Long-term effects of computer training of phonological awareness in kindergarten

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Abstract
The present study examined the long-term effects of a computer intervention for the development of phonological awareness in Dutch kindergartners. Native Dutch and immigrant children worked with the software 15 min/week during one school year. Following a pretest – interim test – post-test – retention test design, the effects on rhyming, phonemic segmentation, auditory blending, and grapheme knowledge were assessed. The intervention showed significant immediate effects on rhyming and grapheme knowledge. The time spent on the computer games also correlated with the learning gains for the experimental group. In the first grade, retention effects were demonstrated after 4 months of formal reading education.

Keywords: CD-ROM, control group, experiment, kindergarten, multimedia, phonological awareness, second language learning

Introduction
In kindergarten, considerable attention is devoted to children’s emergent literacy development in order to facilitate their later reading and spelling development. Teachers try to develop children’s phonological awareness, which has been shown to be an important predictor of success in learning to read (cf. Blachman 2000). Phonological awareness has been described as awareness of – among other things – rhyme, syllables, the beginning parts of words, and the end parts of words (Snow et al. 1998; Yopp & Yopp 2000). Children often develop rhyme and syllable knowledge first, followed by onset-rime knowledge. The awareness of phonemes develops at a later stage (Treiman & Zukowski 1996).

Research on phonological awareness has a rich history. A classic study was conducted by Bradley and Bryant (1983), who showed a causal link between phonological awareness and reading. More specifically, high correlations were found between performance on phonological awareness tasks before reading education and both reading and spelling level 3 years later, even when IQ and memory were controlled for.

The causal link originally suggested by Bradley and Bryant (1983) has been refined by other researchers, who have reached a consensus that a reciprocal relation exists between phonological awareness and reading. Perfetti et al. (1987), for example, found both auditory blending to be a predictor of reading ability and reading ability to be a predictor of such more complex phonological abilities as deletion (e.g., ‘say cat without t’). Wagner and Torgeson (1987) reached a comparable conclusion and went on to speculate that reading plays a causal role in the awareness that words can be divided into separate phonemes. The existence of a reciprocal relation between phonological awareness and reading has been supported by more recent empirical studies by, for example, Bowey (1994), McGuinness et al. (1995), and the overview presented by Blachman (2000) in the Third Handbook of Reading Research.
Effects of phonological awareness training

Phonological awareness does not always develop spontaneously. Lundberg et al. (1988) trained kindergartners before they learned how to read and thereby showed that phonological awareness can be trained before the start of reading education. In addition, long-term retention effects on the reading and spelling abilities of the children in question were demonstrated. The children did not learn about letters, however, while Share et al. (1984) in a longitudinal observation study found phoneme segmentation and knowledge of letter names to be the two most important predictors of learning to read successfully.

In addition to the correlation study mentioned above, Bradley and Bryant (1983) also conducted a training study that is more elaborately described in Bradley and Bryant (1985). At-risk children benefited from the training of phonological awareness just as children developing phonological awareness more spontaneously. They also found that the addition of letter–sound connections to the training had an additional effect on the spelling abilities of the children.

The study by Bradley and Bryant (1985) was conducted when the children were already learning to read. Ball and Blachman (1991) later studied the differential effects of training letter–sounds in combination with segmentation training with non-reading kindergartners and found combined training to be more powerful than letter–sound training alone. Much more research was conducted along these lines. Two recent meta-analyses summarize the results with regard to the training of phonological awareness. Bus and Van IJzendoorn (1999) and Ehri et al. (2001) both found direct positive effects of interventions concerned with phonological awareness and transfer effects for decoding. The long-term effects were still significant for phonological awareness, spelling, and reading comprehension. For decoding, only Ehri et al. found positive long-term effects.

The preceding analyses clearly show combined training addressing both phonological awareness and letter–sounds to be most effective. Training effects were most salient before the start of reading education. And children from both regular and special education benefit equally from such training. The meta-analysis by Ehri et al. (2001) also showed such training and the transfer to decoding to be most effective when only one or two abilities are trained. When more abilities are trained, the average effect-size drops from 0.70 to 0.27, which may reflect the need for the children to divide their attention across too many different tasks or abilities. The training is also most effective with a duration of 5–18 h. Ehri et al. (2001) also compared the training of English with other languages and found the phonological awareness training in other languages with a more transparent orthography to produce weaker effects and a less strong transfer to decoding.

