Computer-Supported Phonological Awareness Intervention for Kindergarten Children With Specific Language Impairment

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Learning to read in an alphabetic orthography depends highly on a child's phonological awareness skills (Brady, 1997; Goswami, 2000; Goswami & Bryant, 1990; Snowling, 2000; Studdert-Kennedy & Mody, 1995). Phonological awareness refers to the general ability to attend to the sounds of language as distinct from their meaning. It has been described as the awareness of words in sentences, rhyme, syllables, the beginning and end parts of words, and phonemes (Adams, 1991; Perfetti, 1992; Snow, Burns, & Griffin, 1998; Yopp & Yopp, 2000). Kindergarten and first-grade children often develop rhyme and syllable knowledge first. The awareness of phonemes develops at a later stage (Treiman & Zukowski, 1996).

Phonological awareness has been shown to be an important predictor of success in learning to read (cf. Blachman, 2000). Additionally, recent meta-analyses have provided evidence that phonological awareness training can facilitate the process of learning to read (Bus & IJzendoorn, 1999; Ehri et al., 2001). It is therefore recommended that

phonological awareness training take place before the actual start of reading education. Attempts have been made to determine the effectiveness of computer programs in phonological awareness training.

Most studies of the effectiveness of computer phonological awareness training have been conducted with typically developing children and children who are at risk for reading problems. For example, Foster, Erickson, Foster, Brinkman, and Torgeson (1994) developed and studied the efficacy of the DaisyQuest computer phonological awareness training program, which focuses on rhyming; recognizing beginning, middle, and ending sounds; word blending; and counting the number of sounds in words. Typically developing kindergarten children were trained for 6.5 hr in one study and for 4.9 hr in a second study. In the second study, an improved version of DaisyQuest was used, introducing onset-rime activities before phoneme synthesis exercises and with an enlarged number of practice items. The children in both studies received training on a daily basis; each training session lasted 20–25 min. The control

ABSTRACT: Purpose: The purpose of the present study was to determine whether kindergarten children with specific language impairment (SLI) could develop phonological awareness skills through computer intervention and whether speech manipulation (i.e., slowing speech rate and enhancing transitions) in instruction produced additional learning. **Method:** The effects of a computer-supported phonological awareness program on a variety of items, including word analysis, syllable analysis, rhyme, phoneme analysis, syllable synthesis, and phoneme synthesis, were tested following a pretest–posttest 1–posttest 2 design. Twenty-four kindergarten children with SLI in the Netherlands received 3.5 hr of phonological awareness intervention via a computer program

using either normal speech (12 children) or manipulated speech (12 children). A control group of 12 kindergarten children with SLI played computer vocabulary games.

Results: The results showed positive effects of the intervention for the normal speech group. Eighteen weeks later, the effect size was still substantial; however, no additional effects of speech manipulation were found.

Clinical Implications: The results suggest that kindergarten children with SLI benefit from computer intervention for phonological awareness skills.

KEY WORDS: phonological awareness, SLI, speech manipulation, intervention, computer

group did not have access to any computer program. The results indicated that the experimental group outperformed the control group on tests of phonological awareness after the training period in both studies. Other studies also have demonstrated positive effects of computer intervention on the development of phonological awareness skills in typically developing children and children who are at risk for reading problems (Barker & Torgesen, 1995; Mioduser, Tur-Kaspa, & Leitner, 2000; Reitsma & Wesseling, 1998).

PHONOLOGICAL AWARENESS INTERVENTION FOR CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT

Children with specific language impairment (SLI) frequently demonstrate difficulties with phonological awareness that place them at risk for the development of reading problems (Bird, Bishop, & Freeman, 1995; Bishop & Adams, 1990; Snowling, 2000; Stackhouse, 2000). SLI is defined as a “delay in normal language development that cannot be explained in terms of mental or physical handicap, hearing loss, emotional disorder or environmental deprivation” (Bishop, 1992, p. 3). The risk of later reading problems for children with SLI can be attributed to their severe language problems, which negatively influence the acquisition of reading skills.

Phonological awareness intervention for young children with SLI is often recommended, although not much has been published regarding the efficacy of such intervention. Van Kleeck, Gillam, and McFadden (1998) showed that phonological awareness can indeed be trained with children with speech and/or language problems. Sixteen preschool children made significant improvements in rhyming and phoneme awareness skills after two semesters of phonological awareness intervention twice a week for 15 min in small groups. Comparison to a no treatment control group of older children with speech and/or language disorders indicated that the noted improvement could be ascribed to the intervention and not only to maturation. In another study, Gillon (2000) showed positive intervention effects for children with spoken language impairment. The children in the intervention group followed an integrated phonological awareness program of 20 hr of intervention by a specialist focusing on the sound structure of spoken language and the link between phonological awareness and letter-sound knowledge. These children showed significantly more gains in their phonological awareness and reading development than the children in the control groups with either a more traditional speech-language intervention program that focused on improving articulation and language skills or a minimal intervention control program.

EFFECTS OF SPEECH MANIPULATION

In one of the few studies on the effects of computer intervention on the phonological awareness skills of children with SLI, Tallal et al. (1996) examined the effects

of manipulated speech as an additional feature of the program. The use of manipulated speech was based on several years of research showing that children with SLI have difficulty processing brief, rapidly sequenced acoustic cues in verbal stimuli (Leonard, McGregor, & Allen, 1992; Reed, 1989; Tallal & Piercy, 1974; Tallal & Stark, 1981; Tallal, Stark, Kallman, & Mellits, 1980b). This difficulty can be overcome by lengthening the fast formant transitions in the speech signal (Alexander & Frost, 1982; Frumkin & Rapin, 1980; Stark & Heinz, 1996; Tallal & Piercy, 1975; Tallal, Stark, Kallman, & Mellits, 1980a).

