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Enhancing vocal imitations in children with autism using the IBM SpeechViewer

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ABSTRACT This experiment compared the effect of computerized visual feedback (computer assisted instruction) with traditional play interaction (personal instruction) in promoting vocal imitation in children with autism. Ten non-verbal children with autism participated in ten sessions. Each session was composed of four sections: a parent and a trainer interacted with the child on the computer or using play interactions. The study was conducted as a simultaneous treatment design and the sequence of experimental conditions was randomized across sessions. Participants showed significantly greater vocal imitations in the computer assisted instruction condition, compared with the personal instruction condition. This trend was present in nine out of ten children. Vocal imitations increased across the sessions, with greater increments in the computer assisted instruction condition. These effects were consistent across both parent and trainer.

KEYWORDS *autism; communication; computer assisted instruction; SpeechViewer; vocal imitations*

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Introduction

Deficits and problems of communication are a core component of the diagnosis and treatment of children with autism (Waterhouse et al., 1996; American Psychiatric Association, 1994). Since a third of all children with autism fail to develop speech, non-verbal communication systems such as hand-signs, pictures or word-cards serve as alternatives (Quill, 1997; Bondi and Frost, 1994; Schuler and Goetz, 1993; LaVigna, 1987). However, recent advances in computer technology have lately given hope to parents of non-verbal children who tend to favour speech over all other means of communication.

Many non-verbal children with autism show reduced vocal imitation rates, a restricted babbling repertoire, and deficient skills in imitating sounds (Stone et al., 1990). At the same time, these children frequently have better or even normal skills in visual discriminations. This is reflected in good performance in completing puzzles or remembering locations (Siegel et al., 1996). In these children, visuo-spatial skills dominate verbal skills to the extent of an average difference of 20 IQ points (Allen et al., 1991; Rutter, 1985). Thus, using computer generated visual feedback to guide the production of vocalizations in non-verbal children with autism is a promising avenue. Research supports the positive influence of vocal and verbal imitation on the enhancement of comprehension (Carr et al., 1984). While the influence of imitation training on spontaneous communication is still unclear, increasing the rate of vocal imitation within the context of a comprehensive communication training package could well be useful.

Computer based speech training has been effectively used with individuals with neurological impairments (Thomas-Stonell et al., 1991). For example, the IBM SpeechViewer system (IBM, 1988), employed by these researchers, provides visual feedback on sound productions, loudness and pitch. The SpeechViewer system has been used to train preschool children with phonological process errors. Parent-administered SpeechViewer training was effective in improving performance across sessions and was comparable to speech productivity achieved with trained clinicians (Ruscello et al., 1993).

Although the SpeechViewer program has not yet been systematically investigated with the autistic population, preliminary results with computer assisted instruction for children with autism have been encouraging. Computer instruction has been found to have positive effects on the attention and performance of children with autism (Pleinis and Romanczyk, 1983) as well as on social skills (Panyan et al., 1984). An enhancement of problem-solving skills among children with autism through a computer based learning environment has also been demonstrated (Jordan and Powell, 1990; Frost and Ed, 1987).

Our own research with children with autism has confirmed higher enthusiasm scores, better compliance and fewer behaviour problems in computer assisted instruction, compared with personal instruction. As far as learning rates are concerned, the results have been mixed. When comparing four participants with autism on tasks taken at random from their individual programme plan, enthusiasm rates and compliance were significantly higher in computer based training compared with personal instruction. For learning rates, only one out of four participants showed a clear positive trend (Chen and Bernard-Opitz, 1993).

Positive effects on the enhancement of speech through computer programs have been demonstrated by Colby (1973). Here children were exposed to games of varying complexity. In one game pressing the letter 'H' on a keyboard would make an 'H' appear on the screen with a voice saying 'H'. In another pressing 'H' would lead to a horse running across the screen with the sounds of the hoofs. Thirteen non-verbal children with autism began to use speech after playing with symbols on a computer. Heimann et al. (1995) and Tjus et al (1998) used a strategy comparable to Colby's, providing language learning through motivating multi-channel feedback (i.e. voice, animation and video). The selection of noun–verb–noun sequences led to corresponding animation (e.g. 'The bear', 'jumps over', 'the horse'). The authors reported that this program enhanced learning of language skills, reading skills and motivation in children with autism, children with mixed disabilities and normal preschoolers. The intervention succeeded in stimulating verbal expressions among children in the classroom.

The role of sensory reinforcers in improving response rates of children with autism is well known (Rincover et al., 1979). While the original experiments simulated autistic children's self-stimulation through simple mechanical devices such as windshield-wipers, recent developments in computer technology have broadened the range of sensory reinforcement. For example, compared with static stimuli, programs using dynamic stimuli elicited a significantly higher percentage of joystick manipulation (Bernard-Opitz et al., 1990).