Computer training of phonological awareness

The first studies on computer training of phonological awareness were published in the 1990s. Foster et al. (1994) developed and studied the software programme DaisyQuest in two studies with kindergartners trained for 6.5 and 4.9 h, respectively. The children worked with the programme about 20–25 min/day, and the control group simply did not have access to the software. Both studies showed positive effects of the training.

Barker and Torgeson (1995) conducted yet another study of DaisyQuest with children at-risk for reading problems. In this study, however, one control group played other games on the computer and one control group received decoding training (not on the computer). Both control groups showed less progress than the experimental group with regard to several aspects of phonological awareness.

In yet another study, Reitsma and Wesseling (1998) trained a group of Dutch kindergartners on one aspect of phonological awareness, namely auditory blending, using the computer. One control group received vocabulary training on the computer and one control group received no training whatsoever. The experimental group showed higher learning gains after training and also better decoding abilities 4 months after training in grade 1 than both of the control groups.

Mioduser et al. (2000) compared computer intervention with regular intervention and found more positive effects for the computer intervention. However, the training of the computer group was more ‘adaptive’ and included such activities as manipulating the letters in words, which the regular intervention
did not. Their conclusion should therefore be considered with care.

The meta-analysis by Ehri et al. (2001) counted only seven computer studies. Less strong effects were found for computer interventions when compared with regular interventions. However, the fact that most studies were conducted with children with reading problems may have influenced these results. As Ehri et al. pointed out, more research in this area is necessary. Only one computer study examined the long-term effects of an intervention in kindergarten (Reitsma & Wesseling 1998), but this study was specifically aimed at the training of blending and not the other aspects of phonological awareness. It may also be noted that none of the computer studies addressed training of phonological awareness of second language learners. As Bialystok and Herman (1999) have pointed out, bilingual children may actually have a small advantage over monolingual children on simple phonological awareness tasks. However, when the disparity between the sound systems of the two languages is too great, this advantage may disappear.

The present study

In the present study, a long-term computer intervention involving the training of several aspects of phonological awareness and grapheme–phoneme knowledge was undertaken in a Dutch kindergarten. The purpose of the study was to identify any direct learning gains and any long-term effects of training after 4 months of formal reading education. The differences in the learning gains for native versus immigrant children were also addressed within the context of the present study as a large group of immigrant children, from – among other places – Turkey and Morocco exists in the Netherlands. Verhoeven and Van Kuyk (1991) have shown Dutch immigrant children to perform below native children on such tasks as rhyming during the first year of kindergarten. Verhoeven and Narain (1996) did not find such differences after a year in kindergarten, although Verhoeven (2000) found Dutch immigrant children to have slight problems with the acquisition of Dutch grapheme knowledge at the start of formal reading education and to clearly lag behind their peers on such tasks as phonemic segmentation and word spelling, which suggests that the situation of Dutch immigrant children should indeed be considered in greater detail.

Method

Participants

The participants were 100 children in their second year of kindergarten (which is a 2-year programme in the Netherlands). This was part of the population that also received a vocabulary intervention that was described in Segers and Verhoeven (2003). Since this vocabulary intervention did not involve any written language or any reference to phonological characteristics of the words involved, but only focused on semantics, this does not interfere with the intervention described in the present study (cf. Snow et al. 1998). The experimental group consisted of 16 native and 26 immigrant children (20 boys, 22 girls) from one school with two different locations. The control group, from two other schools, consisted of 22 native and 36 immigrant children (26 boys, 32 girls). The average age of the children at the start of the experiment was 5 years and 6 months (SD = 4.42 months). In the experimental group, 78.0% of the mothers and 70.0% of the fathers had a lower level of education; in the control group, 79.6% of the mothers and 76.1% of the fathers had a lower level of education.

During the retest in first grade, the experimental group consisted of 13 native and 21 immigrant children; the control group consisted of 20 native and 24 immigrant children. The other children were not available for the retention test because of having moved or staying an extra year in kindergarten.

