize the number of child turns per activity. To maintain naturalness during the game portion of the activities, the number of child turns varied depending on how many trials were needed to match the words (Study 1) or find the hidden animal (Study 2).

On a randomly determined, counterbalanced schedule subjects performed the same speech task in either the tabletop or microcomputer mode during the first and last fourth of a 60-min session. Order of modes was reversed when the task was readministered 2 days later in Study 1 and 1 week later in Study 2. All tasks were administered by the child's clinician, who was familiar with the child's error pattern. In informal probes conducted prior to each study, each clinician had demonstrated consistent agreement with one of the authors on correct-incorrect judgments of the child's responses. The total of nine different clinicians, with five participating in each study, were trained to follow a scripted protocol (Appendix A) to assure similar and consistent task administration in the tabletop and computer modes. The protocol was constructed to closely approximate procedures that were used routinely in this clinic with children at the stabilization stage of speech services (Kwiatkowski & Shriberg, 1986). Specific teaching strategies for handling error responses were individualized to be consistent with strat-

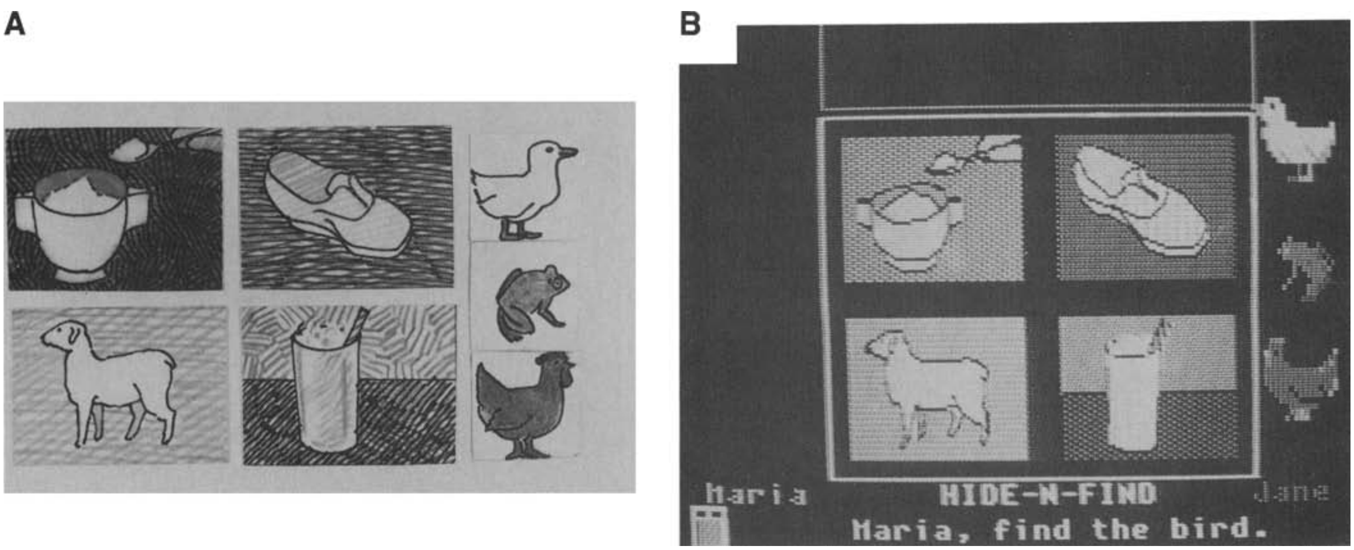

FIGURE 1. Representative materials from the two intervention modes. Panel A is a photograph of sample tabletop materials in the hiding/finding game. Panel B is a photograph of the same activity taken from the color monitor.

egies used in the children's previous sessions. No special strategies were used to maintain on-task behaviors, however, other than verbal redirection following an off-task behavior.

Both versions of the task were administered in the same room with the computer always present. Although all children had some exposure to the computer in the clinic, none had experience with the tabletop and computer versions of the tasks under study. For the periods of each study (Study 1, 1 week; Study 2, 2 weeks), children practiced their targeted sound only during the administration of the tabletop and computer tasks.

All task administrations were simultaneously audio- and videotaped. A Marantz PMD201 audiocassette recorder with matching Sony EC-3 microphones and TDK audiocassettes was used for audio recording. Video recordings were obtained on 3/4-in. 3M UCA videocassettes using a Panasonic WV-6000 color camera feeding a Sony VO600 videocassette recorder housed in an adjacent room. The camera was hidden behind a screened partition in the room and operated quietly by an operator who maintained upper body pictures of both child and clinician. Clinicians were trained to maintain children's lip-to-microphone distance at 15 cm. Audiotape and videotape recording was an accepted part of the speech management routine for the children, and no undue comments about recording equipment were made by children during the study.

Directly after each experimental session in tabletop or computer modes, clinicians annotated their qualitative impressions of the children's behaviors and the clinician-child interaction during the session. Following completion of each study, the children were given the choice of "playing" the table game, the computer game, or neither to obtain an impression of their interests in either of the two modes.

Data Reduction

Children's behaviors were coded from videotapes using three intervention constructs termed *Effectiveness*, *Efficiency*, and *Engagement*. These constructs were operationally defined to reflect the behavioral domains shown in the coding protocol in Appendix B. Only the general behavioral correlates for each of the domains are described in Appendix B. Following approximately 20 hr of training in eight sessions during a 2-week period, three master's-level students were provided a finalized list of behavioral correlates for each of these entries.

Effectiveness reflects the frequency of acceptable, unacceptable, and inappropriate articulatory responses as determined from the feedback of the administering clinician. Hence, the judges did not decide whether children's articulatory responses were correct but rather scored them correct if the clinician's verbal behavioral on the videotape indicated a correct trial.

Efficiency reflects the length of time spent during each of four subsections within the session, including one period for general instructions, and repetitive cycles of preresponse, child response, and postresponse periods. Specific verbal and behavioral cues from the administering clinician identified each of these four period types.

Engagement describes the interaction of the child and clinician with each other and with the task materials as determined by direction of the child's gaze and types of facial expression, verbal responses, and body posture. Behaviors that could not be judged were coded "cannot judge."