Tallal et al. (1996) designed Fast ForWord (FFW), a computer program that makes use of manipulated speech for the treatment of children with SLI. The FFW program consists of computer games that focus on (a) processing and temporal sequencing skills, (b) phonemic sound change discrimination, (c) phoneme identification, (d) matching nonsense syllables that differ by a single phoneme, (e) recognizing words differing by a single phoneme, (f) syntax and listening comprehension, and (g) higher level language skills. Eleven children with SLI, with a mean age of 7;4 (years;months), received intervention with modified speech (experimental group); 11 children with SLI received the same intervention without modified speech (control group). The intervention was extensive, consisting of 100 hr across a 4-week period. After intervention, both groups showed significant learning gains; however, the children in the experimental group had higher learning gains than the children in the control group on such tasks as following auditory commands, speech-sound discrimination, morphology and syntax, and speech articulation.

A crucial question is whether the learning gains can be completely ascribed to the computer program and the use of manipulated speech. Bishop (1997) and Rice (1997) suggested that other aspects of the games, such as direct clinician-to-client interaction or additional listening homework, may explain the observed gains. However, such aspects still do not explain the difference between the control and experimental groups. As Tallal, Miller, Jenkins, and Merzenich (1997) explained, “the modified speech group played temporally adaptive computer games presented auditorially, whereas the normal speech group worked for the same period of time on memory and attention games presented visually” (p. 61). Thus, the experimental and control groups not only differed with regard to speech manipulation, but also on the kind of games to which they were exposed. Hence, the authors seem to contradict their earlier statement that both groups received the same intervention with or without manipulated speech.

In this light, a study by Gillam, Crofford, Gale, and Hoffman (2001) is especially interesting because they compared the effects of standard FFW intervention with that of an equally intensive treatment using a bundle of intervention programs published by Laureate Learning Systems (LLS). Both interventions focused on vocabulary, memory, syntax, and morphology; but, in FFW, modified speech was used. There were 2 children in each condition. Gillam et al. found significant learning gains for the children in both conditions in several domains of language. The FFW intervention, with the manipulated speech, did

not cause higher learning gains than the LLS intervention. The findings of Gillam et al. thus support the view that training with FFW can be effective (Gillam, Frome Loeb, & Friel-Patti, 2001), but leaves open to question whether speech manipulation per se adds to the effects of the intervention. To answer this question, an intervention with speech manipulation should be compared to a similar intervention without speech manipulation.

Habib et al. (1999) conducted such an experiment. They examined the effects of speech manipulation in computer programs in an intervention study with 12 French-speaking children with phonological dyslexia. Six children were trained with acoustically modified speech and 6 were trained without modified speech. At posttest, the modified speech group outperformed the normal speech group on phonological awareness tests similar to the ones used during the intervention. The findings appear to demonstrate the additional effects of speech manipulation; however, the participants involved were children with dyslexia and not children with SLI. Moreover, the speech manipulation was different from the speech manipulation used by Tallal and colleagues in that Habib et al. amplified unstable portions (particularly the consonant-vowel transitions) and then slowed the speech signal by a constant factor (up to 2). Tallal and colleagues, in contrast, first slowed the speech signal and then enhanced the fast formant transitions (Nagarajan et al., 1998).

THE PRESENT STUDY

Thus far, the exclusive contribution of speech manipulation to phonological awareness treatment for children with SLI using the computer has not been experimentally studied, because in the Tallal et al. (1996) study, the groups differed on more than just modified speech. In the present study, the added value of speech manipulation as used in the FFW program was therefore investigated in a pretest–posttest 1–posttest 2 design. The extent to which kindergarten children attending a school for children with severe language delay developed specific phonological abilities by working with a computer program was also explored. Three groups of children received computer treatment: two experimental groups were given rhyming and phoneme synthesis intervention either with or without manipulated speech, and a control group was given vocabulary intervention.

In the Netherlands, there are special schools for children with language and speech problems. Children who enter these schools are clinically diagnosed as having severe SLI. In kindergarten, they are at least 1 year behind in their language development as compared to age-matched peers. Children with hearing impairments may also attend these schools, but were excluded from the present study. Only 0.6% of Dutch children attend such schools. The situation in The Netherlands is comparable to that in the United Kingdom, where less than 1% of the children are diagnosed with SLI (Conti-Ramsden & Botting, 2000), whereas the estimated prevalence of SLI in children is 5% (Law, Boyle, Harris, Harkness, & Nye, 1998).

The specific research questions were as follows:

- To what extent do Dutch kindergarten children with SLI develop their phonological awareness skills by using an adaptive computer program?
- Does speech manipulation as part of the instruction of phonological awareness using an adaptive computer program produce additional learning?

METHOD

Participants

All participants were enrolled in a kindergarten program in special schools for children with SLI. SLI was diagnosed by an interdisciplinary team consisting of clinical linguists and school psychologists for children exhibiting a significant deficit in the production and/or comprehension of language that cannot be explained by general cognitive impairments, sensorimotor deficits, neurological disorders, psychiatric diagnosis, or a general lack of exposure to language (Leonard, 1998). All kindergarten children who were to go to first grade in the next school year were selected. Literacy instruction was not part of the kindergarten curriculum, and teachers' observations revealed no letter knowledge on the part of the children.

The participating children included 31 males and 5 females from a total of five different classrooms in two special schools. It is common to have substantially more males than females in an SLI population (Leonard, 1998). The average age at the initiation of the study was 5;9 (range = 4;10–6;11). When the children entered the special school, they were tested for hearing and intelligence. Audiological assessment (i.e., air conduction audiometry) revealed no significant hearing loss; children responded to less than 30 dB for all frequencies tested. Standardized intelligence testing indicated a level of normal intelligence (standard score was >85). Although the intelligence of the children was tested before they entered the special school, the Coloured Progressive Matrices (Raven, 1965) were nevertheless administered as a control measure. The average standard score for the participants was found to be 4.64. The score did not correlate significantly with scores of the children on the different phonological awareness pretests (Pearson $r < .31$ in all cases).