As the SpeechViewer provides stimulating visual reinforcement upon production of sounds, its effect on the vocal imitation rate of non-verbal children with autism was assessed in the present study. We also investigated the comparative advantage of computer assisted instruction and personal instruction on vocal imitations. To assess the social validity of the results, the mothers were asked to rate the usefulness of both experimental conditions.

Method

Participants

Ten non-verbal children with autism (nine boys and one girl) participated in the study. All children were diagnosed using the Autism Behaviour Checklist (ABC: Krug et al., 1980) and reached the criterion of a score of 65 or above. The children ranged in age from 3 years to 7 years 3 months, with mental ages from 1 year 7 months to 5 years 3 months. Testing was based on either the Bayley Infant Developmental Scale (Bayley, 1969) or the Leiter International Performance Scale (Leiter, 1980). Children were

Table 1 **Non-verbal children's characteristics taken during pre-assessment**

Participant	*Sex*	*Age (years:months)*	*Adapted IQ*	*Mental age (years:months)*	*ABC score*	*Imitation: fewer than 5 sounds*
1	M	6:9	72	4:10	81	Yes
2	M	7:0	<30	1:8	66	Yes
3	M	7:0	<30	1:9	85	Yes
4	M	6:9	<30	1:7	69	Yes
5	M	6:5	31	2:0	83	Yes
6	F	5:5	102	5:6	65	No
7	M	5:5	97	5:3	70	No
8	M	7:3	30	2:0	77	No
9	M	7:3	43	3:1	81	No
10	M	3:0	128	4:11	65	No

selected based on their teachers' or parents' recommendations of suitability for vocal imitation training. Prior to the experiment all the children were able to understand and identify fewer than ten words. They were able to imitate simple actions such as clapping hands or tapping the table. Five participants could not imitate specific sounds, while the others attempted to vocalize sounds but did so inconsistently. Details of participants are provided in Table 1. Parents and the trainer were instructed in the procedures using written instructions, modelling and feedback.

Setting and apparatus

The experiment took place in the observation laboratory of the Department of Social Work and Psychology, in a large room with a computer set up at the children's eye-level for the computer assisted instruction condition. The SpeechViewer system converts sound productions into graphic displays, varying in colours, size or movements. Correct vocal imitations elicited immediate visual feedback (e.g. expanding balloon) on the monitor. The SpeechViewer subprograms are described in Table 2. A children's table was used for toy-play in the personal instruction condition. Sessions were conducted twice per week.

Procedure

Parents and the trainer modelled sounds in both computer assisted instruction and personal instruction conditions (see Table 2). They attempted to elicit these sounds for 5 minutes per session in both conditions. Children spent about 1 minute duration per subprogram of the SpeechViewer in the computer assisted instruction condition. A similar amount of time was spent during interaction games with various toys in

Table 2 **SpeechViewer subprograms**

Subprograms	*Descriptions*	*Target vocal imitations*
Sound awareness (kaleidoscope)	To enhance the awareness of sounds by demonstrating a relationship between the presence of sound and activity on the screen. The kaleidoscope display is active when the sound level exceeds a loudness threshold	'aaa' 'eee'
Loudness awareness (balloon)	To enhance the awareness of loudness by demonstrating a relationship between the loudness of a sound and activity on the screen. The size of the balloon in the screen image varies according to the loudness of the speech signal	'buh' 'ball' 'balloon'
Voicing onset awareness (train)	To increase awareness of voicing onset and to emphasize control over voicing. The display shows the train moving down the track for each onset of voicing. The station house at the bottom right of the screen is the goal	'tuh'
Vowel accuracy skill building (monkey)	To improve vowel production accuracy. A large monkey waits at the bottom of the tree. When a vowel is pronounced that exceeds the threshold, the monkey moves up the tree. It moves back to the ground if the vowel pronounced is below the threshold or if there is no sound	'aaa' 'eee'

Source: IBM (1988).

the personal instruction condition. Responses were scored as correct if they either corresponded to the modelled sound or approximated this sound. When a participant consistently made vocal imitations at an accuracy of 80 percent, new sounds were modelled.

Computer assisted instruction (CAI)

Prior to the experiment the children were familiarized with the SpeechViewer programs through both non-verbal (e.g. tapping the microphone) and vocal imitation games (e.g. babbling into the microphone). Throughout the procedure, the trainer/parent sat next to the child and controlled the microphone. If the child produced inappropriate sounds, such as screams or non-target vocalizations, the microphone was turned off. The CAI subprograms were presented in the following sequence: kaleidoscope, balloon, train, monkey, and back to the balloon. In each of the subprograms, initially a static picture was presented on screen. Next, the trainer/

parent requested attention to the screen and modelled a sound or word (e.g. 'buh' or 'ball'). In the beginning of each training interaction, approximations to the target were reinforced by praise and on-screen animation. Small edibles were sometimes given. As the session progressed, the trainer/parent set increasingly stringent criteria for reinforcement.

