Journal of Speech and Hearing Disorders, Volume 51, 309–324, November 1986

ARTICULATION TESTING BY MICROCOMPUTER

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The picture naming articulation test, one of the most widely used speech assessment procedures, provides an excellent paradigm to study the potential of microcomputers with young, speech involved children. The stimulus-response format of the articulation test is structurally similar to assessment and management procedures crossing the spectrum of speech disorders. Findings from three studies comparing booklet-presented pictures to microcomputer-presented graphics indicate that microcomputers have certain control advantages in motivating children's repeated trials. However, spontaneous articulation testing by microcomputer may take more time than booklet testing if the graphics are less readily identifiable and due to associated novelty effects. Discussion of findings includes suggestions for enhancing the client-clinician-computer interface as this discipline experiences the entry of microcomputers into the speech-language clinic.

Reports since the early 1970s have described how mainframe and, later, microcomputers can be used in articulation assessment (e.g., Blache, 1985a; Compton & Streeter, 1977; Dickerson, 1971; Dyson, 1979; Elbert, Young, & Bruce, 1981; Faircloth, 1971; Riski & DeLong, 1982; Shriberg, in press; Telage, 1980; Van Demark & Tharp, 1973) as well as in articulation management and report writing (e.g., Dalston, 1983; Faircloth, 1971; Fitch, 1974; Meyers, 1984; Rushakoff, 1986; Rushakoff & Lombardino, 1984; Silbar & Konarska, 1984). However, compared to the current dissemination rate of software for assessment and management of both adult and child language disorders, software for childhood articulation disorders seems to be slow to emerge.

One factor that, in part, may account for the slow emergence of articulation assessment software is the shifting theoretical perspectives that characterize the child phonology literature. Theoretical and methodological issues dating from classic descriptive studies and synthesis papers (e.g., Jordan, 1960; Milisen & Associates, 1954; Siegel, Winitz, & Conkey, 1963; Templin, 1957) to critiques of more recent testing and analysis procedures (e.g., Bankson, 1980; Bankson & Bernthal, 1983; Bernthal, 1980; Briere, 1967; Edwards, 1983; Elbert, Dinnsen, & Weismer, 1984; Grunwell, 1980, 1982; Higgs, 1970; Hutchinson, 1972; Ingram, 1976; Schwartz, Messick, & Pollack, 1983; Shelton & McReynolds, 1979; Shriberg, 1986) leave many basic validity issues unresolved. For example, questions concerning the appropriate linguistic unit for an articulation "test" or phonologic analysis procedure have become increasingly complex when viewed in relation to correlative literatures in cognition, language, and speech motor control. Moreover, perennial studies of testing by citation-form articulation tests versus spontaneous speech samples (e.g., Dubois & Bernthal, 1978; Faircloth & Faircloth, 1970; Kenny, Prather, Mooney, & Jerruzal, 1984; Kresheck & Socolofsky, 1972; Madison, Kolbeck, & Walker, 1982; Mullen & Whitehead, 1977; Paynter & Sims, 1979; Prater, 1981; Simmons, Blodgett, & Miller, 1983; Traweek et al., 1984) continue to yield equivocal answers as different linguistic units are proposed (e.g., phonemes, features, phonological processes), and different independent and dependent variables are studied.

Persisting validity issues notwithstanding, there is a need for objective studies of clinical software for articulation assessment. Recent software evaluation procedures (e.g., Committee on Educational Technology, 1984; Rushakoff, 1982; Schwartz, 1984) typically include form and content considerations that only indirectly concern the test validation and empirical criteria by which assessment and intervention approaches traditionally have been judged. The picture naming articulation test, one of the most widely used speech assessment procedures, provides an excellent paradigm within which to begin objective study of the potential of microcomputers with young, speech involved children. The stimulus-response format of the articulation test is structurally consistent with assessment and management procedures crossing the spectrum of childhood speech disorders and is consistent with experimental studies reported in much of the related literature. Extensive and relevant literature on picture identification, computer graphics, and the instructional use of microcomputers with young children is available, as suggested in the following brief discussion.

The basic task in articulation testing by pictures is to structure the stimuli so that children can easily identify and rapidly name the pictures, with a minimum of interactive comments required by an examiner to encourage children to complete an often lengthy task. One empirical question is whether computer screens can serve this function as well as objects or pages in a book. Computer screens have been described as "keyholes" through which relevant text and graphics information are displayed (Woods, 1984). Whereas in the environment and hardcopy world, children see objects and information embedded in structured contexts that more or less indicate relationships vital to the task at hand, the computer

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screen provides a somewhat truncated view. Designing graphic stimuli that children can readily identify requires that computer drawings operate within cognitive, esthetic, and technical constraints. Aspects of color, size, balance, and fidelity, for example, all must subserve the clinical goals of rapid, unambiguous identification.

A problem in assessing children with language and speech involvement is that even seemingly simple picture naming tasks require complex cognitive resources. Jolicoeur, Gluck, and Kosslyn's (1984) discussion of stimulus identification processes is instructive:

> The apparent ease with which people identify common objects belies the subtlety and complexity of the operations and structures involved in such identification. Somehow a visual stimulus must be consistently mapped into a single (or small set) of representations in memory. This mapping is dependent on both perceptual factors (such as an object's shape) and cognitive factors (such as context) .... The identification of objects stands at the interface between perception and semantic memory. (p. 244)

Although the literature in instructional technology suggests that picture perception research has yet to yield a coherent strategy for the use of pictures by practitioners (Brody, 1984), microcomputer-assisted management in speech pathology programs is likely to continue to make heavy use of pictorial graphics (e.g., Blache, 1985b). In the present context, the interest is in the computer's potential for precise yet "friendly" stimulus control of graphic media. Much as laboratory computers have been used for controlled presentations of auditory and visual stimuli, microcomputers can provide the clinician a controlled means for presenting interesting graphics in repeated trials to evoke spontaneous and imitative verbal responses.

The general goals of the three studies reported here were to compare speech-delayed children's responses to booklet-presented pictures with their responses to comparable microcomputer-presented graphics. The primary dependent variables were articulation performance, picture identification scores, total administration time, and several indices of motivational responses to the microcomputer environment. Specific questions posed in each of the three studies are described in the presentation of results.