Pretest, Posttest 1, and Posttest 2

The pretest and posttests, consisting of five phonological awareness tests and the Coloured Progressive Matrices at pretest, were administered by the first author, who as a school psychologist is qualified and experienced in testing young children with SLI. The tests were administered in one session per child, always in the same order. The easier tasks (rhyme and word awareness) were administered in the beginning of each session to ensure that the children would not lose their motivation or confidence at the beginning of the session. The items measured in the tests were not explicitly trained in the intervention.

Separate tasks were administered measuring different aspects of phonological awareness: word awareness, syllabic awareness, rhyme awareness, and phonemic awareness (cf. Goswami, 2000). The tasks that were used for the various aspects of phonological awareness are described below:

- For word awareness, a task was administered in which a series of sentences had to be analyzed into separate words (Verhoeven & Van Kuyk, 1991). The task consisted of four training sentences for which the child received feedback and 10 test sentences. The child was to repeat a sentence that was read by the experimenter and then tap on the table with a pencil once for every word. Sentences included multisyllabic words.
- For syllabic awareness, a task was administered in which the child was to synthesize words by combining separate syllables (Verhoeven, 1987). The syllable synthesis task consisted of 20 words of increasing difficulty (from two- to five-syllable words). Children had to synthesize the words presented by the experimenter in syllables into complete words. Test administration ended when a child could not synthesize five words in succession.
- For rhyme awareness, a task was used that consisted of two training and 10 test items (Verhoeven & Van Kuyk, 1991). The child was to name four pictures and was assisted by the experimenter if he or she could not label a picture or did not know the correct answer. Then, the experimenter presented a new picture and said, "This is a Which of the four pictures rhymes with ...?" The child was to select the rhyming picture from the four options. Distracters included semantically related pictures.
- For phonemic awareness, separate tasks were used for phoneme analysis and phoneme synthesis (Verhoeven, 1987). In the phoneme analysis task, words had to be analyzed into separate phonemes. The task consisted of 4 training words and 20 test words of increasing difficulty (starting with consonant-vowel words). Children had to analyze the words presented by the experimenter into separate phonemes. In order to keep the child motivated, test administration ended when a child could not analyze five words in succession. The phoneme synthesis task required children to synthesize words by combining separate phonemes. The task consisted of 20 words of increasing difficulty (from two to six phonemes). Children had to synthesize the words presented by the experimenter in phonemes into complete words. Test administration ended when a child could not synthesize five words in succession.

All tests yielded Cronbach's alpha values greater than .83, indicating a high degree of internal consistency.

Experimental and Control Groups

A group of children with SLI can form a very heterogeneous population. To ensure that the groups were as homogeneous as possible, the children were assigned to

three groups (12 children per group) and were matched between groups on the basis of chronological age, score on the Coloured Progressive Matrices (Raven, 1965), and scores on each of the five phonological awareness tasks (see Table 1). Experimental Group 1 consisted of 2 females and 10 males (mean age = 5;9, mean Raven score = 4.73). Experimental Group 2 also consisted of 2 females and 10 males (mean age = 5;10, mean Raven score = 4.68). The control group consisted of 1 female and 11 males (mean age = 5;8, mean Raven score = 4.53). Univariate analysis of variance (ANOVA) with group as the between-subjects factor showed no significant pretest differences between the groups with respect to age, $F(2, 33) = .69, p = .51, \eta^2 = .04$; Raven score, $F(2, 33) = .02, p = .98, \eta^2 = .02$; word awareness, $F(2, 33) = .10, p = .90, \eta^2 = .01$; syllabic awareness, $F(2, 33) = .96, p = .39, \eta^2 = .06$; rhyme awareness, $F(2, 33) = .02, p = .99, \eta^2 < .01$; phoneme analysis, $F(2, 33) = .79, p = .46, \eta^2 = .05$; or phoneme synthesis, $F(2, 33) = 1.05, p = .36, \eta^2 = .06$. Group differences also were examined using a combined score on the five phonological awareness tasks because a combined variable has been shown to be a more reliable measure of phonological awareness (Bishop, 1994). For this purpose, the combined z scores for these tests were computed. Z scores were used because the tests had different numbers of items. There was no significant difference between the three groups with respect to the combined variable, $F(2, 33) = .32, p = .73, \eta^2 = .02$.

Computer Program Used for the Intervention

The computer program used in the experiment was an educational software program that the authors developed with support of the Dutch Ministry of Education (Verhoeven, Mommers, & Segers, 1999) that focused on the emergent and beginning literacy skills of kindergarten children. At the time of the present study, it was one of the few educational software packages available in the Netherlands focusing on phonological awareness that (a) included speech that could be manipulated by the researchers, (b) did not include distracting entertainment elements, and (c) provided enough training material for 3.5 hr. The two experimental groups worked with the rhyming and synthesis part of the program; the control group worked with the vocabulary acquisition part of the program.

Experimental intervention. The intervention consisted of the "Rhyming and Synthesis game" from the computer program, which consists of 10 different games. This module of the software is adaptive in the sense that the child only receives a more difficult game when an error percentage less than 20% is achieved on the previous game. The intervention alternates between rhyming and synthesis games. The adaptivity for these two types of games is separate in that a child can be performing at the most difficult level for rhyming while still at the first level for synthesis. Table 2 provides an overview of the different kinds of games. The Appendix contains screen examples and further explanation of the games. Each game has three sets of five exercises, increasing in difficulty. When a child has problems with more than one of the exercises from a

Table 1. Gender, age, Raven standard score (ravenss), and scores on phonological awareness tasks for children in each group. Control group (Control) children received vocabulary training, Experimental Group 1 (Exp 1) children received treatment without manipulated speech, and Experimental Group 2 (Exp 2) children received treatment with manipulated speech.