Personal instruction (PI)

Throughout the procedure, the trainer/parent and the child sat at a small table. The trainer/parent brought the child's attention to an attractive toy. Next, the trainer/parent modelled a sound or word (e.g. 'buh' or 'ball'). As in the CAI condition, small edibles were sometimes given. In the beginning of each training session, approximations to the target were reinforced by praise and play interaction (e.g. bouncing a ball). As the session progressed, increasingly stringent criteria for reinforcement were set.

An example for parent's/trainer's interaction exchanges with a child in the CAI and PI conditions is as follows:

CAI: Instructor says 'say buh' and points to the screen as a tiny balloon appears on screen. When the child responds correctly by saying/approximating 'buh', the balloon on the screen expands and the instructor praises the child.

PI: Instructor says 'say buh' and shows a ball. When the child responds correctly, the instructor bounces the ball on the table and praises the child.

In both the CAI and PI conditions, if the child failed to respond appropriately then the instructor proceeded to the next trial.

Design

The study was conducted as a simultaneous treatment design across ten sessions. In each session, every child went through four treatments (CAI and PI with parent and trainer). The sequence of the four treatments was randomized across the sessions.

Data collection

The first 3 minutes of every condition were videotaped by one of three remote controlled cameras mounted on the ceiling of the observation room. Two undergraduate psychology students analysed the tapes using a time-sampling procedure with the Event Log software (Henderson, 1989). For each of the four conditions, observations were made on alternating intervals of 10 seconds during the 3 minute period. The interrater reliabilities, measured by the proportion of agreement between raters, ranged from 85 to 88 percent across the four conditions.

The percentage of correct vocal imitations, aggregated across the nine

10 second intervals, constituted the dependent variable. Thus every child had four scores, one for each of the conditions. Across the ten sessions every child had a total of 40 vocal imitations scores. The 400 observations thus obtained were subjected to a three-way repeated measures ANOVA. The three factors were *trainer type* (parent or trainer), *teaching method* (CAI or PI) and *sessions* (ten sessions).

Social validity

After the last session parents rated the responsiveness of their child to the SpeechViewer on a four-point scale. They also evaluated the influence of the experimental conditions on behaviour problems and the overall usefulness of the SpeechViewer. Parents' evaluation of the SpeechViewer are shown in Table 3.

Table 3 **Evaluation of the IBM SpeechViewer program by ten parents**

Questions	*Frequency of parents' responses*			
	Not at all	*Just a little*	*Pretty much*	*A lot*
Showed an attraction to the colourful graphics and images	1	3	6	0
Learned to produce appropriate sounds	0	2	5	3
Showed increase of sounds over the sessions	0	2	4	4
Responded to the sensory reinforcements	0	5	4	1
Produced sounds to the sensory reinforcements	0	1	6	3
SpeechViewer motivated through positive feedback	0	3	5	2
Found SpeechViewer sessions useful	0	0	7	3
Showed behaviour problems:				
in the computer assisted instruction	4	4	1	1
in the table task situation	3	5	2	0
Main improvement during the last ten sessions has been:				
(a) ability to produce sounds	0	0	7	3
(b) compliance	0	3	7	0
(c) enthusiasm	0	1	9	0
(d) turn-taking	1	0	9	0
(e) motivation	0	1	8	1
(f) attention	0	1	7	2
(g) responsiveness	0	0	10	0
Did you find the ten sessions:	*Helpful* 10		*Not helpful* 0	
Recommend this program to parents with autistic children?	*Yes* 10		*No* 0	

Results

Compared with the PI condition the children showed significantly greater vocal imitations in the CAI condition ($F(1, 9) = 46.24$, $p < 0.001$, $X_{PI} =$ 39.3 percent, $X_{CAI} = 63.2$ percent) (see Figure 1). Figure 2 shows that the performance of the children in vocal imitations improved across sessions for both the CAI and the PI. The main effect for *sessions* was highly significant. This main effect was qualified by a *sessions* $\times$ *teaching method* interaction ($F(9, 81) = 21.36$, $p < 0.001$). The interaction reveals that the rate of learning for the CAI was much greater than the PI across the session's progress ($F(9, 81) = 5.15$, $p < 0.05$). It is interesting to note that there was no main effect of *trainer type* ($F(1, 9) = 2.1$, n.s.), nor did this interact with *teaching method* ($F(1, 9) = 0.02$, n.s.) or *sessions* ($F(9, 81) =$ 1.69, n.s.) (see Figure 3 and Figure 4). All except one child (subject 10) supported the above trend of improved performance on the CAI compared with the PI setting. Sounds or words correctly imitated at session 10 are shown in Table 4 on page 140.