METHOD

Materials

The Photo Articulation Test (PAT), First Edition (Pendergast, Dickey, Selmar, & Soder, 1969) was selected as the picture naming comparison source because of the reputed quality and recognizability of its pictured stimuli (Shanks, Sharpe, & Jackson, 1970) and its widespread use in both clinical and research settings. PAT stimuli are presented either on individual cards or, more commonly, as arranged in a nine-item format in a test booklet. Each of the eight 8 1/2 × 11 in. (21.59 × 27.94 cm) pages in the test booklet contains nine 1 7/8 × 3 in. (4.76 × 7.62 cm) colored photographs depicting common objects against a blue-grey background. Figure 1 is a black and white screened photograph of the first page of the PAT test booklet. The 72 stimuli in the booklet are each designed to evoke one target consonant, vowel, or diphthong per word (with the exception of *hanger,* which tests two consonants). Several words must be evoked by asking a question *(this/that, yes, thank you)* or directly by imitation *(bathe, measure, beige).* Unlike picture naming articulation tests that sequence items in their order of developmental mastery, the pictured stimuli are arranged in sequence to evoke sounds made with the tongue (first 48 items) and lips (second 18 items). This arrangement is notable in the present context because of its possible effect on children's motivation. That is, because each of the first 18 stimuli evoke sibilant fricatives and affricates, children with errors on these sounds may become aware of their lack of articulation success during the first 25% of the test administration (Shriberg, 1978).

An accomplished artist, who is also a proficient computer graphics programmer, used the PAT photographs as models to create computer drawings that could be presented in three ways: as small (1/16 screen size) drawings, as somewhat larger (1/4 screen size) drawings, and as full-screen, elaborated drawings containing additional content and scale cues that might increase the identifiability of the item. Because of the limited resolution of the computer system, artistic details were constrained by the requirement that pictures be identifiable at the 1/16 screen size. The drawings were used to support three methods of presentation. In the first presentation method, the small graphics were arranged to resemble the nine-item per page format shown in Figure 1. Figure 2 is a black and white screened photograph of this format, taken directly from the colored image on a Taxan Model 210 composite/RGB monitor. The second method presented the same original graphics, but in isolation and at a larger size, filling 1/4 of the monitor screen. The third method of presentation was the single, enhanced graphic which filled the entire screen. Figure 3 includes two such stimuli; they are enhanced versions of two of the items shown in Figures 1 and 2. All programming was done on a 128K Apple IIe in 6502 machine language using Graphics Magician Picture-Painter (TM) routines from Penguin Software.

Command keys allowed an examiner to present PAT items in any of the three sizes—in the nine-item per screen format, the 1/4 screen expanded size, or the full-screen, enhanced size. The Appendix describes in detail how each of the options was used in combination with examiner prompts in the three studies. In Study I, only the nine-item per screen formats were used to attempt to evoke spontaneous, accurate picture identification in both the booklet and computer modes. In Study II, the examiner began with the nine-item per screen formats—then, in the computer mode, gave subsequent trials in the 1/4 size and full-screen graphics as necessary to try to evoke spontaneously correct picture identification. After the findings from Studies I and II were available, several

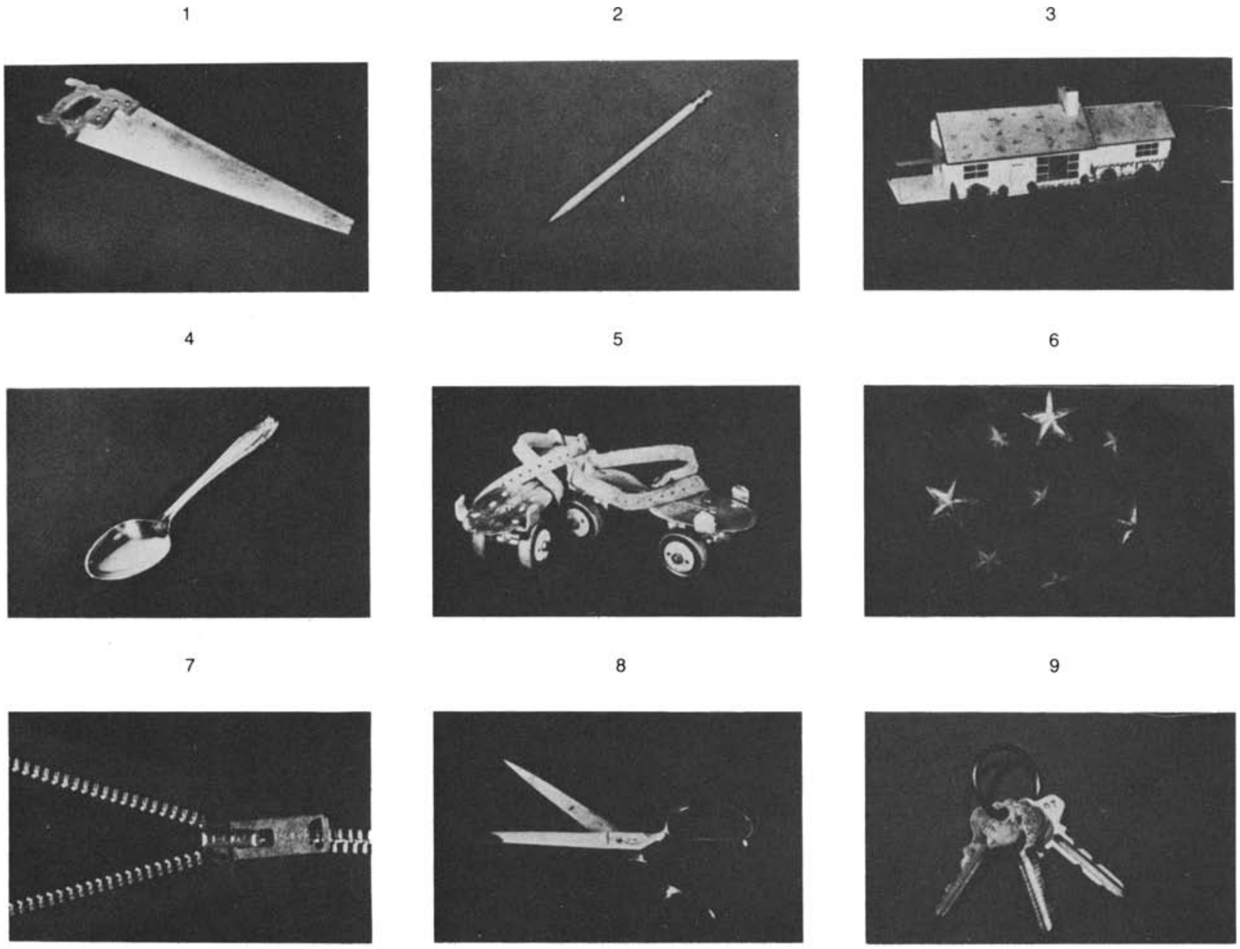

FIGURE 1. A screened photograph of the first nine-item page in the Photo Articulation Test, First Edition [Pendergast, Dickey, Selmar, & Soder (1969)].

graphics and the computer prompt (a frame around the current stimulus; see Appendix) were revised for clarity, and a display was added to let children know how many items remained to complete the task. For Study III, all stimuli were presented first in the 1/4 screen size, then in full-screen size either to evoke correct identification spontaneously or to evoke an imitative response. To assess articulation correctness, picture identification, and motivational issues in each of the three studies, testing involved the usual process of attempts to evoke word naming spontaneously, then with cues and finally, if necessary, by imitation.