Instrumentation, Training Procedures, and Coding

The master tapes were played on a Sony V02610 videotape deck with all start-pause functions controlled by custom software running on a Commodore Vic 20 microcomputer (*VCR CONTROLLER*; Epp, 1987). The *VCR CONTROLLER* program provided periods termed *Viewing*, *Judging*, and *Coding*, correlated with a signal light mounted above a Panasonic CT2010M 20-in. color monitor. A computer-aided behavioral analysis system (*TERMITE*; Ver Hoeve, 1986) allowed judges to keyboard their coding decisions directly into a Harris/800 minicomputer. *TERMITE* classified and stored each occurrence of a behavioral category and timed all categories classified as *continuous* to the nearest 100 ms. Effectiveness and Efficiency events were classified and timed as they occurred throughout the session. The four behavioral variables subsumed under Engagement were coded on an 8-s time-sampling schedule. After an 8-s Viewing period the status light attached to the video monitor signaled a 1-s Judging period. The videotape then automatically stopped, still-framing the screen. The tape then restarted another cycle after a 15-s Coding period in which codes were entered using *TERMITE*. Verbal behaviors were judged as they occurred throughout the 1-s Judging period. All other engagement behaviors were judged on the basis of the still-framed screen image at the end of the Judging period.

Prior to coding the tapes for Study 1, the three judges were trained on all three intervention constructs to familiarize themselves with the entire coding protocol and to select the construct they preferred to code. This period was also used to clarify codes and refine definitions to increase the validity and reliability of the coding protocol. All training was done on randomly selected portions of study tapes that did not exceed one half of the taped session and represented one of the two administrations of both the tabletop and computer version of the task for each child. Prior to coding the tapes from Study 2, portions of one of the tabletop or computer administrations for 5 of the children were randomly selected for training. Fewer training hours were required for Study 2 (approximately 10 hr in four sessions during a 1-week period) because the judges were already familiar with the coding protocol and needed only to learn specific cues for the hiding/finding activity.

Each of the three judges coded behaviors on all 72 videotapes (18 children × 4 taped conditions) for one of the three intervention constructs. All tapes for Study 1 were coded first, followed by tapes for Study 2. Each child's four tapes were coded sequentially, with order of children and mode randomized. Coding was accomplished within a 4-week period. Throughout the training and coding period judges were kept uninformed about the purpose of the study and how the data would be analyzed.

Coding Reliability

To assess coding reliability across studies and modes, one tape was randomly selected from each of the four subsets (2 studies × 2 modes) and recoded 4 weeks after all original coding. *Intrajudge* estimates of the stability of Effectiveness and Efficiency codes were obtained because the task required vigilant attention to the rapid occurrence of specific verbal behaviors in running time. In contrast, *interjudge* estimates of the Engagement codes were obtained because the task required assignment of child and clinician behaviors to behavioral categories. For the latter purpose and after all tapes were coded, the original Engagement judge trained a new judge, using randomly selected videotapes and excluding tapes of children that would be included in the reliability sessions. When training was completed the two judges simultaneously coded the randomly selected reliability tapes, taking precautions to assure independence of judgments. Due to instrumentation limitations in the video deck, which prohibited replicating the judging periods to the exact second on which an original and reliability trial could be compared, an additional intrajudge reliability check for the Engagement pass could not be obtained.

Reliability data for the four samples were calculated by means of a utility program (*RELYONME*; Olson, 1987) that produced point-by-point agreement percentages for original-rejudge comparisons. Average intrajudge coding reliabilities were: Effectiveness, 96% (range: 90%–100%; *SD*: 4%); Efficiency, 90% (range: 87%–97%; *SD*: 5%). For Engagement, interjudge reliability across the four subdomains was 90% (range: 86%–96%; *SD*: 4%).

RESULTS AND DISCUSSION

The 216 computer records (72 tapes × 3 constructs) were prepared for statistical analysis by a utility package that aggregated data for all dependent variables. Output files for each variable were then processed with two-factor, repeated measures analyses of variance to test for the main effects of mode (tabletop versus computer), session (first versus second), and the interaction of Mode × Session. Alpha levels of .05 were used for significance testing in consideration of sample size and the exploratory questions posed.

Interactions and Main Effects for Sessions

One Mode × Session interaction was statistically significant. In Study 1 more incorrect first try responses occurred in the first session in computer mode compared to tabletop [$F(1, 8) = 9.73$; $p < .014$], but this interaction was not replicated in Study 2. There were three statistically significant main effects for sessions and several nonsignificant trends that suggested a coherent pattern of activities taking more time on the first of the two sessions in both modes. Significantly longer first session times were obtained for the average duration of general instructions in Study 1 [$F(1, 8) = 6.10$; $p < .039$] and for the preresponse period in Study 2 [$F(1, 8) = 17.56$; $p < .003$]. Moreover, in Study 2 there was a significantly higher frequency of inappropriate responses in both modes for Session 1 [$F(1, 8) = 7.62$; $p < .025$] and a nonsignificant trend in the same direction in Study 1.

Taken together the newness of the tasks in both modes is a plausible explanation for these findings. In first sessions in both tabletop and computer conditions, clinicians required more time to explain the task and took more time in their postresponse turns. Children, for their part, required more time to learn the picture labels and to learn the linguistic levels required for appropriate responses in each task. On balance, these main effects were viewed as reasonable consequences of the experimental design, where the goal was to create a controlled but natural clinical interaction. Specifically, overtraining the student clinicians would have reduced spontaneity, and pretraining the children on the stimuli would have compromised ecological validity. All subsequent analyses focus on comparisons of tabletop versus computer mode, as summed over the two sessions for each condition.

Effectiveness

Findings for all dependent variables are presented in percentages because the number of turns during the game portion of the activity was left freely to vary. The average number of turns required to complete the activities was fairly consistent across the two intervention modes. The mean number of turns for the tabletop and computer modes, respectively, in Study 1 was 17 ($SD = 2$; range: 14–23) and 20 ($SD = 4$, range: 15–32). In Study 2 the mean number of turns, respectively, for tabletop and computer modes was 25 ($SD = 3$, range: 19–32) and 24 ($SD = 4$, range: 18–29).

Figure 2 is a display of the group means and standard deviations for each of the five Effectiveness variables. Statistically significant differences between tabletop and computer modes are indicated by the asterisks above the standard deviation bars. There were only two significant Effectiveness differences between modes, and each occurred in only one of the two studies. In Study 2 there were significantly more acceptable non-first try responses [$F(1, 8) = 8.35$; $p < .020$], and in Study 1 more inappropriate responses [$F(1, 8) = 8.12$; $p < .021$] in the computer mode compared to tabletop mode. The two findings are related because after an originally inappropriate response to the stimulus, the protocol in both studies required the children to try again until both the carrier phrase and their articulation of the target word were correct. Al-

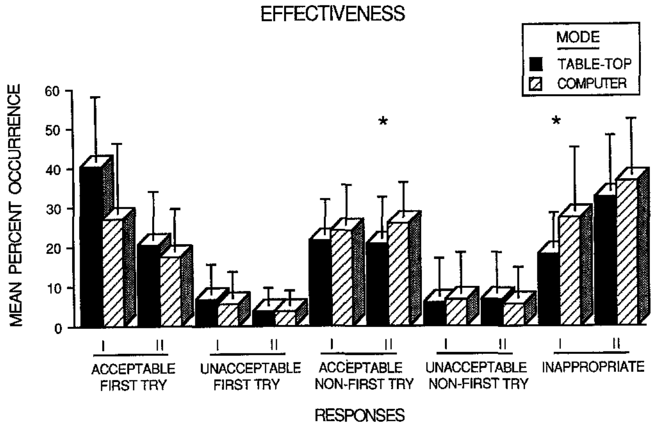

FIGURE 2. Group means and standard deviations for Effectiveness behaviors in tabletop and computer modes in Study 1 and 2, respectively. Asterisks indicate statistically significant differences between modes. See text and Appendix B for a description of Effectiveness behaviors.