Group	Gender	Age	Ravenss	Rhyme	Word aw	Phon an	Syll aw	Phon syn
Control	M	65	4.2	10	1	0	1	1
Control	M	69	6.0	4	5	0	1	0
Control	M	66	1.8	1	4	0	19	1
Control	M	58	4.2	3	0	0	0	0
Control	F	72	2.7	1	4	0	11	0
Control	F	81	4.7	9	1	0	17	0
Control	M	81	5.7	9	4	0	13	0
Control	M	62	6.2	10	3	0	20	0
Control	M	70	3.0	2	2	0	19	1
Control	M	67	6.6	2	3	0	20	1
Control	M	67	8.6	10	5	0	19	0
Control	M	67	3.0	3	1	0	14	0
Exp 1	M	62	8.9	9	3	0	15	1
Exp 1	M	71	2.9	6	4	0	18	0
Exp 1	M	67	4.0	10	2	0	20	1
Exp 1	M	66	6.7	0	0	0	2	1
Exp 1	M	61	6.3	0	2	0	15	1
Exp 1	M	81	0.5	5	2	0	0	0
Exp 1	M	70	0.5	6	4	0	15	0
Exp 1	M	72	6.5	6	2	3	20	3
Exp 1	M	78	8.6	3	6	0	10	0
Exp 1	F	78	3.6	5	2	0	6	0
Exp 1	M	69	4.7	10	1	0	16	0
Exp 1	F	71	2.9	2	2	0	12	1
Exp 2	M	62	6.0	6	3	0	18	1
Exp 2	M	65	3.7	7	4	1	16	0
Exp 2	M	62	7.7	10	1	0	17	0
Exp 2	M	62	5.2	3	0	1	20	0
Exp 2	M	69	3.7	10	3	1	19	0
Exp 2	M	66	4.5	2	3	0	18	0
Exp 2	M	71	0.5	2	3	0	14	0
Exp 2	M	76	6.4	10	2	0	16	1
Exp 2	M	69	0.5	1	2	0	10	0
Exp 2	M	75	8.0	5	4	0	12	1
Exp 2	F	66	5.1	2	5	0	17	0
Exp 2	M	69	3.1	3	3	0	11	1

Note. Rhyme = rhyme awareness task, Word aw = word awareness task, Phon an = phoneme analysis task, Syll aw = syllabic awareness task, Phon syn = phoneme synthesis task, M = male, F = female.

set, this set is presented again when the child returns to this game. If criterion is met with a certain set, a more difficult set is presented the next time. Once all of the sets are completed, the program begins to repeat earlier sets so the child can rehearse the newly learned skills. Only 1 child completed all of the sets and games within the 14 intervention sessions.

The computer program also provides feedback on each action performed by the child. Help is offered when the child provides an incorrect answer for the second time. The correct answer is highlighted by large green arrows pointing to it. When the child still does not choose the correct answer, the computer program takes over mouse control and provides the right answer. In this way, the child never gets “stuck” in the program. The child can also ask for help by clicking on a figure at the bottom of the screen.

Speech manipulation. The children in Experimental Group 1 received the described computer phonological

awareness intervention; for Experimental Group 2, the speech in the computer program was manipulated in the same way as in the FFW program. Initially, the speech was slowed down by 150% by means of a pitch-synchronous overlap-and-add (PSOLA) algorithm. The fast transitional elements in the speech then were enhanced up to 20 dB using an algorithm in the Praat program (Boersma & Weenink, 1998) similar to the one described by Nagarajan et al. (1998). The equality of the two algorithms was established by Nagarajan and Boersma (personal communication, February 14th, 1999).

As in FFW, the amount of speech manipulation decreased as the intervention proceeded. The children in Experimental Group 2 had four sessions with maximum speech manipulation followed by four sessions in which the speech was not delayed but enhancement was up to 20 dB, three sessions with enhancement up to 10 dB, and finally, three sessions with normal speech. This way, all children in

Table 2. “Rhyming and synthesis” games used in the experimental intervention program.

<i>Rhyming</i>	<i>Synthesis</i>
1. Rhyming, with picture support.	7. Synthesis of onset and rhyme, with picture support.
2. Rhyming, without picture support.	8. Synthesis of onset and rhyme, without picture support.
3. Rhyme within a sentence, with picture support.	9. Synthesis of three separate phonemes, with picture support.
4. Rhyme within a sentence, without picture support.	10. Synthesis of three separate phonemes, without picture support.
5. First phoneme matching, with picture support.	
6. First phoneme matching, without picture support.	

Experimental Group 2 received the same amount of intervention with manipulated speech.

Control group intervention. Each child in the control group listened to a story on the computer and answered questions by pointing to pictures of objects on the screen. After listening to the story, the child chose one of four different story settings to play vocabulary games. Each story setting contained 10 sets of five questions each (e.g., “Can you point at the table in the kitchen?”). The program provided both audio (“Well done.” “Try again.”) and visual (lollipops) feedback after each answer. Five lollipops at the top of the screen turn into a different color depending on the number of times it took to answer each question correctly: green if the correct answer was given directly, yellow after one wrong attempt, and red after two attempts.

Procedure

The pretests were administered directly after the fall break and lasted for approximately 2 weeks. At this time, the children had been in school for approximately 10 weeks after the summer holidays. Administration of the pretests took approximately 2 weeks.

Once the pretesting was completed, the children were seen in groups of three for two to three 15-min computer phonological awareness intervention sessions per week for 5 weeks. Three children were randomly taken out of the classroom for a computer session each time (1 child from Experimental Group 1, 1 child from Experimental Group 2, and 1 child from the control group). They were seated in a separate room with three laptop computers that were placed in such a way that each child could only see the computer that he or she was using.