Material

Phonological awareness tasks

- A rhyming task (Verhoeven and Van Kuyk 1991). The task consisted of two training and 10 test items. The children saw a picture and had to select another rhyming picture out of four options. Distracters included semantically related pictures.
- A phonemic segmentation task (Verhoeven 1987). The task consisted of 20 words of increasing difficulty (starting with consonant-vocal words). The test was broken off when a child could not analyse five words in succession.
- An auditory blending task (Verhoeven 1987). The task consisted of 20 words of increasing difficulty (from two to six phonemes). The test was broken...
off when a child could not synthesize five words in succession.

**Literacy tasks**

- A grapheme knowledge task was conducted in which all 34 Dutch graphemes (including digraphs) were presented to the children on a sheet of paper. Children had to produce the letter-sounds and not the letter names (Verhoeven 1995).
- Because not many children can read in kindergarten, a decoding task was only administered as part of the retention test. Children had to read as many cvc words as possible in 1 min. The score was the number of correct words read by the child (Verhoeven 1995).

**Experimental programme**

The experimental programme consisted of five educational CD-ROMs specially designed for use in a school environment. Each CD-ROM contains nine different games, collected in a virtual treasure chest. Although the appearance of the games changes for motivational reasons they are essentially the same for all five of the CD-ROMs. The content on each CD-ROM also differs (e.g., other nursery rhymes, other words to be synthesized, etc.). The children can choose the game they want to play. At the start of the training, not all of the games are available. Once the child shows certain abilities, a more advanced game can be chosen. The nine games can be divided into so-called *discovery games* and *learning games*. The games draw – among others – upon the studies by Lundberg *et al.* (1988), Labbo (1996), and Share (1995). A more elaborate description of the software and its theoretical foundations can be found in Segers and Verhoeven (2002).

**Discovery games**

When the children start playing with the programme, they can select one of five different games. Four of the games are discovery games; the fifth is a rhyming and blending game. The first discovery game contains two songs and two rhymes per CD-ROM. The text appears in karaoke on the screen. By playing this game the child can discover that one starts reading at the top left part of a page, or that the direction of reading is from left to right. Children can also discover that sentences are divided into words and that words can rhyme. Lundberg *et al.* (1988) also used nursery rhymes in their intervention but did not include text. As was already established, however, the combination of phonological awareness and written text elicits higher learning gains (Ehri *et al.* 2001).

The second discovery game is a colouring game. The child must colour a picture by matching the colour name in the picture to the name on a paint bucket. In such a manner, children can learn the names of the colours and see the differences between the relevant graphemes. A child can also choose to leave the words out of the picture by clicking on a letter–flower at the bottom of the screen. The picture can then be filled with the colours that he or she prefers.

The third discovery game involves making a little booklet. Children can fill in the slots in sentences and thereby create their own book to be printed and taken home. In such a manner, they learn how thoughts can be put on paper and be recaptured by print.

The fourth discovery game involves having the children make their own picture postcard by stamping and drawing. The learning goal is about the same as in the third game. Labbo (1996) has highlighted the importance of children’s symbol making, and this activity is supported by these games.

**Learning games**

The rhyming and blending game is the first of the learning games and available at the start of the training. It is an adaptive game that switches between 10 different rhyming and blending exercises. The exercises automatically increase in difficulty when the child shows no problems at a particular level. Making a sentence rhyme by selecting the right picture is an example of such a rhyming exercise: *The cat sleeps on the* (mat, chair, floor). Selecting the right picture to go with a segmented sound pattern is an example of such a blending exercise: /s-ou-p/. Each type of exercise consists of three sets of five questions; this is a total of 750 questions across the five CD-ROMs. These games are comparable with the rhyming and blending games in Lundberg *et al.* (1988).

When a child is able to blend consonant–vowel–consonant words in the rhyming and blending game, the first two games involving graphemes become available. The first letter game demonstrates the basic reading process by spelling the phonemes and com-
bining them into a word. The word is spoken and then removed from the screen. The child must then place the accompanying picture into one of two boxes, selecting the one that represents the correct initial grapheme of the word. Children learn how ‘reading’ is done and gain familiarity with the different graphemes via this game.

The second letter game requires the child to copy simple consonant–vowel–consonant words. The graphemes for each position in the word can be found by clicking on an arrow. This game is easy to perform, which gives the child some reading success experiences. The child can also discover how changing a single grapheme can create a new word.

When a child shows no problems with the previous games, a new game becomes available to test his or her grapheme knowledge. In this letter game, the child is asked to point at the object with the grapheme a parrot asks for. The programme makes a ‘letter book’ containing all the graphemes that a particular child knows.