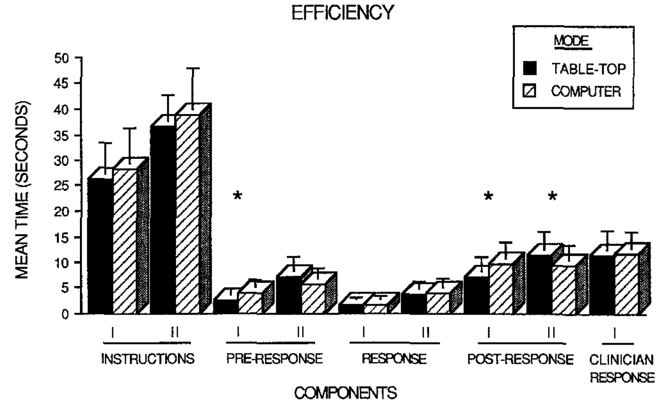

FIGURE 3. Group means and standard deviations for Efficiency behaviors. Asterisks indicate statistically significant differences between modes. See text and Appendix B for a description of Efficiency behaviors.

though differences between the percentage of acceptable first try responses were not statistically significant, inspection of the individual data show that most of the children in both studies were making more acceptable first try responses in the tabletop mode.

A cognitive-motivational hypothesis consistent with these findings is that the activities involved in computer mode may have taken attentional resources away from the current speech task. That is, attentional resources focused on the computer-assisted activities may have been associated with a corresponding withdrawal of resources deployed on the linguistic task. This explanation would account for the children's inconsistency in using the appropriate carrier phrase (i.e., "I found <word>" or "I want to look under <word>") in the computer mode. The vagaries of attentional focus are well known to clinicians, who must be mindful not to overstimulate children's imagination lest they become preoccupied with game elements counterproductive to the goals of management. More generally, associating inconsistency to models of resource allocation and associated concepts of attentional focus are currently the subject of considerable attention in the adult aphasia literature (e.g., McNeil, 1988).

The few main effects favoring tabletop in one or the other study notwithstanding, these data suggest that neither therapy mode was clearly more effective in evoking correct *articulation* responses. The finding is quite consistent with earlier reviews of studies reporting no differences in effectiveness between computer and traditional modes of assessment and speech management.

Efficiency

Figure 3 is a display of average times in seconds spent in each of the time periods coded for Efficiency. As with the Effectiveness data, no statistically significant findings were in the same direction for both studies, suggesting that the two modes did not differ on efficiency criteria. Although average times for preresponse [$F(1, 8) = 13.69$; $p < .006$] and postresponse [$F(1, 8) = 7.40$; $p < .026$] periods for most children were longer in the computer mode in Study 1, the reverse obtained in Study 2, where preresponse and postresponse periods were longer in the tabletop mode with the latter difference reaching statistical significance [$F(1, 8) = 6.61$; $p < .033$]. Actual average differences in time across these mean findings ranged from 1 to 3 s.

Additional analyses of these few efficiency findings indicated that increased average times for the computer mode in Study 1 were related to computer graphics. In Study 1 the computer took more time than the clinician to present the simple graphic stimuli during the preresponse period and to reinforce behaviors during the postresponse period. In contrast, the longer average times for the tabletop mode in Study 2 appeared to be related to the time needed for manipulation of the paper materials. These hiding/finding activities in Study 2 required more complex manipulations than required in the matching activities in Study 1. Hence, the computer accomplished certain graphing tasks more slowly and others more swiftly than clinician and children manipulating comparable physical materials.

Engagement

The four panels in Figure 4 reflect children's engagement in each of the two modes. Behavioral events that were coded "cannot judge" were included in all percentage calculations but are not shown in Figure 4. The percentages of "cannot judge" in each of the Engagement domains was: Gaze 1%–2%, Facial 2%–7%, Verbal <1%, and Posture 1%–2%. Thus, with the possible exception of Facial Expression, uncodable events accounted for a negligible percentage of the data. Moreover, the consistent trend of the findings reported below are not likely to be biased by the slightly higher range of uncoded Facial behaviors in the tabletop mode (5%–7%) compared to the