Subjects

Subjects for the three studies were 21 preschool children with moderate to severe speech delays. The children had previously been enrolled in a university-affiliated phonology clinic and were in either their first or second week of management in a new academic semester with a new student clinician. Of the 21 children, 16 were randomly assigned to either Study I or Study II, and an additional 8 were available for Study III, which was conducted the following semester. One child originally scheduled for Study II was not testable within the protocol, and the data for two children tested in Study III could not be used because of technical problems. Ten of the 21 children had been given the booklet version of the PAT in a previous semester.

Subject information is provided in Table 1. All of the children were from middle-class socioeconomic backgrounds and, with the exception of two children with repaired clefts of the palate (Study I, Subject 4; Study II, Subject 2) and one with Down's syndrome (Study II, Subject 7), were without major speech-hearing mechanism, cognitive-linguistic, or psychosocial deficits. The average ages (years:months) respectively, for the children in Studies I, II, and III were 4:3, 4:2, and 4:3 (average age for Study II was calculated on six of the seven children, excluding the 10-year-old Down's syndrome child). Speech status was calculated from the most recent Percentage of Consonants Correct data from a continuous speech sample (Shriberg & Kwiatkowski, 1982); for 6 subjects distributed across the three studies, speech status was estimated by the child's current clinical supervisor. Language comprehension status reflects the adjec-

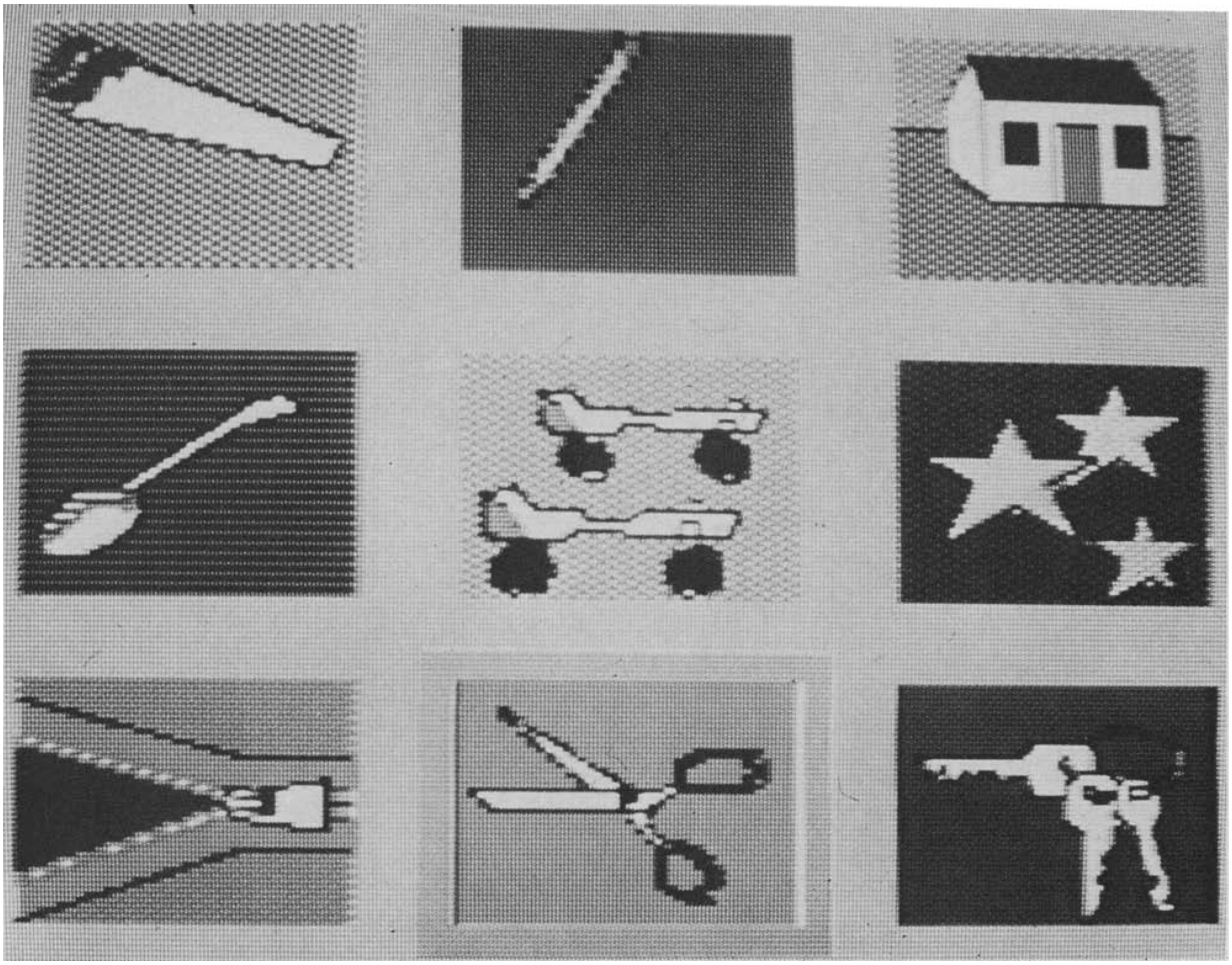

FIGURE 2. A screened photograph (taken from a color monitor) of the first nine items of the microcomputer PAT stimuli.

tive-range percentile equivalents taken from the most recent Peabody Picture Vocabulary Test (Dunn & Dunn, 1981); for 4 subjects distributed across the three studies, language comprehension status was estimated by the child's current clinical supervisor.

Test Procedures

Nine student clinicians and the second author (9 women, 1 man) each tested one to three children in one of the three studies. In each study, the examiner followed a scripted test protocol (see Appendix) that included administration procedures and strategies for handling all on-task and off-task behaviors. Examiners were tutored in the test protocols and in the operation of the computer program. They then practiced administering their assigned protocol in both the booklet and computer models. Explicit directions and training attempted to ensure that booklet versus minicomputer test modes (Studies I and II) were comparable, except for the graphic stimuli.

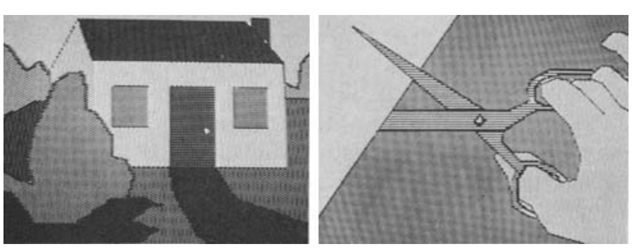

FIGURE 3. Screened photographs (taken from a color monitor) of two enhanced items in the microcomputer PAT stimuli.