When the child knows enough letters to make at least five consonant–vocal–consonant words, the final game becomes available. In this game, the child creates words with the letters he or she knows and tries to find the words for which a picture is available in the programme. All of the words are placed in a ‘word book’.

The games involving graphemes draw upon the self-teaching hypothesis put forth by Share (1995). The words used in these games have a one-to-one correspondence between text and sound, which gets the self-teaching mechanism started (Share 1995).

Control group software
Children in the control group also worked with computer programmes on occasion but not the software used by the experimental group. The teachers reported mostly using entertainment software or software involving stories and games with shapes and colours.

Procedure
During a 40-week period interrupted by 5 weeks of vacation (fall, Christmas, spring), the children from the experimental group worked with the computer language games of the computer programme once a week for a period of 15 min. During the last 10 weeks of the school year, the children could play with the language games up to three times per week. It was checked that they worked with the learning games at least once every 2 weeks. During these last 10 weeks, other games on the CD-ROMs could be played. The other games involved stories and vocabulary acquisition. Because of hardware problems, the computer data for some of the children were lost during the school year; for 35 of the original 42 children from the experimental group, the data were available. On average, these children played 4 h and 21 min (SD = 1 h, 3 min) with the discovery games and 4 h and 3 min (SD = 1 h) with the learning games (2 h and 44 min of which were spent on games involving letters).

In the main building of the school, several computers were placed in the central hall. Volunteer parents took the children from the classroom and helped them get started with the programme. At the end of the session, the volunteers returned the children to their classes. In an annex building of the school in another part of town, two computers were placed right outside the classroom. The teacher did not need volunteer parents and could position the children behind the computer herself.

The five available CD-ROMs were alternated during the school year. The adaptivity of the software spanned all of the CD-ROMs, which meant that a child had access to a certain game on one CD-ROM and the other CD-ROMs as well. The children worked individually with the software and wore headphones during the sessions. The discovery games were not always available. Every other 2 weeks, they were turned off for 2 weeks in order to make sure that the children also worked with the more difficult learning games.

Pre-testing took place at the start of the school year. Interim testing was undertaken halfway through the school year, just after the Christmas vacation. Post-testing was conducted just before the summer vacation. Retention testing took place in first grade after 4 months of formal reading instruction, just before the Christmas vacation. Because of ceiling effects during kindergarten, the rhyming task was omitted at this point.

Data analysis
Multivariate repeated measures analyses were undertaken (Maxwell & Delaney 1990). Time was the
within-subjects factor (pretest, interim test, post-test). The between-subjects factor were Intervention (experimental group, control group) and Ethnicity (native, immigrant). In the case of a two-way interaction of Time with one of the other variables, the results were further explored using independent samples t-tests. Given that five tests were conducted (measurements 1, 2, and 3 and progress between measurement 1 and 2; progress between measurement 2 and 3), the α level was changed from 0.05 to 0.01.

Results

Intervention effects

Table 1 shows the mean scores for each group on the different tests. The following sections will deal with each of the tests separately.

Rhyming

The analysis of the rhyming task revealed a main effect of Time \( (F(2, 95) = 52.253, \ P < 0.001, \ \eta^2 = 0.524) \), an interaction between Time and Ethnicity \( (F(2, 95) = 5.425, \ P = 0.006, \ \eta^2 = 0.103) \), and a three-way interaction between Time, Intervention, and Ethnicity \( (F(2, 95) = 4.042, \ P = 0.021, \ \eta^2 = 0.078) \). Also, a main effect of Ethnicity \( (F(1, 96) = 27.889, \ P < 0.001, \ \eta^2 = 0.225) \) was found.

The three-way interaction was further explored in a series of one-way ANOVAs with the three measurement points as the dependent variables and four groups as the independent variables (native experimental, native control, immigrant experimental, immigrant control). The ANOVAs showed significant between-groups effects at pretest, interim test, and post-test (pretest: \( F(3, 96) = 11.223, \ P < 0.001, \ d = 1.3511 \); interim test: \( F(3, 96) = 6.981, \ P < 0.001, \ d = 0.985 \); post-test: \( F(3, 96) = 4.936, \ P = 0.003, \ d = 0.8753 \). Post hoc tests with Bonferroni's correction revealed significant differences between the two native groups and the two immigrant groups at pretest \((P < 0.02 \text{ in all cases})\). At the other two measurement points, the immigrant experimental group no longer differed from the native groups. The immigrant control group still differed from the native groups \((P < 0.02 \text{ in all cases})\).