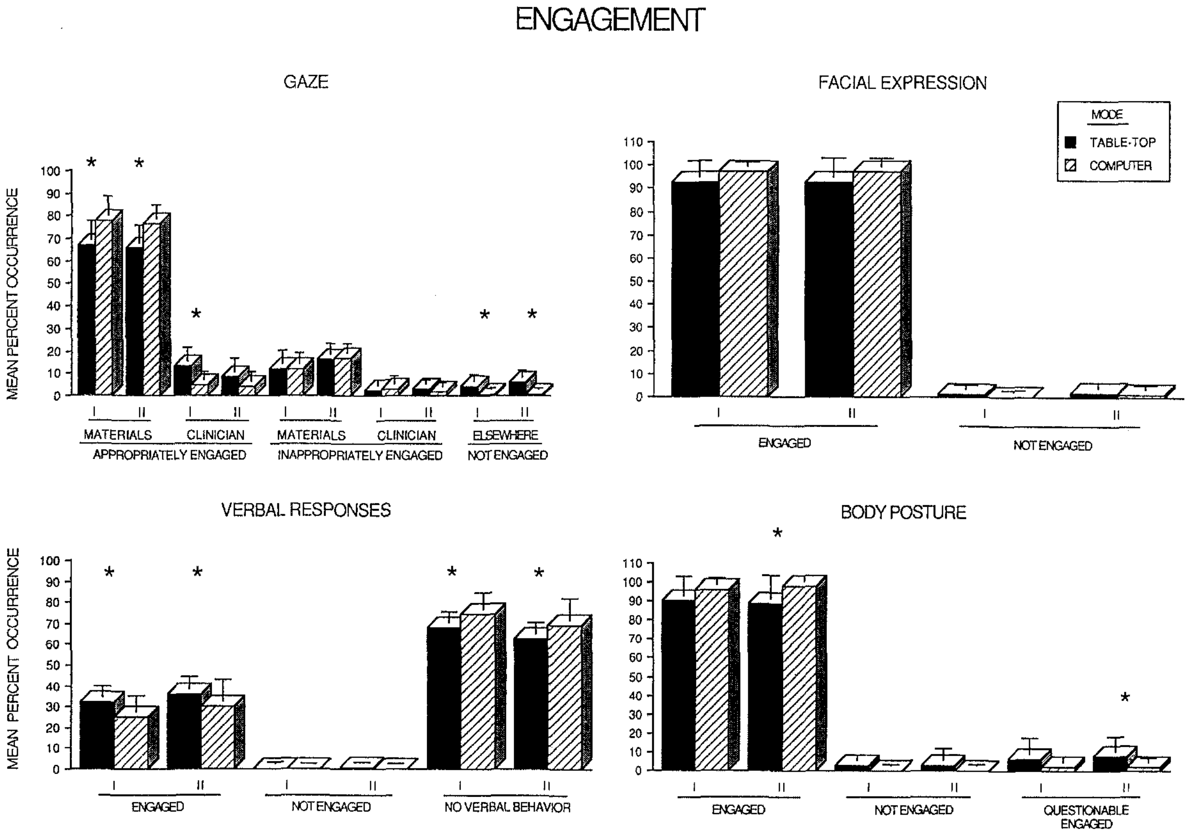

FIGURE 4. Group means and standard deviations for Engagement behaviors for tabletop and computer modes in Study 1 and 2, respectively. Asterisks indicate statistically significant differences between modes. See text and Appendix B for a description of Engagement behaviors.

range of uncodable behaviors in the computer mode (2%–3%).

Gaze. Data in the upper left panel in Figure 4 reflect children's gaze in relation to the management materials and the clinician. For each time-sampling interval occurrences of children's gaze that matched the direction of the clinician's gaze were coded "appropriately engaged." Behaviors directed at the materials or clinician but not matching the direction of the clinician's gaze were coded "inappropriately engaged." Looking behaviors directed "elsewhere" (i.e., children were not looking at the materials or the clinician) were coded "not engaged."

As shown in Figure 4, children's gaze in both Studies 1 and 2 was more often appropriately focused on the materials in the computer mode compared to the tabletop mode [Study 1: $F(1, 8) = 23.81$; $p < .001$] [Study 2: $F(1, 8) = 24.31$; $p < .001$]. In contrast, children's gaze was significantly more often appropriately directed at the clinician in the tabletop mode, but these trends reached statistical significance only in Study 1 [$F(1, 8) = 14.14$; $p < .006$]. Although the difference in clinician-directed gaze was not statistically significant for Study 2, all children gazed more often at the clinician in the tabletop mode and more often at the materials in the computer mode during at least one of the two sessions in both studies. There were no significant differences between modes for inappropriately engaged gaze; however, trends were similar to those observed for appropriately engaged gaze. In both modes children spent more time looking at the materials (12%–17%) than they did looking at the clinician (2%–3%). Finally, in both studies, children had significantly higher percentages of not engaged gaze (i.e., not looking at either the clinician or the materials) in tabletop mode [Study 1: $F(1, 8) = 16.40$; $p < .004$] [Study 2: $F(1, 8) = 27.98$; $p < .001$].

To this point the engagement data suggest that in both modes of intervention, clinicians and children spent considerably more time looking at the materials than they did looking at each other. Although we are not aware of such data elsewhere in the clinical process literature, they are perhaps not surprising given the focus on linguistic materials during response stabilization. Consider the needs at the response development stage of management, where the clinician typically uses various face-to-face modeling and stimulability cues to evoke correct phonetic behaviors. Similarly, at later-stage generalization management where the attempt is to structure ecologically valid discourse contexts for stimulus generalization, children and clinicians may be more likely to look at one another rather than at materials. These general trends notwithstanding, the findings also indicate that computer mode was associated with proportionally more child focus on the computer, whether appropriate or inappropriate to the context. The power of the computer to compel attentional focus, as previously observed in an assessment context (Shriberg, Kwiatkowski, & Snyder, 1986), is apparently well supported also in the present management data.

Facial expression. The upper right panel in Figure 4 is a display of engagement data based on children's facial expression during the same periods randomly sampled for gaze. There were no significant differences between modes for engaged facial expression in either Study 1 or 2. As evident in this figure, only rarely were children not engaged in either mode. It should be noted that these data were undoubtedly influenced by the conservative response definitions that were necessary to ensure reliable coding of facial expression. The time-sampling analysis system may not have been sensitive to subtle differences in facial expression, with behaviors judged "engaged" unless *clearly* "not engaged" (see Appendix B).

Verbal behaviors. The lower left panel in Figure 4 is a display of engagement as reflected in the percentage of occurrence of engaged and not engaged verbal behavior. Two statistically significant findings for both studies suggested that the tabletop mode was more frequently associated with verbal engagement. Not only were the children's verbalizations more frequently coded as engaged in the tabletop mode than in the computer mode [Study 1: $F(1, 8) = 8.64$; $p < .019$] [Study 2: $F(1, 8) = 6.35$; $p < .036$], but also they were more talkative in the tabletop mode as indicated by a lower frequency of no verbal behavior in tabletop mode [Study 1: $F(1, 8) = 8.64$; $p < .019$] [Study 2: $F(1, 8) = 6.35$; $p < .036$]. Hence, these data suggest that for the response stabilization activities studied, children's verbal behaviors were more frequent and judged more engaged (see Appendix B) in tabletop mode. As above, such findings might not be generalizable to earlier and later stages of management, where more interactive client-clinician dialogue might be expected.

Posture. The lower right panel in Figure 4 summarizes child engagement as judged from body posture, such as leaning toward the materials (see Appendix B). Although children were engaged in both modes in over 90% of the time-sampling intervals, there was a significantly higher percentage of engaged postures during the computer mode in Study 2 [$F(1, 8) = 7.08$; $p < .029$] along with significantly fewer occurrences of questionably engaged postures during this mode [$F(1, 8) = 8.41$; $p < .020$]. Hence, in both studies and most clearly in Study 2, the computer mode was more often associated with postures that clearly reflected interest and involvement in the task materials, whereas in the tabletop mode postures were more often equivocal.

In summary, data for the four Engagement domains suggest that the tabletop and computer modes were equally engaging for children. Very few behavioral events across modes were coded as not engaged on the bases of children's gaze, facial expression, verbal comments, or body posture. Inspection of the individual data indicated that only 2 of the 18 children were ever coded as not engaged in all four of the behavioral domains; both instances occurred in the tabletop condition.

For the engaged periods, the findings support a developing model that divides the engagement construct into two subtypes: person-related engagement and materials-related engagement. Tabletop mode may be more person engaging than the computer mode. Although children tended to gaze elsewhere rather than at either the clinician or the materials in the tabletop mode, in this mode they also were more often looking at the clinician and talking to the clinician. The computer mode, in contrast, may be more materials engaging. While in computer mode children maintained more frequent visual focus on the materials, they made fewer verbal responses, and they more frequently showed physical postures that suggested interest and involvement with the materials.