Comparison of vocal imitations for individual children (see Figures 5 and 6 on pages 141 and 142)

Participant 1 After the third session, child 1 showed a consistently higher vocal imitation rate during the CAI as compared with the PI

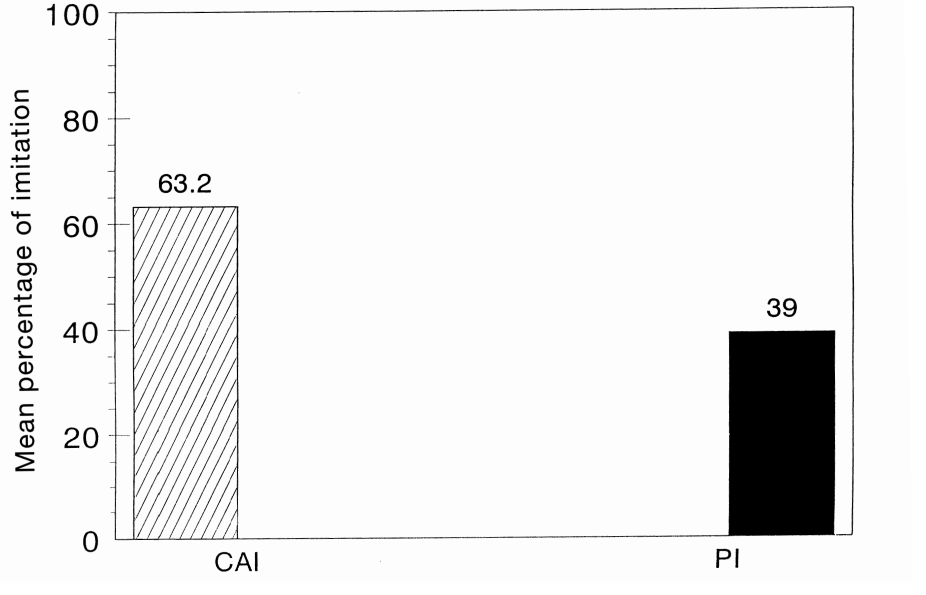

Figure 1 **Computer assisted instruction and personal instruction: comparing imitation across teaching method**

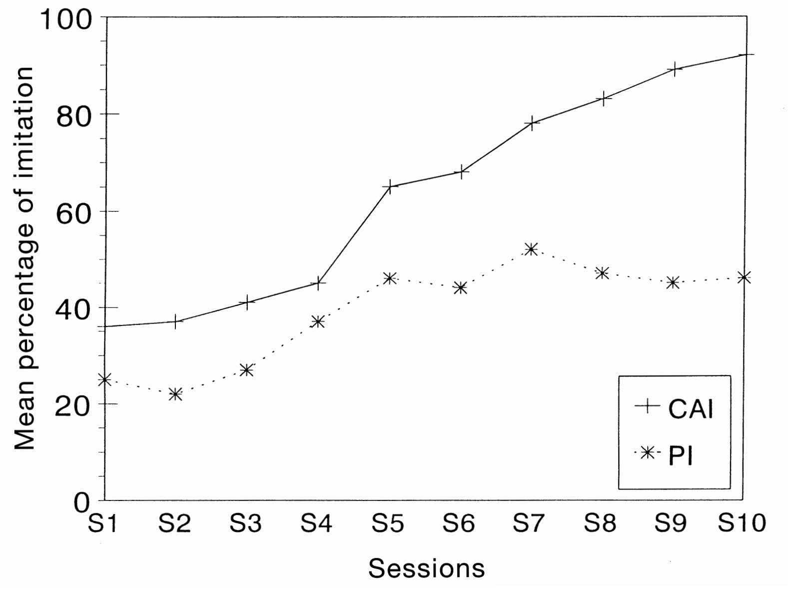

Figure 2 **Computer assisted instruction and personal instruction: comparing imitation across sessions**