The experimenter ensured that the children attended to the computer program. When a child was distracted, the experimenter told the child to keep on working with the software. During the sessions, the experimenter also watched what the children were doing on the computer and gave motivational signs (thumbs up) when they were actively involved in working with the program. The computer program was designed in such a way that instruction before training was not necessary. Occasionally, a child did not understand the purpose of a particular exercise and did not understand what he or she was

expected to do. The experimenter then clarified the instructions of the exercise and guided the child through a few questions by providing instructions on how to move the mouse. No instruction on phonological awareness was provided. After each session, the children were rewarded with a sticker to place on their own “computer card.” After the 14 sessions, the computer card was full and could be taken home. During the intervention, all children showed positive feelings about the program.

Posttest 1 was administered in the weeks directly following the intervention, just before the Christmas holidays, and included the same five phonological awareness tasks that were administered as pretests. Eighteen weeks after the intervention, the phonological awareness tasks were re-administered to investigate possible long-term intervention effects (posttest 2).

RESULTS

A multivariate repeated measures ANOVA using Time (pretest, posttest 1, posttest 2) and Test (five phonological awareness tasks) as the within-subjects factors and Group (two experimental groups and control group) as the between-subjects factor was first undertaken (see Table 3 for mean raw scores). The scores for the rhyme and word awareness task were multiplied by two to have the same range as the other phonological awareness tasks, so the different tasks could be compared. Results revealed significant main effects for Time, $F(2, 32) = 46.79$, $p < .01$, partial $\eta^2 = .75$, and Test, $F(4, 30) = 223.34$, $p < .01$, partial $\eta^2 = .97$, and a significant interaction between Time and Test, $F(8, 26) = 4.55$, $p < .01$, partial $\eta^2 = .58$. However, no significant interactions between Test and Group, $F(8, 62) = .90$, $p = .52$, partial $\eta^2 = .10$, and between Time and Group, $F(4, 66) = .82$, $p = .52$, partial $\eta^2 = .05$, were found, suggesting that differences in group performance were not dependent on a particular test or time of testing. There was also no significant difference between the groups on the different phonological awareness tasks during the course of the intervention, $F(2, 33) = .38$, $p = .69$, partial $\eta^2 = .02$. The three-way interaction between Time, Group, and Test was not significant, $F(16, 54) = 1.00$, $p = .47$, partial $\eta^2 = .23$.

Table 3. Mean pre- and posttest raw scores and standard deviations (in parentheses) for the three groups on phonemic awareness tasks. Control group children received vocabulary training, Experimental Group 1 children received treatment without manipulated speech, and Experimental Group 2 children received treatment with manipulated speech.

	<i>Control group</i>			<i>Experimental Group 1</i>			<i>Experimental Group 2</i>		
	<i>Pretest</i>	<i>Posttest1</i>	<i>Posttest2</i>	<i>Pretest</i>	<i>Posttest1</i>	<i>Posttest2</i>	<i>Pretest</i>	<i>Posttest1</i>	<i>Posttest2</i>
Rhyme awareness	5.0 (3.9)	5.8 (3.8)	6.9 (3.7)	5.2 (3.5)	7.1 (4.3)	8.1 (2.8)	5.1 (3.5)	6.6 (3.2)	7.8 (3.5)
Word awareness	2.5 (1.8)	2.7 (1.6)	2.5 (1.4)	2.5 (1.6)	3.2 (1.5)	3.8 (1.4)	2.8 (1.4)	3.3 (2.0)	3.4 (1.7)
Phoneme analysis	0.0 (0.0)	0.0 (0.0)	1.00 (3.0)	0.3 (0.9)	0.9 (1.8)	1.5 (2.4)	0.3 (0.5)	0.3 (0.7)	0.8 (1.2)
Syllabic awareness	12.4 (7.7)	16.6 (3.9)	18.1 (4.3)	12.4 (6.7)	16.5 (5.5)	19.2 (1.4)	15.7 (3.2)	17.8 (5.4)	19.1 (1.1)
Phoneme synthesis	0.3 (0.5)	0.4 (0.7)	1.2 (2.2)	0.7 (0.9)	2.3 (3.2)	2.5 (3.2)	0.3 (0.4)	2.1 (2.1)	2.9 (3.2)

Further analyses by means of paired samples *t* tests, with Bonferroni correction, of the interaction between Time and Test showed that, in general, significant progress was made between pretest and posttest 1, and posttest 1 and posttest 2 on the syllabic awareness task, rhyme awareness task, phoneme analysis task, and phoneme synthesis task ($p < .01$ in all cases). For the word awareness task, there was only a marginal difference between pretest and posttest 2 ($p = .04$). Because there was no interaction between Time and Group, or between Time, Group, and Test, this type of analysis does not show any effects of the intervention by group membership.

Bishop (1994), however, suggested combining scores of phonological awareness tests to gain a more reliable measure of phonological awareness, and Tallal et al. (1996)

performed analyses using difference *z* scores. The analysis following these suggestions is a univariate ANOVA with Group as the between-subjects factor on the difference *z* scores (*z* scores posttest 1 minus pretest) for the combined test results. This time, a significant main effect of Group was found directly after intervention, $F(2, 33) = 3.33$, $p = .05$, partial $\eta^2 = .17$. Post-hoc analysis for Group with Bonferroni correction showed that the difference could be attributed to a difference between Experimental Group 1 and the control group ($p = .05$). Experimental Group 1 made more progress than the control group. Experimental Group 2 did not differ significantly from Experimental Group 1 ($p = .40$) or the control group ($p = .94$) (see Figure 1). However, note that the effect size would suggest that this finding only accounted for 17% of the variance.

Figure 1. Difference *z* scores of posttest 1–pretest (directly after intervention) and posttest 2–pretest (18 weeks after intervention) for the control group ($n = 12$), Experimental Group 1 (normal speech, $n = 12$), and Experimental Group 2 (manipulated speech, $n = 12$).