Clinician Impressions and Child Preferences

Anecdotal information from clinicians lends some support to the view that materials-based engagement may be the more powerful objective at the stabilization phase of management. Table 2 includes a representative sampling of the nine clinicians' positive and negative responses to the questionnaire completed after each session in one or the other of the two intervention modes. On balance, clinicians' comments appear to recommend the engagement value of the computer, with children perceived as more responsive in computer compared to tabletop sessions. Clinicians also appeared to favor the computer mode. They reported that the computer-assisted activities allowed them better control over materials, and they felt more interested and responsive in computer mode because they judged the children as more responsive in computer mode. Not shown in Table 2 are clinician

TABLE 2. Representative summary of clinicians' positive and negative written impressions of the children's responses in tabletop and computer modes in Studies 1 and 2.

Type	*Tabletop*	*Computer*
Positive	Child had a more active role	Held child's interest longer Child more responsive than usual Clinician more interested, responsive Clinician had more control over activity and responses
Negative	Child bored, restless Child wasted time manipulating materials	Child distracted by mechanics Child had difficulty learning the screen placements on the Koala Pad

comments that indicated the wide individual differences in children's perceived responses to the computer, with some children perceived to enjoy both modes equally and a few children not enjoying speech services in either mode.

The individual differences in children's perceived responses to the two modes are reflected at least somewhat in the entries in Table 3. At the conclusion of each of the two studies, after having two sessions with each of the intervention modes, children were asked what they wanted to do in the next session: play the tabletop activity, the computer activity, or neither. As shown, most of the children chose the computer mode, with 1 child choosing tabletop mode, and 2 children choosing neither activity.

CONCLUSIONS

The descriptive and inferential statistical data from these two studies can be summarized in the following five testable observations about computer-assisted speech management at the stabilization stage:

1. Tabletop and computer versions of the same activity can be equally effective, efficient, and engaging when form and content are appropriate to the child's cognitive, linguistic, and affective needs.
2. Computer-assisted management may be less time efficient than tabletop activities when programs use graphics to emulate simple materials manipulations.
3. Computer-assisted management may be more time efficient than tabletop activities when programs use graphics to emulate complex materials manipulations.
4. Computer-assisted management may be less effective for some children who need frequent clinician eye contact because it compels both the child and the clinician to look more at the computer than at each other.
5. Computer-assisted management may be more effective for some children due to its higher engagement value.

The first of these conclusions for computer-assisted speech-language management is generally consistent with current views elsewhere in the general and special education literatures. Good teaching is apparently independent of specific instructional approaches (Niemiec & Walberg, 1987). However, the failure to find stable and replicable group effects in the present data could also mask individual difference trends, as studied in current Aptitude × Treatment designs in other areas of computer-assisted learning with special needs preschoolers (e.g., Lehrer, Harckham, Archer, & Pruzek, 1986). Descriptive summaries of each child's data for these purposes were only suggestive of better performance in one or another mode, however, with no clear trends. Hence, although all clinicians and most children expressed a preference for the computer mode, as assessed by self-report procedures, these data have not provided quantitative support for clear group-level or individual-level effects favoring one or another mode of management. The statistical approach used probability statistics only as a guide to differences that might prove also to be clinically relevant. Because the few findings in either direction were not replicated in both studies, it was not deemed appropriate to calculate effect sizes for the effectiveness and engagement data (i.e., mean differences divided by the standard deviation obtained in the tabletop condition) (Glass, 1976; Glass et al., 1981; Nye, Foster, & Seaman, 1987) or duration ratios for subsections of the efficiency data (i.e., elapsed times in computer-assisted mode divided by elapsed times in tabletop mode) (cf. Kulik et al., 1980). As with the better designed studies in other areas of general and special education, procedures that match children's needs to specific teaching modes (i.e., Aptitude × Treatment designs) will be necessary in communicative disorders to demonstrate clinically relevant effect sizes.

TABLE 3. Number of children who expressed a preference for the tabletop, computer, or neither activity in Studies 1 and 2.

Study	*Tabletop*	*Computer*	*Neither*
1	1	7	1
2	0	8	1

Three constraints on generalizations from the present findings warrant brief comment. First, the computer programs were deliberately written to be in every way comparable to the drill and practice activities that clinicians routinely do to stabilize newly developed phonetic behaviors. Additional studies in this series are exploring computer-assisted intervention for response development and for generalization. Form and content for these teaching tasks are substantially different from stabilization-stage tasks, allowing different features of microcomputer software to be developed and tested.

Second, the challenge of present interest is to explore the use of computers with very young speech-involved children. In contrast to the types of computer-assisted activities that can be envisioned for school-aged children, the restricted cognitive, attentional, and sensory-motor skills of preschoolers places severe constraints on potential elements in the design of management software. The goal is to develop procedures that balance form and content. What must be avoided are situations that result in learning environments such as reported with older children by Carrier and Sales (1987): "The students were so involved in playing the game that they missed the point of the lesson." For the samples of speech-delayed children seen in the present studies, software requires extensive flexibility, including stimulus option menus that the clinician must tailor to a variety of essential individual needs. For example, to accommodate individual differences in both trait and state characteristics of young children's attentional focus, the length and rate of stimulus presentations must be under the clinician's immediate control, much like it is on the tabletop. Educational researchers have written extensively on these topics (e.g., Cohen, 1985; Grover, 1986; Heywood, 1986). Software developers in communicative disorders would be well advised to consult such sources for cogent discussions of technical, cognitive, and motivational principles underlying effective software development for young children.

Finally, a methodological need in further studies is to seek optimum ways to assess efficacy. For example, the concept of effectiveness in the current study was defined by measures of sentence-frame appropriateness and articulatory correctness on the first or second try. More refined measures might focus both on more molecular effects, such as trial-to-trial time-motion elements (form) and allophone-level phonetic behaviors (content), as well as more molar variables such as the long-term learning and maintenance curves associated with the two modes of intervention (e.g., Diedrich & Bangert, 1980). Moreover, an efficacy dimension wholly unexamined in the present data set is the effects of mode on the linguistic and paralinguistic content of clinician behavior. Our impressions were that modes were associated with subtle interactive-style differences across the student clinicians. Such anecdotal observations could be studied using appropriate discourse measures. Assembling data on these and many other clinical process variables provides a challenging task for an eventual informed use of microcomputers in the speech-language clinic.