Children in Studies I and II were randomly counterbalanced for either booklet or computer mode for the first test session. A retest session in the alternative version was held 1–2 weeks later with the same clinician, at the same appointment time, and in the same test suite. Children in Study III were tested on only one occasion and only in the revised computer mode. The purpose of Study III was to assess the effects of revisions of the computer PAT on all dependent variables (see Appendix). Marantz Superscope audiocassette recorders with matching Sony EC-3 microphones and TDK audiocassettes were used to record test sessions. Lip-to-microphone distance was monitored at approximately 15 cm.

TABLE 1. Descriptive data for 21 subjects in three studies of booklet- versus computer-presented pictures. See text for description of speech and language measures.

				Speech status				*Language status*				
Study	*Subject*	*Sex*	*Age (mos.)*	*Severe*	*Moderate-severe*	*Mild-moderate*	*Mild*	*Extremely low*	*Low average*	*Average*	*High average*	*Extremely high*
I	1	M	35	X						X		
	2	M	41			X					X	
	3	M	58		X						X	
	4	M	60			X					X	
	5	M	60		X				X			
	6	F	45		X					X		
	7	F	45			X					X	
	8	F	64			X						X
II	1	M	37	X						X		
	2	M	38		X			X				
	3	M	39		X						X	
	4	M	62		X					X		
	5	F	61			X			X			
	6	F	62			X					X	
	7	F	120		X			X				
III	1	M	40		X				X			
	2	M	45		X				X			
	3	M	48		X						X	
	4	M	51		X				X			
	5	M	56			X				X		
	6	F	63		X					X		

Observation windows allowed one of the authors to observe test sessions.

Scoring Procedures

The 30 audiocassettes for Studies I and II were scored by consensus by the first two authors, using traditional categories of *correct, deletion, substitution,* or *distortion* for the target consonant(s). Items on which examiners disagreed in their independent scoring were replayed to resolve differences. Differences averaged less than 10% of items per test administration. Most disagreements involved substitution versus distortion errors, which were generally resolved by discussion in favor of distortion. The six samples from Study III were scored by the second author using the same categories.

As the articulation data were scored, data were also kept on total administration time, on the occurrence of examiner prompts and reinforcers, and on children's behaviors during testing. Criteria and conventions for classifying behaviors were developed as each behavior occurred on the audiotapes. Examiner prompts included prompting the child to move on to the naming of the next picture, calling the child's attention to the "box" in the computer version (i.e., attention to the framed prompt), directing the child to "slow down," directing the child to just name the picture and not routinely comment about it, and indicating to the child that there were only a few more pictures to come. Noncontingent examiner reinforcers included socials (e.g., "good," "nice job," "you know how to do this," etc.), tangibles [e.g., use of small tokens or displaying the progress bar (Study III) after several responses or page completion], or mention of secondary reinforcers (e.g., reminding the child that there are some other interesting things to do when all pictures have been named). Off-task child behaviors, for the purposes of these studies, included being asked to hold hands down, being asked to talk louder or softer, yawning, comments about pictures, comments about computers, repeating words unnecessarily, pushing the computer keys too forcefully, comments about the length of the task (e.g., "when will we finish"), moving too close to the pictured stimuli, being asked to listen to the modeled word, and being asked to "stop messing around."

Test-retest reliability by consensus (first two authors) was completed 2–4 months after original scoring dates on a randomly selected 15% sample of responses drawn to represent conditions and children across all three studies. Rescoring of the articulation responses from five children yielded an average retest item agreement of 89%; average retest agreement for classification of examiner and child behaviors was 95%.

RESULTS AND DISCUSSION

For Studies I and II, analyses of variance with an order factor and repeated measures on the test mode factor (booklet versus microcomputer) were run on nine dependent variables. All percentage data were first arcsine transformed; statistical significance for study-wise F tests was set at an alpha level of .05. For Study III, in which subjects had not been randomly assigned and were tested only in the computer mode, comparative descriptive data are presented on relevant dependent variables.

Order Effects and Interactions

Order of test administration was not a significant main effect in either Study I or Study II, but two significant Mode × Order effects were obtained. In Study I, significantly more verbal reinforcers were used when the computer version was given in the second test session [$F(1,7) = 27.25$; $p < .05$]. This variable assessed the proportion of noncontingent verbal reinforcers (e.g., "You're doing a good job.") clinicians used in each mode. The assumption was that an increased frequency of such responses reflects clinician concern that a child is experiencing lack of success in picture naming. For the first trials in Study II, spontaneously correct picture naming of booklet pictures was significantly higher on the first trial when the booklet version was given in the second test session [$F(1,5) = 8.63$; $p < .05$]. Each of these two interactions is consistent with the results of main effects for test mode discussed next. Because some of the computer-presented graphics will be shown to have been more difficult to identify, children may have experienced more frustration when they received the computer version in the second session. In contrast, the experience of having had the more difficult computer version in the first session may have enhanced the picture naming task during the subsequent booklet-presented session.

Booklet Mode Versus Computer Mode

Articulation scores. The three panels in Figure 4 present the group means for the percentage of consonants articulated correctly in each of the three studies. Percentages were used because the number of stimulus items presented ranged from 70–75 in Studies I and II due to minor examiner errors. Mode of stimulus presentation (booklet versus microcomputer) clearly did not affect children's articulation scores in Study I, $F(1,7) = <1.00$, $p > .05$, or Study II, $F(1,6) = <1.00$, $p > .05$. Descriptively, children in Study II were less proficient speakers than children in Study I (see Table 1, speech and language

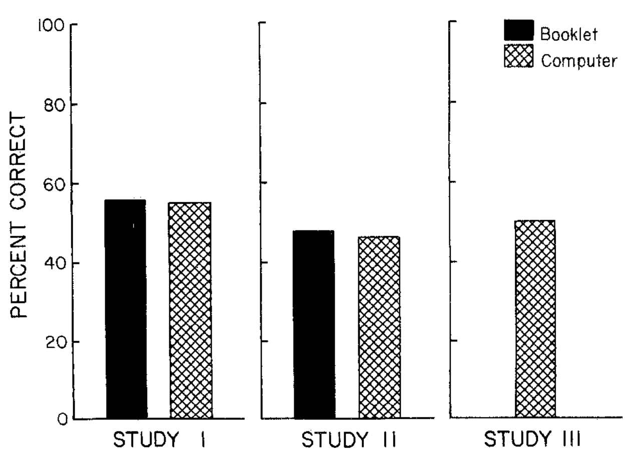

FIGURE 4. Percentage of consonants articulated correctly in each test mode in Studies I, II, and III.

data). The mean and standard deviation for Study III children, who were tested only in the computer mode, were comparable to the articulation scores obtained in the other two studies. Comparative analysis of the error type categories in each assessment mode in Studies I and II also yielded comparable results. Differences in item-by-item tallies of error types (i.e., deletions, substitutions, distortions) averaged only 4%, with a range of 0% to 10% difference in the 45 between-mode comparisons (15 children × 3 error classes).

These several analyses indicate that whether pictures were named spontaneously or, when necessary, by imitation (see next section), the two modes of stimulus presentation were not associated with clinically or statistically significant differences in the number or type of articulation errors.