Figure 1 shows the most gain to be made between the first and second measurement points. An ANOVA shows a significant Group effect on the progress made between the first and second measurement points \((F(3, 96) = 4.036, \ P = 0.009, \ d = 0.844)\), but not between the second and third measurement points \((F(3, 96) = 1.948, \ P = 0.127, \ d = 0.554)\). According to post hoc comparisons with Bonferroni’s correction, the significant Group effect can be attributed to the immigrant experimental group, which makes more progress than the immigrant control group \((P = 0.013)\) and the native experimental group \((P = 0.04)\) within the same time frame.

Figure 1 shows the average scores on the rhyme task. One can see that native children reach ceiling at post-test.

Table 1. Average pretest, interim test, and post-test scores on rhyming, phonemic segmentation, auditory blending, and grapheme knowledge of native and immigrant experimental \((n = 42)\) and control children \((n = 58)\)

<table>
<thead>
<tr>
<th></th>
<th>Experimental native</th>
<th></th>
<th>Experimental immigrant</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Interim test</td>
<td>Post-test</td>
<td>Pretest</td>
</tr>
<tr>
<td>Rhyming</td>
<td>7.63 (3.36)</td>
<td>8.75 (2.14)</td>
<td>9.50 (1.15)</td>
<td>2.92 (3.03)</td>
</tr>
<tr>
<td>Phonemic segmentation</td>
<td>0.56 (1.99)</td>
<td>2.69 (3.98)</td>
<td>3.31 (4.51)</td>
<td>0.08 (0.27)</td>
</tr>
<tr>
<td>Auditory blending</td>
<td>1.88 (2.36)</td>
<td>2.94 (3.15)</td>
<td>5.25 (4.96)</td>
<td>1.08 (1.49)</td>
</tr>
<tr>
<td>Grapheme knowledge</td>
<td>0.13 (0.34)</td>
<td>3.25 (4.31)</td>
<td>4.56 (6.48)</td>
<td>0.85 (2.15)</td>
</tr>
<tr>
<td>Control native</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhyming</td>
<td>6.73 (2.88)</td>
<td>8.91 (1.80)</td>
<td>9.36 (1.71)</td>
<td>4.19 (2.99)</td>
</tr>
<tr>
<td>Phonemic segmentation</td>
<td>0.73 (2.05)</td>
<td>2.00 (3.09)</td>
<td>2.55 (4.37)</td>
<td>0.12 (2.48)</td>
</tr>
<tr>
<td>Auditory blending</td>
<td>1.18 (1.59)</td>
<td>3.68 (3.12)</td>
<td>5.68 (4.79)</td>
<td>1.83 (3.90)</td>
</tr>
<tr>
<td>Grapheme knowledge</td>
<td>1.55 (3.26)</td>
<td>4.23 (3.68)</td>
<td>5.18 (5.96)</td>
<td>2.14 (4.90)</td>
</tr>
</tbody>
</table>

Standard deviations in parentheses.
For phonemic segmentation, only a main effect of Time was found ($F(2, 95) = 19.342$, $P < 0.001$, $\eta^2 = 0.289$). The average score for the entire group of children increased from 0.560 (SD = 1.945) at pretest to 1.870 (SD = 3.264) at interim test to 2.860 (SD = 4.264) at post-test.

For auditory blending as well, only a main effect of Time was found ($F(2, 95) = 34.486$, $P < 0.001$, $\eta^2 = 0.421$). The average score for the entire group of children increased from 1.492 (SD = 0.287) to 3.418 (SD = 0.449) to 5.821 (SD = 0.591).

Once again the analyses reveal a main effect of Time ($F(2, 95) = 27.821$, $P < 0.001$, $\eta^2 = 0.369$). There were trends towards an interaction between Time and Intervention ($F(2, 95) = 2.627$, $p = 0.078$, $\eta^2 = 0.052$) and between Time and Ethnicity ($F(2, 95) = 2.813$, $P = 0.065$, $\eta^2 = 0.056$). Although the groups did not differ significantly at any of the three measurement points, independent sample $t$-tests to examine the Time by Intervention interaction showed the experimental group to have a higher learning gain between the second and third measurement points than the control group ($t(73.543) = 2.620$, $P = 0.011$, $d = 0.547$).