ACKNOWLEDGMENTS

We are grateful to Annette Ortiz, Sara Hoffman, and Patty Ostegard for their effective, efficient, and engaged coding of the videotapes, respectively. We also thank nine former student clinicians for their capable participation in the two studies: Maria Cavicchio, Claudia Doerr, Maureen Dolan, Suzanne Griffin-Ziebart, Jane Loncke, Giuliana Miolo, Cathy Pierce, Susan Shifrin, and Mary Jo Tryba. Thanks are also extended to Carmen Rassmussen and Patty Engebose for their competent research assistance and Joel R. Levin for his always cogent statistical consultation. These studies were supported by Field-Initiated Research Grant No. G00840063 from the United States Department of Education, Office of Special Education and Research, Research in Education of the Handicapped Program.

REFERENCES

CARRIER, C. A., & SALES, G. C. (1987). A taxonomy for the design of computer-based instruction. *Educational Technology, 27*, 15–17.

CLARK, R. E. (1985a). Confounding in educational computing research. *Journal of Educational Computing Research, 1*, 137–148.

CLARK, R. E. (1985b). The importance of treatment explication: A reply to J. Kulik, C. L. Kulik and R. Bangert-Drowns. *Journal of Educational Computing Research, 1*, 389–394.

COHEN, V. B. (1985). A reexamination of feedback in computer-based instruction: Implications for instructional design. *Educational Technology, 25*, 33–37.

DIEDRICH, W., & BANGERT, J. (1980). *Articulation learning*. San Diego, CA: College-Hill Press.

EPP, M. (1987). *VCR CONTROLLER* [Computer program]. University of Wisconsin-Madison, Waisman Center Research Computing Facility.

GLASS, G. V. (1976). Primary, secondary, and meta-analysis of research. *Educational Researcher, 5*, 3–8.

GLASS, G. V., MCGAW, B., & SMITH, M. L. (1981). *Meta-analysis in social research*. Beverly Hills, CA: Sage Publications.

GROVER, S. C. (1986). A field study of the use of cognitive-developmental principles in microcomputer design for young children. *Journal of Educational Research, 79*, 325–332.

HEYWOOD, G. (1986). Forms and functions of feedback in CAI and CAL. *Journal of Computer Assisted Learning, 2*, 83–92.

JOHNSTON, V. M. (1987). The evaluation of microcomputer programs: An area of debate. *Journal of Computer Assisted Learning, 3*, 40–50.

KULIK, C. C., KULIK, J. A., & COHEN, P. A. (1980). Instructional technology and college teaching. *Teaching of Psychology, 7*, 199–205.

KULIK, J. A., KULIK, C. C., & BANGERT-DROWNS, R. L. (1985). Effectiveness in computer-based education in elementary schools. *Computers in Human Behavior, 1*, 59–74.

KWIATKOWSKI, J., & SHRIBERG, L. D. (1986). *A basic management program for experimental intervention studies with speech-delayed children*. Unpublished manuscript.

LARSON, V., & STEINER, S. (1985). Language intervention using microcomputers. *Topics in Language Disorders, 6*, 41–45.

LASKY, E. Z. (1984). Introduction to microcomputers for specialists in communication disorders. In A. Schwartz (Ed.), *Handbook of microcomputer applications in communication disorders* (pp. 1–15). San Diego, CA: College-Hill Press.

LEHRER, R., HARCKHAM, L. D., ARCHER, P., & PRUZEK, R. M. (1986). Microcomputer-based instruction in special education. *Journal of Educational Computing Research, 2*, 337–355.

MCNEIL, M. R. (1988). Aphasia in the adult. In N. J. Lass, L. V. McReynolds, J. Northern, & D. E. Yoder (Eds.), *Handbook of speech-language pathology and audiology* (pp. 738–781). Toronto: Brian C. Decker.

MILLER, J. (1981). *Assessing language production in children*. Baltimore: University Park Press.

MILLER, J. M., YODER, D. E., & SCHIEFELBUSCH, R. (Eds). (1983). *Contemporary issues in language intervention. ASHA Reports, 12*.

MINIFIE, F. D. (1984). The personal computer as a professional tool. *Asha, 26*(6), 23–25.

MULLENDORE, J. M. (1984). Microcomputer applications: A perspective in the development of the profession. In A. Schwartz (Ed.), *Handbook of microcomputer applications in communication disorders* (pp. 259–273). San Diego, CA: College-Hill Press.

NIEMIEC, R., & WALBERG, H. J. (1987). Comparative effects of computer-assisted instruction: A synthesis of reviews. *Journal of Educational Computing Research, 3*, 19–37.

NYE, C., FOSTER, S. H., & SEAMAN, D. (1987). Effectiveness of language intervention with the language/learning disabled. *Journal of Speech and Hearing Disorders, 52*, 348–357.

O'CONNOR, L., & SCHERY, T. K. (1986). A comparison of microcomputer-assisted and traditional language therapy for developing communications skills in nonoral toddlers. *Journal of Speech and Hearing Disorders, 51*, 356–361.

OLSON, D. (1987). *RELYONME: A program for estimating inter-observer reliability* [Computer program]. University of Wisconsin-Madison, Waisman Center Research Computing Facility.

PALIN, M. W., & COHEN, C. G. (1986). Technology in the schools. *Asha, 28*(5), 35.

RUSHAKOFF, G. E. (1984a). Clinical applications in communication disorders. In A. Schwartz (Ed.), *Handbook of microcomputer applications in communication disorders* (pp. 147–171). San Diego, CA: College-Hill Press.

RUSHAKOFF, G. E. (1984b). A clinician's model for the review of speech, language, and hearing microcomputer software. *Asha, 26*(8), 43–44.

RUSHAKOFF, G. E., & LOMBARDINO, L. J. (1986). Microcomputer applications. *Asha, 28*(6), 27–31.

SCHWARTZ, A. H. (1984). Microcomputer applications: Facts, functions, fads, and fallacies. *Journal of Childhood Communication Disorders, 8*, 89–111.

SHRIBERG, L. D., & KWIATKOWSKI, J. (1982a). Phonological disorders II: A conceptual framework for management. *Journal of Speech and Hearing Disorders, 47*, 242–256.

SHRIBERG, L. D., & KWIATKOWSKI, J. (1982b). Phonological disorders III: A severity metric. *Journal of Speech and Hearing Disorders, 47,* 256–270.

SHRIBERG, L. D., KWIATKOWSKI, J., BEST, S., HENGST, J., & TERSELIC-WEBER, B. (1986). Characteristics of children with phonologic disorders of unknown origin. *Journal of Speech and Hearing Disorders, 51,* 140–160.

SHRIBERG, L. D., KWIATKOWSKI, J., & SNYDER, T. (1986). Articulation testing by microcomputer. *Journal of Speech and Hearing Disorders, 51,* 309–321.

TAYLOR, R. P. (1987). How will computing change education? *Education and Computing, 3,* 101–105.

VER HOEVE, J. N. (1986). *TERMITE: A behavioral observation system for the Harris 800 minicomputer* [Computer program]. University of Wisconsin-Madison, Waisman Center Research Computing Facility.