Picture identification. The three panels in Figure 5 are graphs of the picture identification data in each of the three studies. The bars in Figure 5 indicate mean performance on successive trials in each protocol, with trials differing by the types of examiner prompts and whether the small, 1/4 screen or full-screen graphics were shown in the computer modes.

Data for the first trial in both Studies I and II indicate that significantly more pictures were identified in the nine-item per page booklet format than in the comparable nine-item computer format [Study I: $F(1,7) = 35.43$, $p < .05$; Study II: $F(1,6) = 230.11$, $p < .05$]. The mean percentages of correct identification for the booklet version in both studies, approximately 84% and 76% respectively, are somewhat lower than averages of above 90% for PAT stimuli reported by Harrington, Lux, and Higgings (1984) for 21 3- to 5-year-old children with normal speech. The somewhat lowered identification scores of the present children in the booklet version may be a result of associated lexical problems in some speech-delayed children, differences in scoring criteria, or sampling error associated with small samples. Several efforts to understand why even fewer of the computer graphics were correctly identified in the three studies (means of 66%, 63%, 72%, respectively), will be discussed shortly. As shown in Figure 5, the mean performance of approximately 72% by children in Study III—in which the graphics had been redrawn as required and shown in the medium-sized version for the first trial—was still somewhat lower than identification scores for booklet-presented stimuli in Studies I and II and lower than the above-90%-correct scores reported both by Harrington, Lux, and Higgings (1984) and by Pendergast et al. (1969).

Graphed data in Figure 5 for additional trials in Studies I, II, and III show the usefulness of the computer for evoking correct picture identification after an initial unsuccessful trial. Because the total number of successive trials was dependent on correct identification in previous trials, adjusted percentage figures were used in all calculations. In Study I and Study II, the second trial data reflect the spontaneous attempts by children to identify correctly a picture in the nine-item format after an initial unsuccessful trial. As shown in the crossed-hatched bars, few of them were successful. In Study I, successful

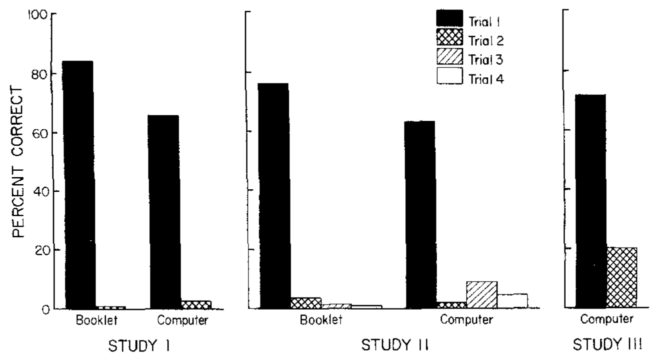

FIGURE 5. Percentage of pictures identified correctly in each test mode in Studies I, II, and III. See text and Appendix for description of trial conditions in each study.

identifications averaged less than 3% in both booklet and computer modes; the difference between modes was nonsignificant, $F(1,7) = <1.00$, $p > .05$. Study II attempts averaged less than 4% in both modes; the difference between modes also was nonsignificant, $F(1,6) = 2.05$, $p > .05$. For the third trials in Study II, the examiner specifically asked children to "try again" in both the booklet and computer modes. In the computer mode, the clinician also advanced to the 1/4 screen graphic. Statistical analysis of correct picture identifications yielded a significant difference, $F(1,6) = 16.97$, $p < .05$, with an average of 1.4% successful identifications in the booklet mode and 8.9% in the computer mode.

Finally, if there was need for a fourth trial in Study II, clinicians in both modes provided the child with a verbal prompt that gave added semantic information, such as "You use it to ________ ." In the computer mode, clinicians also advanced the computer to the full-screen graphic. Obtained gains were below 5% in each mode; differences in mean scores could not be tested statistically because of inadequate cell sizes.

These data suggest that the clarity of the pictures was the critical variable. Even with strong semantic prompts, children were unable to identify correctly certain pictured stimuli. This interpretation is supported by data for the second trials in Study III. Recall that the first trial involved the revised graphics presented in the 1/4 screen format, which alone resulted in a higher average percentage of correct picture identifications than obtained in the computer modes in Studies I and II. For the second trial in Study III, the examiner advanced from the 1/4 screen graphic to the full-screen, enhanced graphic and specifically asked the child to "try again." As shown in Figure 5, correct picture identification occurred on an additional 20.1% of trials, a sizable increase in relation to data for all other additional trials in Study I and Study II, although the reliability of differences could not be assessed statistically.

Table 2 is a summary of an analysis of the misidentification data in the three studies. Extending an analysis approach used in Harrington, Lux, and Higgings (1984), children's incorrect picture identifications on the first trial were divided into the following error types: *Part Word* (e.g., "brush" for "toothbrush"); *Action-Related Word* (e.g., "cut" for "scissors," "teeth" for "toothbrush"); *Visually Related Word* [e.g., "bunnies" for "angels" (where wings on the angel picture might be perceived as large ears)]; *Semantically Related Words* (e.g., "chair" for "table," "animal" for "dog"); *Novel Word,* which was any intelligible word not included in the four preceding categories; and *Unintelligible Word,* where a word production was completely unintelligible and could not reliably be assumed to be the correct word. The percentage of occurrences of each of these six response types (nonresponses were excluded) in booklet and computer modes suggests the following observations.

First, comparison of the data in the first and second rows in Table 2 indicates that picture identification was highly individualized across these preschool, speech-delayed children. Although from 38% to 71% of the pictures were misidentified by at least one of the children in the three studies (first row) only 7% to 43% of the pictures were misidentified by more than half of the children in any one study (second row).

A second observation concerns the relative stability of occurrence of error types labeled *Action-Related Words* and *Semantically Related Words* across studies and test modes. These two categories combine in approximately equal percentages to account for approximately 50% of misidentification errors in both booklet and computer modes. Computer graphics did not differ from booklet photographs in evoking these high percentages of linguistically based misidentifications from this sample of speech-delayed children.

The third observation concerns an interesting and possibly reciprocal relationship between the categories *Visually Related Words* and *Novel Word* misidentification categories for children in the three studies. Children in Study II, who were the most speech-language delayed and the poorest overall in picture identification, had a substantially high percentage (51%) of *Visually Related* misidentifications in the computer mode. In contrast, children in Studies I and III had relatively higher percentages of *Novel Word* misidentifications (50% and 42%, respectively) in the computer modes. These differences in error types among groups supports previous discussion of the complex mapping operations in picture identification tasks (Jolicoer, Gluck, & Kosslyn, 1984). Children with less well-developed lexicons may focus on specific context clues to aid identification, whereas children with more well-developed lexicons may arrive at completely novel words owing to their richer visual-semantic store.