Eighteen weeks after the intervention (i.e., posttest 2), the phonological awareness tasks were administered again, and again the difference z scores were computed (posttest 2 minus pretest). This time, there was no significant effect of Group, $F(2, 33) = 1.56$, $p = .23$, partial $\eta^2 = .09$. The effect size of the intervention for Experimental Group 1 versus the control group was, however, average ($p = .28$, $f = .29$), indicating that the progress of Experimental Group 1 exceeded the progress of the control group. Hence, because the results were not significant, the effect sizes should be considered with caution. Figure 1 displays the difference z scores for posttest 1 and posttest 2 for the experimental groups and the control group.

DISCUSSION

In general, the findings of the present study show that kindergarten children with SLI benefited from a short, intensive computer phonological awareness intervention. Three groups of 12 children worked with a computer program for fourteen 15-min sessions across 5 weeks. Experimental Group 1 received phonological awareness intervention while listening to normal speech. Experimental Group 2 listened to manipulated speech, in which the speech was delayed and fast formant transitions were enhanced. The speech became less manipulated during the course of the intervention. The control group also used the computer, but worked with vocabulary exercises rather than phonological awareness exercises.

No significant effects of the intervention were found when the data were analyzed for the individual phonological awareness tasks. An explanation for this effect is the low power of the analysis when the phonological awareness tasks are taken individually. On the other hand, positive treatment results were found for Experimental Group 1 when the phonological awareness task results were combined into difference z scores. The positive results were no longer significant 18 weeks after completion of the intervention, but the effect size of treatment for Experimental Group 1 compared to the control group ($f = 0.29$) continued to be average (Cohen, 1988) and was comparable to results from other studies (Ehri et al., 2001). In a meta-analysis of the effects of phonological awareness interventions, Ehri et al. found an average effect size of $d = 0.61$ (which is comparable to an f of .29) for phonological awareness intervention when the length of instruction was similar to that in the present study. For computer treatment of phonological awareness, Ehri et al. reported an average effect size of 0.66. Tallal et al. (1996) reported significant long-term effects of the intervention when the children were retested 6 weeks after completion of the intervention. In the present study, however, there was a period of 18 weeks between the intervention and posttest 2.

Speech manipulation did not produce an additional effect on the intervention, as the children in Experimental Group 2 did not differ significantly from the children in Experimental Group 1 or the control group. These results could be explained by several factors.

First, the intervention time with manipulated speech in the present study was far less than the one provided by Tallal et al. (1996): 3.5 hr versus 100 hr in a 5- versus 4-week period. That is, the effects of speech manipulation may only become visible after many hours of intensive treatment because new neural pathways must be formed or existing pathways have to be strengthened (cf. Verhoeven & Segers, 2004).

Furthermore, age differences might also be responsible for differential effects of speech manipulation. The children in the present study were all kindergarten children, with a mean age of 5;9, whereas children in the study by Tallal et al. (1996) had a mean age of 7;4.

Another explanation is based on what was already mentioned in the introduction of this article. In the study by Tallal et al. (1996), the experimental groups differed on more than just speech manipulation, indicating that speech manipulation may not have been the deciding factor for the successful treatment of phonological awareness. Other factors such as direct clinician-to-client interaction, additional listening homework, or a difference in intervention games between the experimental and control group may have been responsible for the reported learning gains. The experimental groups in the study by Habib et al. (1999) only differed in speech manipulation; thus, only speech manipulation seems to have been responsible for the additional learning gains. However, the participants were children with dyslexia rather than children with SLI.

The third explanation for not finding additional effects of speech manipulation is the fact that only natural speech was used in the intervention. In FFW, part of the intervention is based on synthetic speech and acoustic games (Merzenich et al., 1996) and (a larger) part on natural speech (Tallal et al., 1996). Children are adaptively guided through the FFW program and work with the synthetic speech and acoustic part until they have reached a certain level. When that level is reached, several games using natural manipulated speech can be played. The positive effects of FFW that were reported by Merzenich et al. are solely based on the synthetic speech part. The positive results by Tallal et al. are based on a combination of the synthetic speech part and the natural speech part. Segers and Verhoeven (2002) found no effects of speech manipulation when using natural speech in a discrimination task, and speech manipulation seemed to undo the positive effects of the intervention in the present study. One could hypothesize that the manipulation of the speech signal may only yield additional results for children with SLI when used in a synthetic speech and acoustic sounds environment. The consequence would be that only the first part of the FFW program is responsible for the additional learning effects due to speech manipulation. More research is needed in this area, also to determine why in the study by Habib et al. (1999) positive effects were found in a natural speech environment for older children with dyslexia.

Contrary to the children in Experimental Group 1, the children in Experimental Group 2 did not seem to benefit from the intervention. After intervention, children in Experimental Group 2 did not differ significantly from the children in the control group. One could speculate that the

children in Experimental Group 2 were distracted from the phonological awareness tasks because of the manipulated speech. The possibility that the manipulated speech was also less intelligible should be examined in a future experiment.

The present study can only be seen as a first step in uncovering the role of intervention in processes of phonological awareness development in children with SLI. The present study was limited to a predefined set of phonological variables considered important for the explanation of intervention effects in the domain of phonological awareness. Moreover, the intervention was restricted to one type of phonological training only. Well-controlled studies combining a multitrait with a multimethod design can be effective in validating new methodologies for the remediation of developmental language problems. Future studies could also be extended, with a deeper focus on classroom activities during the time of the intervention. Possible interactions between intervention and classroom activities could then be documented.