YANG, J. (1987). Individualizing instruction through intelligent computer-assisted instruction: A perspective. *Educational Technology, 27,* 7–15.

Received March 28, 1988
Accepted June 8, 1988

Requests for reprints should be sent to Lawrence D. Shriberg, Ph.D., Waisman Center on Mental Retardation and Human Development, 1500 Highland Avenue, Madison, WI 53705.

APPENDIX A

CLINICIAN PROTOCOL: STUDY 1

Protocol element	*Tabletop mode*	*Computer mode*
Introducing the tasks to the child	Say, "Let's play a matching game with words that have your _____ sound."	Say, "Let's play a computer matching game with words that have your _____ sound."
Task 1: Word—imitation level	Say, "First we need to get ready. Let's practice the words we'll use in our game."	Same as tabletop
	Place one member of each pair of word cards face down on the table.	Reveal the first Discovery screen.
	Say, "Pick a card and turn it over. Then I'll say the word and you say it after me."	Say, "Pick the card you want to turn over. Look at the color of the card you want. Press that color on this board (point to the Koala Pad) to make the card turn over. Then I'll say the word and you say it after me."
	Handle verbal feedback, and so forth, as noted below.	Same as tabletop
Task 2: Word—spontaneous level	Place the matching member of each pair of word cards face down on the table.	Reveal the second Discovery screen.
	Say, "Pick a card and turn it over. This time you say the word by yourself just like we practiced it. Then we'll be ready to play the matching game."	Same as tabletop
	Handle verbal feedback, and so forth, as noted below.	Same as tabletop
Task 3: Carrier phrase—spontaneous level	Place all the cards face down on the table. Explain the game but do not demonstrate.	Reveal the Pick-a-Pair game screen. Explain the game but do not demonstrate.
	Say, "Now you're ready to play the game. Pick a card and tell me what you picked. Maybe you'll pick <possible word>; then you'll tell me 'I picked <possible word>.' Say the word just like we practiced and you can pick another card and see if it's the same.	Same as tabletop
	Every time you pick two cards that are the same you'll get to keep them on your side of the table.	"Every time you pick two cards that are the same they'll go on your side of the screen (point to area)."
	I'll play the game too. We'll take turns. At the end of the game, whoever has the most cards is the winner."	Same as tabletop
	Handle verbal feedback, and so forth, as noted below.	Same as tabletop

APPENDIX A *continued*

Protocol element	*Tabletop mode*	*Computer mode*
Task 4: Carrier phrase—spontaneous level	Repeat Task 3	
Verbal feedback; handling wrong responses; maintaining on-task behavior	Use the same procedures that you have been using with the child during previous teaching sessions on the target. These procedures have been developed for the child based on his/her needs and learning style. Interact with the child as you typically do. Handle off-task behavior by verbally redirecting the child to the task. The child must produce each target stimulus correctly before moving to the next target stimulus.	

CLINICIAN PROTOCOL: STUDY 2

Protocol element	*Tabletop mode*	*Computer mode*
Introducing the tasks to the child	Say, "Let's play a Hide-n-Find game with words that have your _____ sound."	Same as tabletop
Task 1: Word—imitation level	Say, "First we need to get ready. Let's practice the words we'll use in our game. I'll say the word and then you say it just like I did."	Same as tabletop
	Place one of the word cards on the table in front of the child. Place each pictured word card on top of the preceding card as each word card is presented.	Reveal the first of the four single picture screens.
	Say the word for the child to imitate. Repeat this procedure for all four target words.	Same as tabletop
Task 2: Word—spontaneous level	Place all four word cards face up on the table in front of the child. Use the same picture arrangement as on the computer; simultaneously place an animal under each picture.	Reveal the screen that contains the four word cards.
	Say, "Now you say the words by yourself. Say the word just like we practiced and I'll take the card away. There's an animal under each card that we can use in our Hide-n-Find game. When all the animals are on your side of the table (point) we're ready to play the game."	Say, "Now you say the words by yourself. Press this box (point to Koala Pad) for this picture (point to the picture on the screen), press this box (point) for this picture (point), this box (point) for this picture (point), and this box (point) for this picture (point). You press the box you want. Say the word just like we practiced, and the picture card will turn over. There's an animal under each card that we can use in our Hide-n-Find game. When all the animals are on your side we're ready to play the game."
	Handle verbal feedback, and so forth, as noted below.	Same as tabletop
Task 3: Carrier phrase—spontaneous level (clinician hides)	Begin with a clear table.	The computer will automatically reveal an empty screen.
	Say, "Now we're ready to play the Hide-n-Find game. I'll hide an animal and you try to find it. Before you look under a picture you need to tell me where you're going to look. Maybe you're going to look under <word>. Then say, 'I'm going to look under <word>.' Say the word just like we practiced, and you can see if you're right."	Say, "Now we're ready to play the Hide-n-Find game. I'll hide an animal, and you try to find it. Before you can look under a picture you need to tell me where you're going to look. Maybe you're going to look under <word>. Then say, 'I'm going to look under <word>.' Say the word just like we practiced, and you can press a box to see if you're right."

APPENDIX A *continued*

Protocol element	*Tabletop mode*	*Computer mode*
	Again place the four pictured word cards face up on the table in front of the child. Use an arrangement that is exactly like the presentation on the computer screen. Place three of the animals in a vertical line to the right of the picture arrangement. Place the fourth animal at the top of the four-picture arrangement. Repeat this latter procedure before hiding each animal. Say, "I'm going to hide an animal. Close your eyes." Hide an animal. Say, "Open your eyes. Tell me where you're gonna look."	Reveal the four-picture screen for the Hide-n-Find game with an animal pacing in the space above the pictures and three animals in a vertical line on the clinician's side of the screen. Say, "I'm going to hide an animal. Close your eyes. I have to press a box to show the animal where to hide." Hide an animal. Say, "Open your eyes. Tell me where you're going to look."
	When the child produces the word correctly in the carrier phrase, remove the picture he/she named to reveal whether or not the animal is under it. (If the child wants to remove the picture, permit him/her to do so.)	When the child produces the word correctly in the carrier phrase, say, "Press the box to see if you're right."
	When the child finds an animal, say, "You found it," and put the animal in a vertical line to the child's side of the picture arrangement.	Same as tabletop
	During the course of the game respond in a natural way (i.e., however you choose according to the child finding/not finding an animal on each turn). Continue to use the prompt, "Tell me where you're going to look," as needed to elicit production of the carrier phrase.	Same as tabletop
	When there is only one picture remaining, say after the child's production of the carrier phrase, "We know where the animal is now. Nobody found him. Let's put him over here." Remove the animal to the side, out of view. Say, "He tricked us."	When there is only one picture remaining, say after the child's production of the carrier phrase, "We know where the animal is now. Nobody found him." After the animal moves off the screen, press <space bar> to reveal the next screen.
	Repeat the above hiding-and-finding routine until all the animals are hidden and found. Handle verbal feedback, and so forth, as noted below. Reinstruct as necessary. At the end of the game say, "That was fun. You're good at finding animals. You found <number> animals."	Same as tabletop
Task 4: Carrier phrase—spontaneous level (child hides)	Begin with a clear table.	Press <right arrow> to reveal the empty screen.
	Say, "Now you can hide the animals and I'll try to find them. I'll ask you where I should look for the animal and you tell me, 'Look under <word>,' or 'Look under <different word>.' Sometimes you can be my helper and tell me the right place to look. Sometimes you can play a trick and tell me the wrong place. When I think you're playing a trick I won't look where you told me."	Same as tabletop
	Place the four picture cards face up on the table in front of the child. Arrange them as they appear on the computer screen. Place three animals in a vertical line on the child's side of the four-word card arrangement. Place the fourth animal at the top of the arrangement. Say, "This animal is ready to be hidden. I'll close my eyes." Repeat this procedure before the child hides each animal.	Reveal the four-picture screen with an animal pacing in the space above the pictures and three animals in a vertical line on the child's side of the screen. Say, "This animal is ready to be hidden. Press a box to show him where to hide. I'll close my eyes." Repeat this procedure before the child hides each animal.