A fourth observation is based on the intelligibility data in the last row of Table 2. The high percentage of error responses classed as *Unintelligible* indicates that young speech-delayed children present assessment difficulties even in word-level, controlled evocation procedures. In comparison to children in the other two groups, the misidentifications of the more severely involved Study II children were frequently a result of their responses being embedded in unintelligible utterances in both booklet (49%) and computer (74%) modes.

To review findings to this point, the first trial performance data in the three studies indicate that computer

TABLE 2. Summary of identification error analysis on the first trial for 69 pictured stimuli in the three studies.

	Percentage of misidentified words				
	Booklet mode		*Computer mode*		
Error category	*Study I*	*Study II*	*Study I*	*Study II*	*Study III*
Percentage overall					
Words misidentified at least once	38	71	50	62	52
Words misidentified by at least half of the subjects[a]	7	19	36	43	13
Percentage by error type[b]					
Part word	0	0	3	2	3
Action-related word	27	37	21	37	28
Visually related word	15	10	21	51	28
Semantically related word	23	23	27	28	17
Novel word	23	6	50	19	42
Unintelligible word	15	49	32	74	31

[a]Four or more children in Studies I and II; three or more children in Study III.
[b]Percentages based on numbers of misidentified words in each study. Column totals do not sum to 100 because words may have been misidentified in more than one error-type category.

graphics did not affect the percentage of sounds articulated correctly, but that picture identification scores were significantly higher in the nine-item booklet format. However, enhanced computer graphics (larger pictures and more detail) were associated with significantly more successful picture identifications in subsequent trials (Studies I and II) and were successfully revised for higher first trial and second trial identifications in Study III.

Efficiency comparisons. The consequences of incorrect spontaneous picture identification for the efficiency of testing and hence for validity concerns (poor performance resulting from fatigue, disinterest, etc.) are shown in Figure 6. It took significantly longer to administer completely the computer version than the booklet version in both studies [Study I: $F(1,7) = 29.57$, $p < .05$; Study II: $F(1,5) = 13.69$, $p < .05$]. Descriptive data for Study III include the additional time for the imitative trials on each

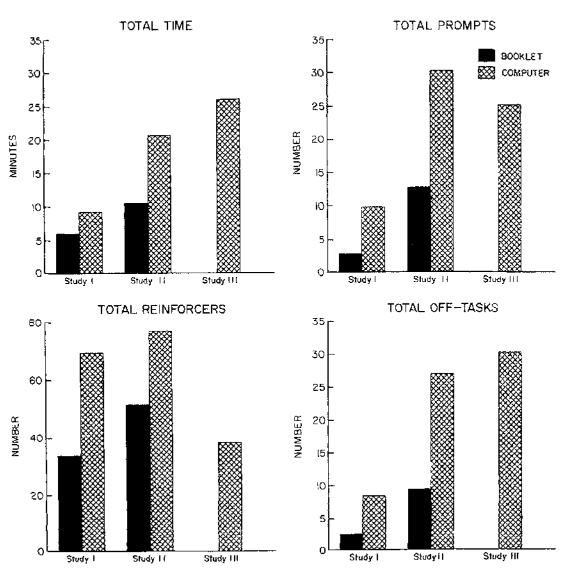

FIGURE 6. Efficiency data for booklet and computer modes in Studies I, II, and III.

word and the time consumed by showing the progress bar whenever the examiner felt it was necessary or whenever the child requested it (see Appendix). A target administration time is suggested by Pendergast et al. (1969) who report that even young children can successfully complete the booklet PAT in 5 min or less (which requires a brisk 14–15 words per minute).

As shown in the remaining panels in Figure 6, increased administration time was associated with several examiner and child behaviors. Examiners used significantly more prompts for picture identification in one of the two computer mode studies [Study I: $F(1,7) = 2.27$, $p > .05$; Study II: $F(1,6) = 8.18$, $p < .05$] and significantly more verbal reinforcers in the computer modes in both studies [Study I: $F(1,7) = 47.84$, $p <. 05$; Study II: $F(1,6) = 12.94$, $p < .01$]. There also was a trend for a higher occurrence of off-task behaviors by the children in the computer modes in one of the studies [Study I: $F(1,7) = 5.57$, $p > .05$; Study II: $F(1,6) = 8.97$, $p < .05$]. In Study III, off-task behaviors continued to be high. The most frequent type of off-task behavior in all studies was a comment about the picture, with other high frequency behaviors being unsolicited word repetitions, comments about the computer, or asking when the test would be over. Not all such behaviors are undesirable, of course, but they do consume clinical time.

Although the evident novelty associated with computer procedures was one source contributing to the obtained time differences (see next section), these efficiency data essentially reflect the difficulties that result when children cannot spontaneously identify a series of pictures. The validity of the performance data becomes questionable as the testing situation becomes tedious for both examiner and child. Off-task behaviors increase as children anticipate continued lack of success and as they become distracted and irritable. As noted by Madison, Kolbeck, and Walker (1982), vocabulary selection and visual presentation are the primary variables associated with failure when stimuli are not readily identified (see also discussion by Whitehead & Mullen, 1975). In the present context, because the vocabulary was held constant, differences in visual presentation are assumed to account for the children's difficulties in identifying the stimuli in Studies I and II. These efficiency findings, as they pertain to the microcomputer environment, are elaborated in the following discussion of the 10 cinicians' impressions.

Clinician Impressions

An item analysis of the diary impressions of all clinicians in the three studies was performed by sorting their anecdotal comments about test sessions into categories termed "generally positive" and "generally negative." The statements were then inspected for commonalities and tallied by topic. These qualitative data, which are summarized in Table 3, parallel the quantitative findings just reviewed. Overall, the positive and negative aspects of computer-presented stimuli highlight the importance of attention to graphic and procedural details. The children seemed to be more engaged overall in the computer mode, but technical problems in the graphics and the cueing and reinforcement systems impeded their initial disposition to "play the game." Despite repeated instructions and demonstrations (see Appendix), some children seemed unable to follow the framed prompt or to learn in the time provided which of the few keys they were optionally allowed to press. The data in Studies I and II suggest that if a young, speech-delayed child is to interact with a computer, he or she must understand the task and be engaged by either the procedural or substantive content.

Clinicians' comments after Study III suggested that three program changes were associated with notable gains in children's behavior. First, as described, the revised pictures were more often correctly identified on the first and second trials than in Studies I and II. Even slight increases in the percentage of correct picture naming may have provided a more favorable variable ratio

TABLE 3. Summary of 10 clinicians' written impressions of children's responses in the booklet and computer test modes.