With respect to the clinical practice, the present study can be seen as promising. The study is the first to show that a group of kindergarten children attending a special school for children with speech and language problems can develop phonological awareness by working with a computer program without additional intervention from speech therapists or other specialists. Because of the small size of the experimental groups, one should, however, be cautious to generalize the results to the population at large. In order to further demonstrate the effectiveness of computer phonological awareness intervention, more follow-up studies with larger groups of participants are needed focusing on (a) the effects of more intensive intervention over an extended period of time with manipulated speech, (b) the long-term effects of computer intervention with and without manipulated speech, and (c) the difference between interventions using synthetic versus natural speech. In future studies, the impact of individual differences in intervention effects should also be recognized. Given the substantial standard deviations found in the present study, it seems essential to uncover the complex interaction between child characteristics and intervention alternatives. As such, the heterogeneity of children with learning problems, such as SLI, can be seen as a challenge to search for multifaceted and multicomponent interventions using information and communication technologies.

REFERENCES

- Adams, M. (1991). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT Press.
- Alexander, D. W., & Frost, B. P. (1982). Decelerated synthesized speech as a means of shaping speed of auditory processing of children with delayed language. *Perceptual and Motor Skills* 55, 783–792.
- Barker, T. A., & Torgesen, J. K. (1995). An evaluation of computer-assisted instruction in phonological awareness with below average readers. *Journal of Educational Computing Research*, 13, 89–103.
- Bird, J., Bishop, D. V. M., & Freeman, N. H. (1995). Phonological awareness and literacy development in children with expressive phonological impairments. *Journal of Speech and Hearing Research*, 38, 446–462.
- Bishop, D. V. (1997). *Uncommon understanding: Development and disorders of language comprehension in children*. Cambridge, UK: Psychology Press.
- Bishop, D. V. M. (1992). The underlying nature of specific language impairment. *Journal of Child Psychology and Psychiatry*, 37, 3–66.
- Bishop, D. V. M. (1994). Is specific language impairment a valid diagnostic category? Genetic and psycholinguistic evidence. *Philosophical Transactions of the Royal Society of London, Series B Biological Sciences*, 346, 105–111.
- Bishop, D. V. M., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *Journal of Psychology and Psychiatry*, 31, 1027–1050.
- Blachman, B. A. (2000). Phonological awareness. In M. L. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research, Vol. III* (pp. 483–501). Mahwah, NJ: Lawrence Erlbaum Associates.
- Boersma, P., & Weenink, D. (1998). Praat, a System for Doing Phonetics by Computer (Version 3.8beta) [Computer software]. Amsterdam: University of Amsterdam.
- Brady, S. (1997). Ability to encode phonological representations: An underlying difficulty of poor readers. In B. Blachman (Ed.), *Foundations of reading acquisition and dyslexia* (pp. 21–47). Mahwah, NJ: Lawrence Erlbaum Associates.
- Bus, A. G., & IJzendoorn, M. H. (1999). Phonological awareness and early reading: A meta-analysis of experimental training studies. *Journal of Educational Psychology*, 91, 403–414.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
- Conti-Ramsden, G., & Botting, N. (2000). Educational placements for children with specific language impairments. In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 131–155). Hove, UK: Psychology Press.
- EHri, L. C., Nunes, S. R., Willows, D. M., Schuster, B. V., Yaghiub-Zadeh, Z., & Shanahan, T. (2001). Phonemic awareness instruction helps children learn to read: Evidence from the National Reading Panel's meta-analysis. *Reading Research Quarterly*, 36, 250–287.
- Foster, K. C., Erickson, G. C., Foster, D. F., Brinkman, D., & Torgesen, J. K. (1994). Computer administered instruction in phonological awareness: Evaluation of the DaisyQuest program. *The Journal of Research and Development in Education*, 27(2), 126–137.
- Frumkin, B., & Rapin, I. (1980). Perception of vowels and consonant-vowels of varying duration in language impaired children. *Neuropsychologica*, 18, 443–454.
- Gillam, R. B., Crofford, J. A., Gale, M. A., & Hoffman, L. M. (2001). Language change following computer-assisted language instruction with Fast ForWord or Laureate Learning Systems software. *American Journal of Speech-Language Pathology*, 10, 231–247.
- Gillam, R. B., Frome Loeb, D., & Friel-Patti, S. (2001). Looking back: A summary of five exploratory studies of Fast ForWord. *American Journal of Speech-Language Pathology*, 10, 269–273.
- Gillon, G. T. (2000). The efficacy of phonological awareness