APPENDIX A *continued*

Protocol element	*Tabletop mode*	*Computer mode*
	Before you look for the animal, say, "Tell me where I should look. Remember to say the words just like we practiced." Continue to use this prompt as needed to elicit the child's use of the words in the carrier phrase. Handle verbal feedback, and so forth, as noted below. Reinstruct as needed.	Same as tabletop
	After each animal is found, say, "I found it," and place it on your side of the picture arrangement.	After each animal is found, say, "I found it," and press <forward arrow> to place it on your side of the picture arrangement.
	During the course of the game respond however you choose according to your assumption about the child helping/tricking you. For example, you could say, "I think you're tricking me," and so forth. Routinely assume that the child is tricking you until only one or two pictures remain. Repeat the above game-play routine until all the animals are found. Never find more animals than the child found.	Same as tabletop
	When there is only one picture remaining, say after the child's production of the carrier phrase, "We know where the animal is now. Nobody found him. Let's put him over here." Remove the animal to the side, out of view. Say, "He tricked us."	When there is only one picture remaining, say after the child's production of the carrier phrase, "We know where the animal is now. Nobody found him." As the animal leaves the screen say, "He tricked us."
	Handle verbal feedback, and so forth, as noted below. Reinstruct as needed. At the end of the game say, "That was fun. I found <number> animals."	
Verbal feedback; handling wrong responses; maintaining on-task behavior	Use the same procedures that you have been using with the child during previous teaching sessions on the target. These procedures have been developed for the child based on his/her needs and learning style. Interact with the child as you typically do. Handle off-task behavior by verbally redirecting the child to the task. The child must produce each target stimulus correctly before moving to the next target stimulus.	

APPENDIX B

CODING PROTOCOL

TABLE B-1. Effectiveness: All child behaviors are coded during the response period. Coding of behaviors as one of five classes is based on clinician behaviors following child responses. The term *behavioral signal* includes clinician's verbal behaviors, gestural behaviors, and the procedural behaviors.

Behavior	*Behavioral signal*
Acceptable first try response	Clinician signals that articulation in the first try response was appropriate and acceptable.
Acceptable non-first try response	Clinician signals that articulation in a response that followed one or more unacceptable or inappropriate responses was appropriate and acceptable.
Unacceptable first try response	Clinician signals that articulation in a first try response was unacceptable.
Unacceptable non-first try response	Clinician signals that articulation in a response following one or more unacceptable or inappropriate responses was unacceptable.
Inappropriate response	Clinician signals that the child produced the wrong word or responded at a wrong linguistic level. Unacceptable articulation responses at the wrong linguistic level were coded as unacceptable.

APPENDIX B *continued*

TABLE B-2. Efficiency: All time periods are contiguous. Instructions occur only at the beginning of each of the four tasks and are followed by successive preresponse, response, and postresponse periods. Specific verbal and nonverbal behaviors, included in the clinician's protocol for each study (Appendix A), are used to signal the beginning of each time period.

	Description of time periods	
Period	*Content*	*Beginning signal*
Instruction	Directions for all tasks	Clinician begins to verbalize the instructions for the task.
Preresponse	All instructional and motivational events that precede the child's first try attempt to produce the target and the child's first try response.	Clinician presents a stimulus for a first try response.
Response	All antecedent instructional and motivational events for all non-first try attempts to produce the target.	Clinician's feedback identifies the child's first try response as acceptable, unacceptable, or inappropriate.
Postresponse	All subsequent motivational events for an acceptable response.	Clinician's feedback identifies the child's response as acceptable. When the first try response is acceptable, the response and postresponse periods are coded in immediate succession.

TABLE B-3. Engagement: All behaviors are classified during a 1-s Judging period after an 8-s Viewing period. Gaze judgments are made on the basis of direction of eye gaze and/or angle of the head, with the clinician's gaze as the point of reference. "Clinician" includes any part of the clinician's body when the clinician gazes at any part of the child's body; "materials" includes all task materials and equipment such as the computer keyboard. Events are coded "cannot judge" whenever the direction of the clinician's or child's gaze cannot be determined.

Behavior	*Code*	*Behavioral signal*
Gaze	Appropriately engaged	
	Matched: clinician	Child and clinician gaze at each other.
	Matched: materials	Child and clinician gaze at materials.
	Inappropriately engaged	
	Nonmatched: clinician	Child gazes at clinician while clinician gazes at materials.
	Nonmatched: materials	Child gazes at materials while clinician gazes at child.
	Not engaged	
	Nonmatched: elsewhere	Child gazes neither at clinician nor at materials.
Verbal	Engaged	Child attempts to produce the target or produces speech or nonspeech vocalizations that suggest interest, enjoyment, or involvement in the task.
	Not engaged	Child produces speech or nonspeech vocalizations that suggest lack of interest, enjoyment, or involvement in the task.
	No verbal behavior	Child is silent.
Facial	Engaged	Child's positive or negative facial expression suggests interest, enjoyment, or involvement in the task.
	Not engaged	Child's facial expression suggests lack of interest, enjoyment, or involvement in the task.
Posture	Engaged	Child assumes a positive or negative posture that suggests interest, enjoyment, or involvement in the task.
	Not engaged	Child assumes a posture that suggests lack of interest, enjoyment, or involvement in the task.
	Questionable	Although the child's posture suggests interest, enjoyment, or involvement in the task, there is some other behavior that prohibits coding the posture as "engaged."