Comment type	Studies I and II Booklet	Studies I and II Computer	Study III Computer
Positive	Smooth, efficient administration	No difficulty with administration	Distractible child, yet stayed with task
	Turning pages a sufficient reinforcer	Child was motivated by pushing the screen change button	Very attentive to the pictures
	Good cooperation	Seemed to enjoy game; was motivated	Seemed to really like pressing the bar to advance picture
	Children named nearly every picture correctly	Needed only social reinforcers	Childeren were "into" the task; did not need the progress indicator bar
		Seemed "amazed," "caught up" with computer pictures	Progress bar was very reinforcing
			Would return to task after the progress bar with no further comment needed
Negative	Needed frequent reminders to respond when examiner pointed	Box prompt too subtle contrast with background	Appeared disinterested during the entire task
	Lost interest in turning pages	Didn't understand left to right sequencing of box prompt; difficulty tracking movement	Repeatedly asked whose turn it was to press button
	Not greatly interested or excited about activity	Children didn't recognize pictures because too small, too "blurry" or otherwise too hard to identify	Did not seem to attend to blinking stimulus cue
		Children wanted to press advance button too often, hold it down too long; gazed at it rather than screen	Had trouble understanding the sequence of operations
		Children may be "stalling" so they could get to see the large size picture	Never learned to press the bar to get larger picture
			Repeatedly asked for progress bar

schedule of self-perceived successes, which resulted in better task persistence. Second, when the framed prompt was made more salient (different colors), children more reliably performed their picture naming task. Finally, when they were provided a cumulative display of how many trials they had completed relative to the total needed (which was available by key press any time the child desired to see it), all children's motivation to complete the task appeared to be enhanced significantly. The children in Study III ranged from attentive and compliant to distractible and noncompliant, yet all completed the task even though some took a relatively long time. An observation was that the children seemed to feel that the computer "required" that they finish the task (i.e., completely fill the progress bar). Therefore, the revised computer version may have been successful in motivating children to stay with the task, while yielding only limited improvements in picture identification scores (Figure 5). Much of the difficulty facing clinicians who work intensively on speech production behaviors with young children involves this general problem of obtaining sustained effort during repeated trials of word-level speech targets.

CONCLUSIONS

These studies have attempted to investigate some methodological issues associated with the entry of microcomputers into the speech-language clinic. Using the articulation test as a convenient paradigm for comparative study, several facets of the client-clinician-computer interface have been explored. For their possible value as stimuli for future study, the following summary conclusions are offered.

First, computer-presented graphics can be used successfully to evoke spontaneous naming from even severely speech-delayed children. By means of interactive prompting and reinforcement devices, computer graphics may have certain control advantages over hard-copy materials as they allow the examiner more readily to evoke repeated trials for citation-form testing. Graphics will need to be fully tested and redrawn as required to ensure their ready perception and identification by the widest number of children from the population of interest. Although technical innovations in both software and hardware for graphics display will undoubtedly provide higher resolution (much as progress continues in the quality of synthetic speech), the successful implementation of complex visual stimuli in the clinic may require skilled artistic and programming support.

Second, assessment and management software that allows for interactive client participation has considerable potential. However, individual differences in the cognitive abilities of young children present special problems in design of the child-machine interface. As observed in the present study, even simple keyboard sequences used for game activities may not easily be understood or performed by speech-language involved children. In this regard, much of the "off-the-shelf" educational software may be unsuitable in form as well as content.

Finally, assessment and management software that tightly programs both the contingent and noncontingent reinforcement for children's verbal responses may fail to meet individual differences in children's affective needs. As observed in the variety of schedules of noncontingent reinforcers used by clinicians in the present study, the competent clinician appears to be monitoring many levels of children's performance. Programs that do not allow and encourage the clinician to respond to perceived affective needs may fail to engage and sustain the child's attention. In contrast, programs that provide for clinician-mediated knowledge of results and reinforcement appear to have the potential to become effective tools in the art and science of clinical intervention.

ACKNOWLEDGMENTS

We are grateful to the authors of the Photo Articulation Test and to the Interstate Publishers and Printers, Inc., Danville, Illinois, for permission to use PAT materials in this study. Thanks are also extended to the clinicians who so effectively participated in the three studies: Mark Aschenbrenner, Deborah Brauer, Maria Cavicchio, Caryn Conlin, Cheryl Felmus, Jennifer Hyland, Susan Rohe, Catherine Ross, and Gloria Straight. We thank Joel R. Levin for his always informative statistical consultation and Patty Engebose, Lee Fixmer, Pam Hughes, Maureen McGowan, and Carol Widder for their competent research and editorial assistance. Finally, we appreciate the excellent editorial suggestions of Carla Dunn, Laurence Leonard, and an anonymous reviewer. These studies were supported by a Field-Initiated Research Grant from the United States Department of Education, Research in Education of the Handicapped Program, No. G008400633.

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Received March 3, 1986
Accepted March 3, 1986

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APPENDIX

PROTOCOLS FOR STUDIES I, II, AND III

I. General Information

A. List of Computer Function Keys

KEY	FUNCTION
ESC	Displays a screen of all keys and function
1	Displays PAT pictures one by one
9	Displays PAT pictures page by page
→	Displays next picture
←	Displays previous picture
↓	Displays next page
↑	Displays previous page
OPEN APPLE	Displays the blinking frame (i.e., the "please repeat" signal)
CLOSED APPLE	Displays the progress marker box
RETURN	Saves the picture and repeats it following administration of the entire PAT. Pictures are repeated one at a time when the (→) key is pressed
SPACE BAR	Displays the enhanced version of the current picture

B. General Instructions to Examiners

1. Tape-record the entire administration of the PAT including the directions at the beginning and the child's comments on the task at the end.
2. Use minimal verbalization throughout the task.
3. Some of the items on the PAT are administered only in imitation. Included are *beige, measure,* and *bathe.* Other words may be obtainable spontaneously when the child is given a verbal prompt.
   These include:
   THIS or THAT: After the child labels the picture of *feathers* ask the child, "Which feather do you like the best?" If the child points, say, "Tell me."
   YES: Ask the child, "Do you like ice cream?" If the child conveys "yes" but does not say some form of the word, say, "Tell me yes or no."
   THANK YOU: Following the "yes" response, say, "What do you say when Mom gives you ice cream?" If the child says, "please," ask, "And then what do you say?"
4. (Study III only) Save pictures that the child does not name spontaneously by pressing the RETURN key. Re-administer these items at the end of the administration of the PAT. Use the same procedures as during the initial administration.