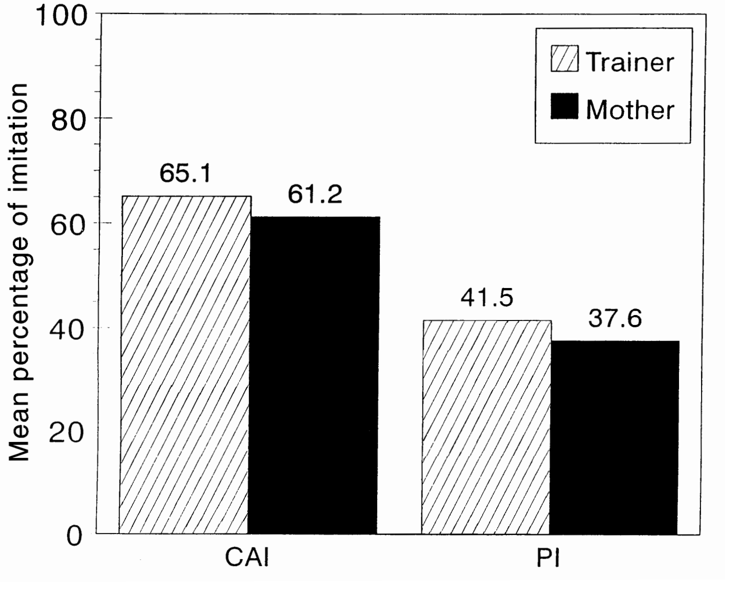

Figure 3 **Computer assisted instruction and personal instruction: comparing imitation across trainers and teaching method**

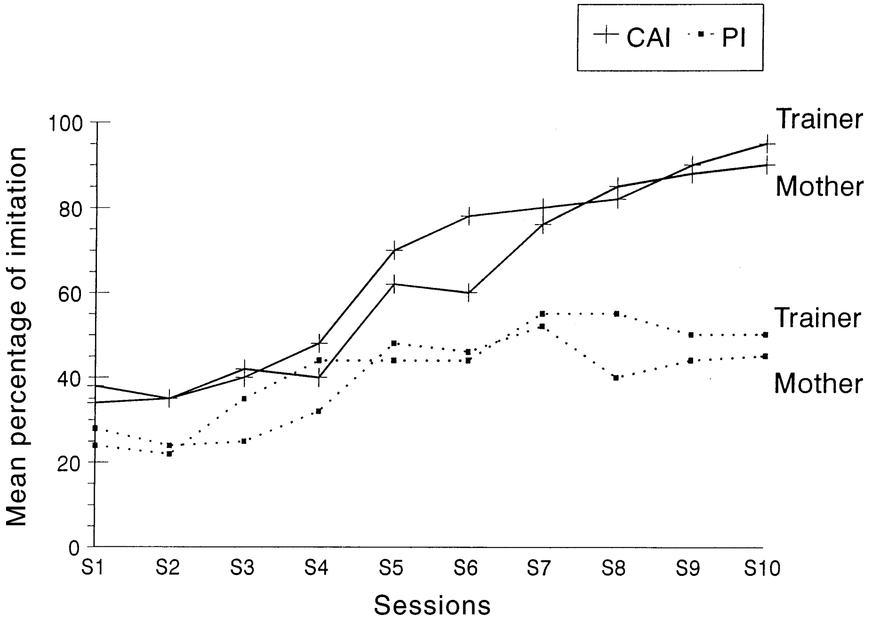

Figure 4 **Computer assisted instruction and personal instruction: comparing imitation across trainers and sessions**

condition. At session 10 he was able to consistently vocalize 'aaa', 'buh' and 'eee'. Steady progress was noted from the third to the eighth session. His percentage of vocal imitations on CAI showed an average increment of 13% for trainer (X_{CAI} = 59% v. X_{PI} = 46%) and 26% for parent (X_{CAI} = 72% v. X_{PI} = 46%).

Table 4 **Imitation of sounds/words learned across sessions**

Participant	*Sounds/words successfully vocalized at session 10*
1	aaa, buh, eee
2	aaa, eee
3	aaa, buh
4	aaa, buh, eee
5	aaa, buh, eee
6	aaa, buh, eee, ball, eat, train
7	aaa, buh, eee, ball, eat, train
8	aaa, buh, eee, ball, eat, train
9	aaa, buh, eee, ball, eat, train
10	aaa, buh, eee, ball, eat, train