The trend towards an interaction between Time and Ethnicity was also further explored. There was no difference between the native and immigrant children at any of the specific measurement points. However, the immigrant children learned slightly more new graphemes between the second and third measurement points than the native children ($t(98) = -2.016$, $P = 0.046$, $d = 0.426$). Figure 2 visualizes the results.

**Effects of computer time**

In Table 2, the correlations between the learning gains during the school year and the amount of time spent on the computer intervention for the 35 children from the experimental group whose data were not corrupted by hardware problems are presented. One can see significant negative correlations between the amount of time spent on discovery games and the learning gains for rhyming, phonemic segmentation, auditory blending, and grapheme knowledge. The amount of time spent on the rhyming and blending learning game...
on the computer positively correlated with the learning gain for the rhyming task but not the blending task. Finally, the amount of time spent on the learning games involving letters positively correlated with the learning gains for phonemic segmentation, auditory blending, and grapheme knowledge.

**First grade retest effects**

Multivariate analyses of variance with phonemic segmentation, auditory blending, grapheme knowledge, and decoding as the dependent variables and Intervention and Ethnicity as the fixed factors showed a main effect of Intervention ($F(4, 71) = 4.346$, $P = 0.003$, $\eta^2 = 0.197$). No significant effect of Ethnicity was found and also there was no significant interaction between Ethnicity and Intervention. Tests of the between-subject effect showed the grapheme knowledge of the experimental and control groups to differ significantly after 4 months of reading education ($F(1, 74) = 10.781$, $P = 0.002$, $\eta^2 = 0.127$). Table 3 contains a summary of the results.

**Discussion and conclusion**

**Effects of the computer intervention**

The present study was aimed at discovering whether extended computer intervention could promote the development of phonological awareness among native and immigrant kindergartners. The children worked with the software once a week for 15 min throughout the entire school year. Discovery games were only available half of the time while the learning games were always available. Contrary to our expectation, the intervention did not directly affect the children’s auditory blending and no transfer effects were found for phonemic segmentation. However, on rhyme the intervention showed significant positive effects for the immigrant children, which was explicitly trained within the computer programme. The intervention thus allowed the immigrant children to catch up to the native children in this regard.

The intervention also showed significant positive effects for grapheme knowledge. The entire experimental group benefited from the presence of computer games involving letters. The experimental children showed more progress on grapheme knowledge during the second half of the school year than the control group.

The intervention showed significant positive effects on early literacy in first grade. Apparently, the programme facilitates children’s process of learning to read in first grade. In first grade, after 4 months of reading education and 6 months after completion of the intervention, all of the tasks were again administered, with the exception of the rhyming task, because

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**Table 2. Correlations between amount of time spent on various computer games and progress on various tasks during the school year ($n = 35$)**

<table>
<thead>
<tr>
<th></th>
<th>Progress rhyming ($r$)</th>
<th>Progress phonemic segmentation ($r$)</th>
<th>Progress auditory blending ($r$)</th>
<th>Progress grapheme knowledge ($r$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time discovery games</td>
<td>– 0.337*</td>
<td>– 0.451**</td>
<td>– 0.359*</td>
<td>– 0.358*</td>
</tr>
<tr>
<td>Time rhyming and blending game</td>
<td>0.469**</td>
<td>0.116</td>
<td>0.101</td>
<td>– 0.111</td>
</tr>
<tr>
<td>Time games involving letters</td>
<td>– 0.216</td>
<td>0.470**</td>
<td>0.400*</td>
<td>0.657**</td>
</tr>
</tbody>
</table>

*P < 0.05; **P < 0.01.