II. Examiner Protocols

Study I

Protocol Element	*Booklet Version*	*Computer Version*
Introducing the task to the child	Have the PAT booklet open to the title page, on the table in front of the child's chair when he/she enters the room. Turn to the first page of pictures and say, "We're going to look at some pictures. I'll point to a picture and you tell me what it is. When we're done looking at all the pictures on the page, you can turn the page."	Have the "HELP" screen of computer version of the PAT on the screen, and the child's chair in front of the terminal when the child enters the room. Make no mention of the use of a computer. Press the "new page" key on the terminal to reveal the first page of pictures and say, "We're going to look at some pictures. I'll put a box around a picture, and you tell me what the picture is. When we're done looking at all the pictures on the screen you can press this button and change the screen."
	Point to the first picture and say, "What's this?" After the child responds, point to the second picture, but do not say, "What's this?" Beginning with the second picture, use the prompt, "What's this?" only to prompt the child to name the picture as needed and not as part of the administration routine.	Direct the child's attention to the first boxed picture and say, "What's this?" After the child responds, box the second picture, but do not say, "What's this?" Beginning with the second picture, use the prompt, "What's this?" only to prompt the child to name the picture as needed and not as part of the administration routine.
If the child does not name the picture because he/she does not know what it is	Identify the picture and have the child imitate the word. Say, "that's (*label*)." If the child does not immediately, spontaneously imitate the label, say, "Tell me (*label*)."	Same as Booklet
If the child comments on a picture or initiates a topic unrelated to the PAT picture	Acknowledge the child's comment in some interested way and immediately present the next stimulus word. For example if the child says, "My dad's gonna make me a tree house," you could say, "That sounds great," and then move on to the next PAT picture. If the child makes another comment about the same topic, acknowledge the topic and your interest in it and indicate that it can be pursued later. For example you could say, "I want to hear all about your tree house. Let's talk about it after we're done naming all my pictures."	Same as Booklet
Reinforcing the child	Reinforce the child however and whenever you feel it is necessary for naming the pictures, for looking at the pictures, for sitting in his/her chair, for attending, etc.	Same as Booklet
If the child is inattentive or nonresponsive for any reason other than he/she does not know the picture	Do whatever you think is necessary to motivate the child to attend and respond. For example, you may need to use some type of tangible reinforcer such as earning bristle blocks, pegs, fruit loops, etc., for each picture named, or each row of pictures, or each page of pictures named.	Same as Booklet

Study II

Protocol Element	*Booklet Version*	*Computer Version*
Introducing the task to the child	Same as Study I	Same as Study I
If the child does not name the picture because he/she does not know what it is	First encourage the child to think about the picture. Say, "Look at it again; maybe you'll know what it is."	Press the advance key to go from the small grouped picture version to the individual medium-sized picture and say, "Look at it again; maybe you'll know what it is."
	If the child cannot identify the picture, provide a verbal prompt. If you had to prompt this word in the computer version administration, use exactly the same prompt.	If the child cannot identify the picture, press the advance key to reveal the full screen version and provide a verbal prompt. If you had to prompt this word in the booklet version administration, use exactly the same prompt.
	If the child still cannot identify the picture, label the picture for the child to imitate. Say, "That's (*label*)." If the child does not immediately spontaneously imitate the label, say, "Tell me (*label*)."	If the child still cannot identify the picture, label the picture for the child to imitate. Say, "That's (*label*)." If the child does not spontaneously imitate the label, say, "Tell me (*label*)."
If the child comments on a picture or initiates a topic unrelated to the PAT picture	Same as Study I, III	Same as Study I, III
Reinforcing the child	Same as Study I, III	Same as Study I, III
If the child is inattentive or nonresponsive for any reason other than he/she does not know the picture	Same as Study I, III	Same as Study I, III

Protocol Element	*Study III: Computer*
Introducing the task to the child	Have the medium-sized version of the first stimulus word on the screen and the child's chair in front of the terminal when the child enters the room. Say, "Look what I have for us to use today—a computer." Seat the child at least 20 inches from the computer monitor. After the child is settled in front of the computer, say "I have lots of pictures to show you. We can take turns naming them. First I'll show you a little picture, and you tell me what it is." Have the child name the picture and then say, "Then we can press this bar one time to see a big picture of the same thing." Press the bar and say, "It's my turn to say the word—(*saw*)." Press the (OPEN APPLE) to obtain the repeat signal. Say, "Then I'll make the picture blink, and you say the word again. Let's try it." Press the (OPEN APPLE) to obtain the repeat signal and have the child repeat the word. Then press the (→) key to move to the medium-sized version of the second stimulus word. Say, "Let's see if you know how to play my game. I show you a little picture, and. . ." Wait briefly to give the child time to respond, because he/she may already know what to do. If the child responds, acknowledge the response. If the child does not respond, say ". . .you tell me what it is." After the child names the picture, say, "Then we'll press the bar and see the big picture." Press the bar to reveal the large, enhanced version of the picture. From this point on, you or the child can press the bar to reveal the enhanced picture. Say, "Then I say the word—(*pencil*). Then I make the picture blink (press the OPEN APPLE) and. . ." Wait briefly to give the child time to respond because he/she may already know what to do. If the child responds, acknowledge the response. If the child does not respond, say, ". . .you say the word again." Have the child say the word. Then say, "Okay, you're learning how to play my game. Before we start, let me show you one more thing in my game." Press the (CLOSED APPLE) and say, "Here is a special box. The box tells us how many more pictures we have to look at. Right now there is only a little bit of red inside the box. That's because we only looked at two pictures. When the inside of the box is all red we're done looking at my pictures. During my picture naming game we can look at this box sometimes to see how many more pictures we need to name."
Beginning the task	Say, "Okay, let's play my picture naming game." If the child gave an acceptable spontaneous and imitated trial during the practice items, accept these as test items and press (→) to move to the next picture (Picture 3). If the child did not give an acceptable spontaneous and imitated trial during the practice items, press (←) to return to the medium-sized version of the first stimulus word.
If the child does not immediately name the picture because he/she does not recall what he/she is to do	Point to the picture and say, "What's this?" Use this prompt only as needed and not as a part of the administration routine. Signal that you are saving the picture by saying, "Let's save that one."
If the child mislabels the picture	If the picture is truly mislabeled, say, "It looks kind of like (*child's label*). Can you think of another idea? Let's look at the big picture." If the child still does not correctly name the picture or fails to name it at all, move on to the imitation trial. Before moving on to the next stimulus picture, press (RETURN) in order to save the current picture for display (after all the PAT items have been administered) to potentially obtain a spontaneous level production. Signal that you are saving the picture by saying, "Let's save that one."
If the child does not name the picture within seconds because he/she does not know what it is	Say, "That's a hard one to see. Let's look at the big picture." If the child still does not label the picture or mislabels it, move on to the imitation trial. Before moving on to the next stimulus picture, press (RETURN) in order to save the current picture for display after all the PAT items have been administered to potentially obtain a spontaneous level production.
Marking progress through the task	Periodically (as often as you feel it is necessary) press the (CLOSED APPLE) to reveal the box that marks progress through the task. Call the child's attention to the "red in the box" in whatever ways you judge are appropriate to the child and to the situation. Unless more frequent presentation is needed, present the progress bar approximately once every nine items.

Protocol Element	*Study III: Computer*
If the child comments on a picture or initiates a topic unrelated to the PAT picture	Same as Study I, II
If the child is inattentive or nonresponsive for any reason other than he/she does not know the picture	Same as Study I, II
Reinforcing the child	Same as Study I, II

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