- intervention for children with spoken language impairment. *Language, Speech, and Hearing Services in Schools*, 31, 126–141.
- Goswami, U.** (2000). Phonological and lexical processes. In M. L. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research, Vol. III* (pp. 251–268). Mahwah, NJ: Lawrence Erlbaum.
- Goswami, U., & Bryant, P.** (1990). *Phonological skills and learning to read*. Hillsdale, NJ: Lawrence Erlbaum.
- Habib, M., Espesser, R., Rey, V., Giraud, K., Bruas, P., & Gres, C.** (1999). Training dyslexics with acoustically modified speech: Evidence of improved phonological performance. *Brain and Cognition*, 40, 143–146.
- Law, J., Boyle, J., Harris, F., Harkness, A., & Nye, C.** (1998). Screening for speech and language delay: A systematic review of the literature. *Health Technology Assessment*, 2(9), 1–84.
- Leonard, L. B.** (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.
- Leonard, L. B., McGregor, K. K., & Allen, G. D.** (1992). Grammatical morphology and speech perception in children with specific language impairment. *Journal of Speech and Hearing Research*, 25, 1076–1085.
- Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., & Tallal, P.** (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. *Science*, 271, 77–81.
- Mioduser, D., Tur-Kaspa, H., & Leitner, I.** (2000). The learning value of computer-based instruction of early reading skills. *Journal of Computer Assisted Learning*, 16, 54–63.
- Nagarajan, S. S., Wang, X., Merzenich, M. M., Schreiner, C. E., Johnston, P., Jenkins, W. M., et al.** (1998). Speech modification algorithms used for training language learning-impaired children. *IEEE Transactions on Rehabilitation Engineering*, 6(3), 257–268.
- Perfetti, C. A.** (1992). The representation problem in reading acquisition. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 145–174). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Raven, J. C.** (1965). *Coloured Progressive Matrices*. London: H. K. Lewis & Co.
- Reed, M. A.** (1989). Speech perception and the discrimination of brief auditory cues in reading disabled children. *Journal of Experimental Child Psychology*, 48, 270–292.
- Reitsma, P., & Wesseling, R.** (1998). Effects of computer-assisted training of blending skills in kindergartners. *Scientific Studies of Reading*, 2, 301–320.
- Rice, M. L.** (1997). Speaking out: Evaluating new training programs for language impairment. *Asha*, 39(3), 13.
- Segers, E., & Verhoeven, L.** (2002). Does speech manipulation make word discrimination easier? In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of functional literacy* (pp. 109–118). Amsterdam/Philadelphia: John Benjamins.
- Snow, C. E., Burns, M. S., & Griffin, P.** (1998). *Preventing reading difficulties in young children*. Washington, DC: National Academy Press.
- Snowling, M. J.** (2000). Language and literacy skills: Who is at risk and why? In D. Bishop & L. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 245–259). Hove, UK: Psychology Press.
- Stackhouse, J.** (2000). Barriers to literacy development in children with speech and language difficulties. In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 73–97). Hove, UK: Psychology Press.
- Stark, R. E., & Heinz, J. M.** (1996). Perception of stop consonants in children with expressive and receptive-expressive language impairments. *Journal of Speech and Hearing Research*, 39, 676–686.
- Studdert-Kennedy, M., & Mody, M.** (1995). Auditory temporal perception deficits in the reading-impaired: A critical review of the evidence. *Psychonomic Bulletin and Review*, 2, 508–514.
- Tallal, P., Miller, S. L., Bedi, G., Myma, G., Wang, X., Nagarajan, S. S., et al.** (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science*, 271, 81–84.
- Tallal, P., Miller, S. L., Jenkins, W. M., & Merzenich, M. M.** (1997). The role of temporal processing in developmental language-based learning disorders: Research and clinical implications. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia, implications for early intervention* (pp. 49–66). Mahwah, NJ: Lawrence Erlbaum Associates.
- Tallal, P., & Piercy, M.** (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologica*, 12(1), 83–93.
- Tallal, P., & Piercy, M.** (1975). Developmental aphasia: The perception of brief vowels and extended stop consonants. *Neuropsychologica*, 13(1), 69–74.
- Tallal, P., & Stark, R. E.** (1981). Speech acoustic-cue discrimination abilities of normally developing and language-impaired children. *The Journal of the Acoustical Society of America*, 69, 568–574.
- Tallal, P., Stark, R. E., Kallman, C., & Mellits, D.** (1980a). Developmental dysphasia: Relation between acoustic processing deficits and verbal processing. *Neuropsychologica*, 18, 273–284.
- Tallal, P., Stark, R. E., Kallman, C., & Mellits, D.** (1980b). Perceptual constancy for phonemic categories: A developmental study with normal and language impaired children. *Applied Psycholinguistics*, 1, 49–64.
- Treiman, R., & Zukowski, A.** (1996). Children's sensitivity to syllables, onsets, rimes, and phonemes. *Journal of Experimental Child Psychology*, 61, 193–215.
- van Kleeck, A., Gillam, R. B., & McFadden, T. U.** (1998). A study of classroom-based phonological awareness training for preschoolers with speech and/or language disorders. *American Journal of Speech Language Pathology*, 7, 65–76.
- Verhoeven, L.** (1987). *Ethnic minority children acquiring literacy*. Dordrecht, The Netherlands: Floris Publications.
- Verhoeven, L., Mommers, C., & Segers, E.** (1999). Schatkist met de muis [Treasure Chest With the Mouse] [Computer software]. Tilburg, The Netherlands: Uitgeverij Zwijsen.
- Verhoeven, L., & Segers, E.** (2004). Benefits of speech manipulation for children with language disorders. In L. Verhoeven & H. van Balkom (Eds.), *Classification of developmental language disorders* (pp. 383–400). Mahwah, NJ: Lawrence Erlbaum Associates.
- Verhoeven, L., & Van Kuyk, J. J.** (1991). Peiling van conceptuele en metalinguïstische kennis bij de aanvang van het basisonderwijs [Assessment of conceptual and metalinguistic knowledge at the entrance of kindergarten]. *Pedagogische Studiën*, 68, 415–425.

Yopp, H. K., & Yopp, R. H. (2000). Supporting phonemic awareness development in the classroom. *The Reading Teacher*, 54, 130–143.

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APPENDIX. SCREEN EXAMPLES OF COMPUTER INTERVENTION

Example of Game 1: Find the two rhyming pictures (*voet-hoed*, foot-hat). The same screen is used for variant 6: Find the set of pictures with the same initial phoneme. The three word sets are auditorially presented to the child and could also be heard again by pointing to a set of pictures.

Example of Game 2: Find the funny man who can rhyme. Each funny man presents the child with one word set. The three word sets are automatically presented to the child and could also be heard again by pointing to a funny man. When a funny man says something, he moves his lips, so the child knows which man is speaking.

Example of Game 8: What did the bunny say? (e.g., m-oon), or, in Game 10: m-oo-n. The same screen is used for Game 4. The bunny says a word in segments, automatically followed by three different words, represented by the three little figures. One of the three words is the same as the word spoken by the bunny, but not in segments.

Example of Game 9: The clown says m-oo-n, the black dots below the clown fill up at the moment a phoneme is being spoken. Then, the computer automatically presents the words represented by the pictures. The child has to find the correct picture. The same screen without the black dots is used for Game 7.

Screen examples from “Schatkist met de muis” [Treasure Chest With the Mouse] [Computer software] by L. Verhoeven, C. Mommers, and E. Segers, 1999. Copyright 1999 by Uitgeverij Zwijsen. Reprinted with permission.

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