**Table 3. Average scores on phonemic segmentation, auditory blending, grapheme knowledge, and decoding of native and immigrant experimental ($n = 34$) and control children ($n = 44$) after 4 months of formal reading education**

<table>
<thead>
<tr>
<th></th>
<th>Phonemic segmentation (max = 20)</th>
<th>Auditory blending (max = 20)</th>
<th>Grapheme knowledge (max = 34)</th>
<th>Decoding (no. of words/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>13.26 (4.45)</td>
<td>17.43 (3.04)</td>
<td>33.76 (.55)</td>
<td>20.38 (10.47)</td>
</tr>
<tr>
<td>Control group</td>
<td>14.11 (4.76)</td>
<td>15.88 (3.81)</td>
<td>32.64 (1.97)</td>
<td>17.93 (7.39)</td>
</tr>
</tbody>
</table>

Standard deviations in parentheses.
of ceiling scores at the end of kindergarten and the additional administration of a decoding task in order to examine the early reading abilities of the children. The experimental group differed significantly from the control group in multivariate analyses of variance, which could mainly be ascribed to a higher grapheme knowledge.

After calculation of the correlations between the amount of time spent on the various computer games and the progress made on the different tasks during the school year, significant positive correlations between time spent on games involving letters and progress on auditory blending, phonemic segmentation, and grapheme knowledge were found. This suggests that the use of the computer programme clearly influenced these aspects of the language development of the children. We also found positive correlations between the amount of time spent on the rhyming and blending game and the children’s rhyming progress. In addition, those children who played the discovery games more often showed less progress than those children who played the learning games more often.

Some limitations of the present study

Although the intervention showed positive training results, we did not find the expected differences in learning gain for the experimental versus control groups on the auditory blending task. The correlations between computer training time and progress nevertheless showed a positive effect for blending while Reitsma and Wesseling (1998) found positive effects of a computer training programme on blending. The training in the Reitsma and Wesseling study was specifically focused on this aspect of language and consisted of various blending games while our training was much broader and only included one specific blending game. The results are thus in line with the conclusion by Ehri et al. (2001) that effect sizes drop when more abilities are trained.

The effects of the training on such variables as grapheme knowledge and decoding were smaller than we had hoped for. The adaptivity of the computer programme could be partly responsible for this. Children must keep playing different rhyming and blending games until they reach a certain level. It therefore takes a considerable amount of time for the children to start playing games involving letters. The fact that no effects of the intervention on grapheme knowledge were found in the first half of the year of the intervention can probably be ascribed to this. Also, those children who can already rhyme but not blend spend a lot of time on unnecessary rhyming exercises. Once children have access to the games involving letters, access to the other games is also not denied. A computer training is probably more effective when the adaptivity is thus more stringent. The negative correlations between time spent on discovery games and learning gain also point in this direction as the discovery games are less directly focused on learning. In light of Ehri et al.’s (2001) conclusion that the training of only one or two abilities at a time is most effective, a game addressing an aspect of phonological awareness that has already been mastered should no longer be available to the children at a certain point. A disadvantage of such strictness, of course, is that children may be less motivated because they cannot choose the games they want.

In addition to the adaptivity of the computer programme, it should be recognized that the awareness of kindergarten teachers on the importance of phonological awareness should be considered. Teachers spend considerable time on several elements of phonological awareness during the school year. A short-term computer intervention – such as the one conducted by Foster et al. (1994) – may therefore produce particularly positive results simply because the training was conducted before the teacher addressed that aspect of phonological awareness with the class as a whole.

The present study compared an experimental group from one school with a control group from two other schools. We acknowledge that certain differences between the groups may be related to differences between the teachers. Given that there were five different teachers in the experimental school and seven different teachers in the control schools, we nevertheless consider such a conclusion to be highly unlikely.

Practical implications

The computer proved to be a useful tool for helping children enhance their linguistic abilities. Compared with human teaching, the computer has obvious advantages such as endless repetition, direct feedback, and the fact that children do not feel judged. However, the computer could not take the place of human
intervention, as the effect sizes are smaller (Ehri et al. 2001). Effect sizes could maybe improve if the software would be made even more adaptive than the software used in this study. In such a manner, the children can benefit most from their computer time, which is a conclusion that Atkinson already reached back in 1974. Although computer programmes have advanced a lot since that time, it is amazing how little research has been conducted on how to optimize the software in such a promising area of application (cf. Ehri et al. 2001). Future research should also try to focus more on the interaction between computer activities and classroom activities. If the teachers refer to computer games or if children talk to each other about what they are doing on the computer, this could have an effect on the learning outcomes. This has not been taken into consideration in the present study. With respect to educational practice, the results of the present study show that it is possible to enhance the early literacy development of children with different linguistic and cultural backgrounds by using a computer training programme.

References