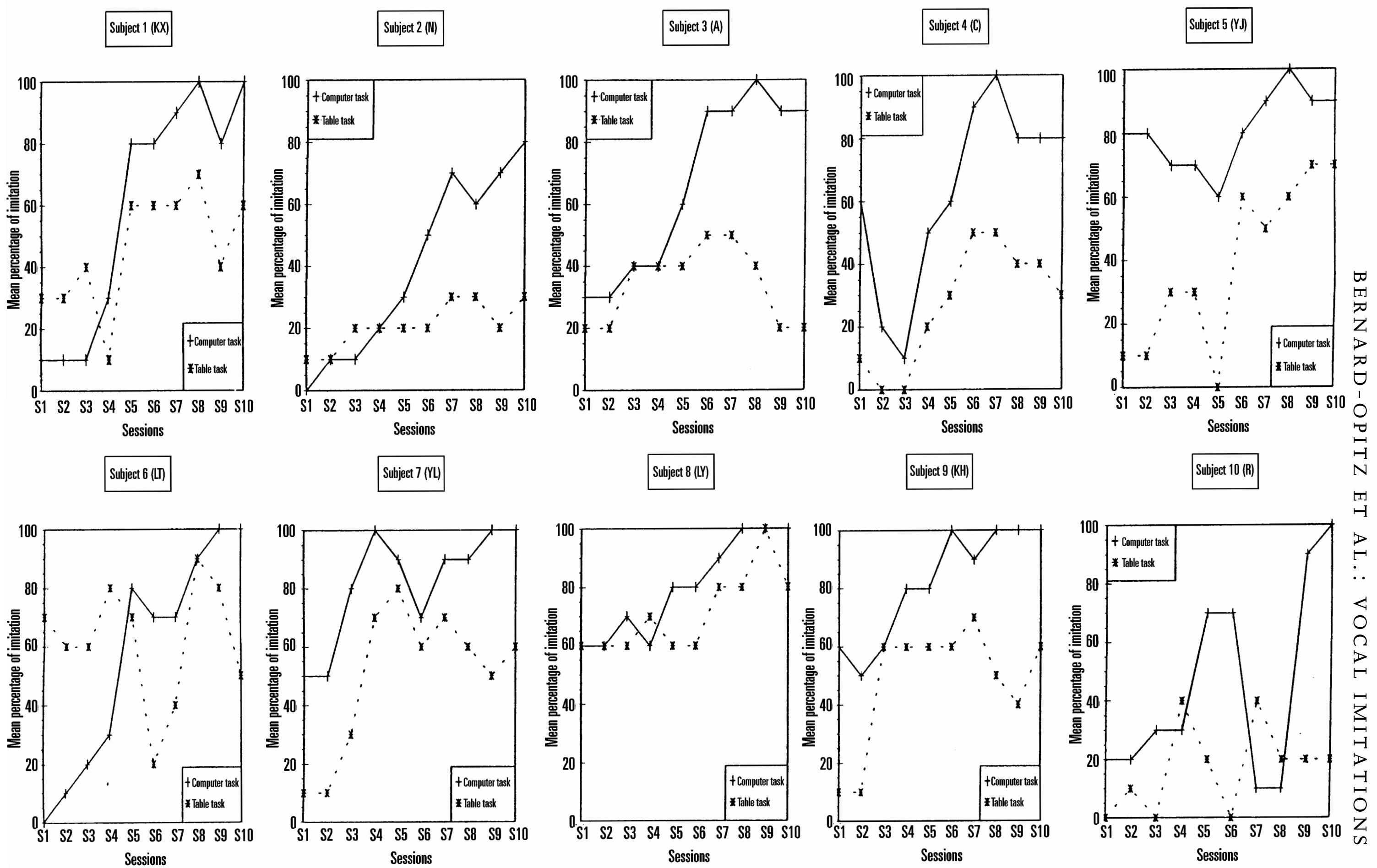

Figure 5 **Participants on CAI and PI conditions: comparing imitation within children with trainer across sessions**

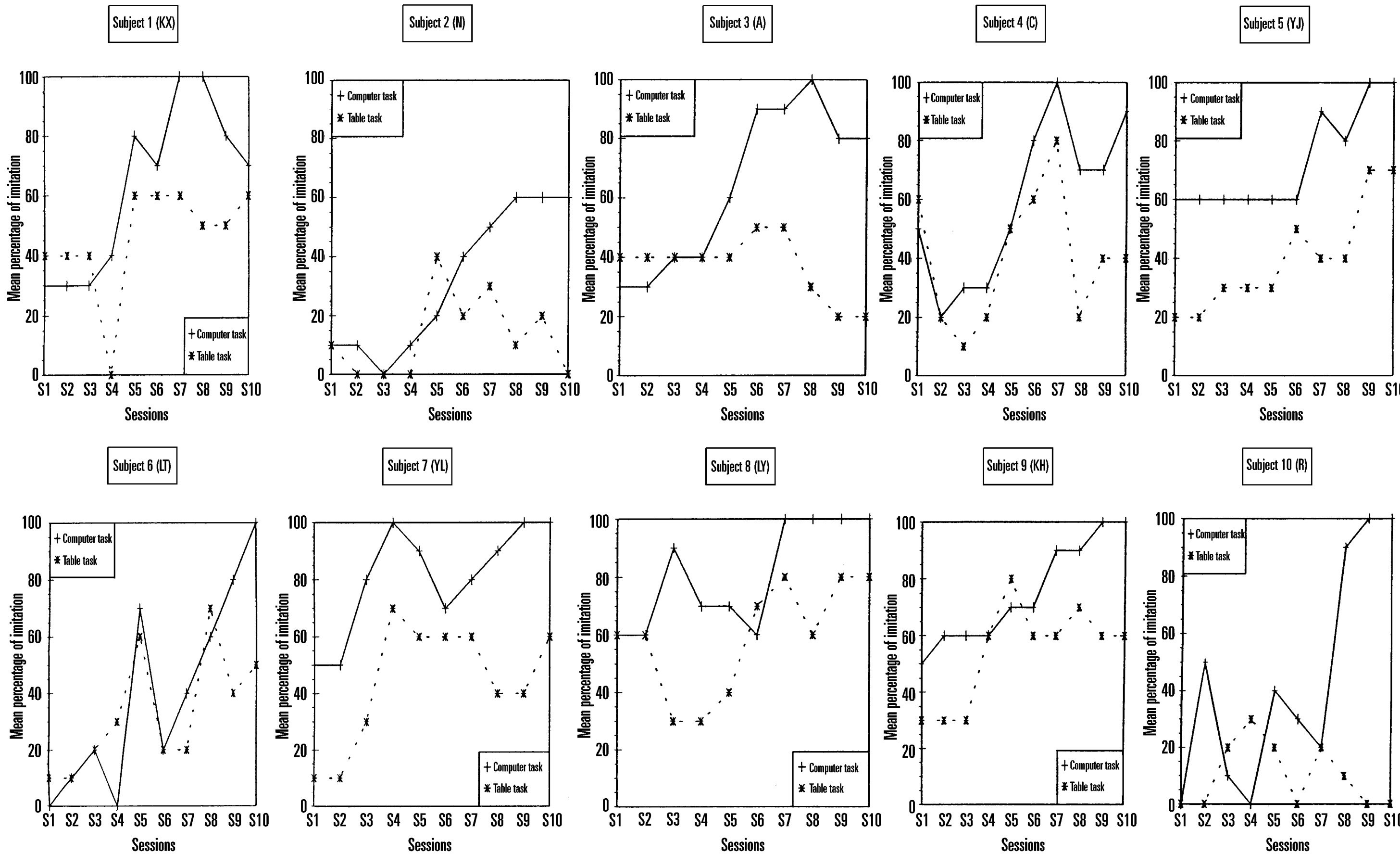

Figure 6 **Participants on CAI and PI conditions: comparing imitation within children with mother across sessions**

Participant 2 Child 2 showed a higher vocal imitation rate across sessions for CAI. At session 10 he was able to consistently vocalize 'aaa' and 'eee'. His vocal imitation rate showed an increasing trend for CAI with an average increment of 19% for trainer (X_{CAI} = 40% v. X_{PI} = 21%) and 19% for parent (X_{CAI} = 32% v. X_{PI} = 13%).

Participant 3 Child 3 also showed a higher vocal imitation rate across sessions for the CAI compared with the PI condition. At session 10 he was able to consistently vocalize 'aaa' and 'buh'. His percentage of vocal imitations on CAI was consistently higher across both trainers, averaging to an increment of 32% for trainer (X_{CAI} = 66% v. X_{PI} = 34%) and 27% for parent (X_{CAI} = 64% v. X_{PI} = 37%).

Participant 4 From the third session onwards, child 4 managed to increase his learning rate for vocal imitations for the CAI condition. At session 10 he was able to consistently vocalize 'aaa', 'buh' and 'eee'. His percentage of vocal imitations on CAI was higher than in PI sessions (X_{CAI} = 63% v. X_{PI} = 27%).

Participant 5 During the first session, child 5 had already attained an 80% vocal imitation rate for vocalizing 'aaa' during CAI. In addition, at session 10 he was able to vocalize 'buh' and 'eee'. His percentage of vocal imitations on CAI was consistently higher than on PI across both trainers, averaging to an increment of 42% for trainer (X_{CAI} = 81% v. X_{PI} = 39%) and 33% for parent (X_{CAI} = 73% v. X_{PI} = 40%).

Participant 6 Initially, child 6 occasionally vocalized 'aaa' sounds, but not 'buh' and 'eee'. From session 5, she showed a consistently higher imitation rate for CAI. At session 10 she was able to consistently vocalize 'aaa', 'buh', 'eee', 'eat', 'ball' and 'train'. Her percentage of vocal imitations on CAI showed a decline of 5% for trainer when compared with table task (X_{CAI} = 57% v. X_{PI} = 62%).

Participant 7 At the beginning, child 7 sometimes vocalized 'aaa' and 'eee' but not 'buh'. On the first session he attained 50% vocal imitation rate for CAI. At session 10 he was able to imitate six of the targeted sounds. He showed a consistently higher rate of vocal imitations during CAI compared with PI, averaging to an increment of 32% for trainer (X_{CAI} = 82% v. X_{PI} = 50%) and 42% for parent (X_{CAI} = 81% v. X_{PI} = 39%).

Participant 8 At the beginning, child 8 occasionally vocalized 'aaa' and 'eee' but not 'buh'. He attained 60% of the targeted sounds during the first session for both CAI and PI. At session 10 he was able to consistently vocalize 'aaa', 'buh', 'eee', 'eat', 'ball' and 'train'. His percentage of vocal imitations on CAI showed an average increment of 9% for trainer (X_{CAI} = 80% v. X_{PI} = 71%) and 22% for parent (X_{CAI} = 81% v. X_{PI} = 59%).

Participant 9 Initially, child 9 made occasional singing tunes. He occasionally vocalized vowel 'aaa' and 'eee' but not 'buh'. He attained 60% of the targeted vowels on the first session for CAI compared with 10% in the PI condition. At session 10, he was able to consistently vocalize 'aaa', 'buh', 'eee', 'eat', 'ball' and 'train'. His rate of vocal imitations on CAI was consistently higher across both trainers, averaging an increment of 35% for trainer (X_{CAI} = 78% v. X_{PI} = 43%) and 21% for parent (X_{CAI} = 75% v. X_{PI} = 54%).

Participant 10 Child 10 occasionally vocalized vowel 'aaa' and 'eee' but not 'buh'. From sessions 1 to 6 he showed more progress in CAI compared with the PI condition. During the seventh and eighth session with the trainer he showed a drop in vocalizations, which was attributed to off-task behaviours. Consistent imitation rates were achieved at sessions 8 and 9 on the sounds 'aaa', 'buh', 'eee', 'eat' and 'train'. His rate of vocal imitations on CAI showed an average increment of 28% for trainer (X_{CAI} = 45% v. X_{PI} = 17%) and 34% for parent (X_{CAI} = 44% v. X_{PI} = 10%).

Discussion

Comparison of the percentage of imitated sounds between the CAI and PI sessions with both a trainer and a parent revealed the beneficial effect of the SpeechViewer system on sound imitations for non-verbal children with autism. An enhancement of sounds through visual feedback was effective for nine out of ten children. Seven children with vocal imitation rates below 20 percent at the outset of the study increased their performance to 80 percent and above in the computer condition. While experimenter expectancies may have influenced these results, the advantage of computers over traditional sound imitation procedures was also documented during the conditions involving the parents. The novelty of the CAI condition can be viewed as contributing to its greater efficacy. However it should be noted that, for the majority of children, the percentage of imitation during the CAI condition showed a consistent increase across time. This trend was not solely limited to the initial sessions wherein novelty could be presumed to play a greater role. Also, while the number of participants was small, it should be noted that the range of mental age was considerable (from MA below 30 to adapted IQ 128).

An important issue in evaluating these results is the selection of sounds that the children had to model. The parents and the trainer were instructed to model sounds that were related to the activities on the screen or objects used during the play setting and to select sounds that the child might be able to produce. While this might have affected the ease of sound production over time, it is unlikely that this would specifically favour the computer over the play setting. Further studies might need to control sound difficulty, variety, familiarity and functionality with more care.

In their evaluation of the SpeechViewer, eight out of ten mothers indicated that they thought that enhanced learning had led to an increase of sound production over the sessions. Seven out of ten rated it as a positive influence on motivation and learning. All mothers perceived the sessions as helpful and indicated that they would recommend the SpeechViewer to other parents with non-verbal autistic children.

Overall the enhancement of sounds through visual feedback using the SpeechViewer seems promising for the non-verbal autistic population. It supports established findings on the skills of children with autism in visuo-spatial versus verbal tasks (Wing, 1981). As such, visual feedback to sounds might be an avenue for non-verbal children to understand one important basis of communication: that sounds have an effect on the environment. It also supports the assumption that computers have the potential to elicit speech in children with autism through visualizing sounds (Jordan, 1988). It remains to be seen if the possible advantage of computer based imitation training is due to its sensory qualities or due to the consistency, regularity and on-demand stimulation provided by computers that may satisfy the need of children with autism for predictability.

While imitation is not a necessary prerequisite in normal language acquisition (Bloom & Lahey, 1978), it may play a more important role in the language development of autistic children. While discrete trial approaches to enhance vocalization through computer based training seem useful, these should also be complemented by natural language interactions to facilitate verbal communication (Koegel et al., 1987; Lord, 1985). Methods combining computer based vocal imitations with psycholinguistic teaching interactions involving trained parents might prove even more effective.

To enhance functional communication, it would be useful to have a variety of software packages related to the interests and needs of the autistic population. While the present study was restricted by the software package used, future research could investigate the effect of computer programs that match preferences (such as spinning or flickering stimuli) or specific interests of children with autism. It would also be useful to provide a system that allows choice of specific sounds and words and relates these to corresponding visual feedback. Even though the present pilot study has indicated potential in the area of enhancing vocal imitations of non-verbal children with autism, it is only a starting point in the complex area of communicative development in this group.

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