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# Spelling feedback in an ICT-learning environment: Issues of proficiency, training efficiency, and transfer

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**Abstract**

This study was designed to compare the effectiveness of two different forms of feedback on spelling performance of Dutch Grade-2 students, that is, knowledge-of-results and informational feedback. In the knowledge-of-results feedback condition, the speller is told *that* the word is spelled incorrectly, whereas in the informational feedback condition, the speller is told *what* is spelled incorrectly. Three main questions were investigated. One, to what extent does the nature of feedback affect students with good and poor spelling skills differently? Two, does the nature of feedback affect various forms of spelling difficulties differently? Three, is training efficiency differentially affected by the nature of feedback?

The results showed that both feedback conditions were equally effective in teaching students the spelling of words, irrespective of spelling level and spelling difficulty. Both feedback conditions led to a similar level of transfer to a set of new words, the effect being stronger in good than in poor spellers. Transfer was best on analogy spellings, followed by rule-based, and worst on idiosyncratic spellings. The poor spellers learned the spelling of words more efficiently in the informational-feedback condition than in the knowledge-of-results condition, whereas for the group of good spellers efficiency was equally large in both conditions.


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## 1. Introduction

Previous research has shown that at least six aspects of a spelling training determine its effectiveness. Spelling *words from memory* yielded higher spelling gains than a training in which words remained visible (e.g., Bosman & de Groot, 1992; Roberts & Ehri, 1983; van Leerdam, Bosman, & Van Orden, 1998). Practising the *entire word* rather than the ambiguous phoneme–grapheme part is also more effective (e.g., Bosman & de Groot, 1992; Bosman & van Leerdam, 1993; van Leerdam et al., 1998). The word context in which the ambiguous phoneme–grapheme relationships is embedded, presents essential cues for its disambiguation (Bosman & Van Orden, 1997). There is also consensus about the fact that the word has to be produced *using bodily kinematics*, whether it be handwritten or typewritten (for a discussion on Orton-Gillinghams's multi-sensory technique, see Hulme & Bradley, 1983). The discussion regarding the question whether handwriting is more beneficial than the use of the computer keyboard is undecided. Cunningham and Stanovich (1990) and Berninger et al. (1998) showed that handwriting was superior to the computer keyboard in first graders, whereas Stainthorp (1997) and Vaughn, Schumm, and Gordon (1993), found equal benefits of handwriting and keying words in using a computer for a group Grade-2 students, and learning-disabled children. *Overlearning*, that is, learning until a perfect command of the spelling of a set of words is reached, is yet another component of an effective spelling training (Gerber, 1986). The value of learning until 100% correct is achieved is probably that at the end of the training students are exposed to correct models only.

The role of *immediate feedback* as opposed to delayed feedback is also crucial for effective spelling instruction in students with (e.g., Kearney & Drabman, 1993; Kulik & Kulik, 1988) and in students without spelling disabilities (e.g., Gettinger, 1993). Delayed feedback occurs when students receive the corrections of their spelling exercises hours, days, or even weeks after they have finished their exercise or test. Research has shown that particularly in a spelling training this kind of delayed feedback is not as effective as immediate feedback (Harward, Allred, & Sudweeks, 1994; Kearney & Drabman, 1993; Murphy, Hern, Williams, & McLaughlin, 1990). The positive effect of immediate feedback is probably because exposure to incorrect spellings depresses spelling performance in the short and in the long term (Brown, 1988; Dixon & Kaminska, 1997; Jacoby & Hollingshead, 1990). Finally, *self-correction* also appears an important factor in learning to spell (e.g., Murphy et al., 1990; Vaughn et al., 1993). Inspecting the word one has just written and correcting it when necessary not only provides immediate feedback on the accuracy of spelling the word, but is also an important step in the development of self-monitoring skills (cf., Reid & Harris, 1993).

Thus, important clues for effective spelling instruction have been known for a while, but at the same time some aspects have not been resolved yet. A salient and highly important one is the role of the nature of feedback. For example, it is unknown whether feedback affects the learning of good and poor spellers differentially or whether it influences training efficiency and knowledge transfer differently. The present study was designed to provide insights in these issues.

### 1.1. ICT and spelling

There is no doubt that computers provide an effective additional tool in teaching spelling (see for a meta-analysis, Torgerson & Elbourne, 2002). The current training was

developed in an ICT-learning environment that enabled students to practice the spelling of words without the presence of a human tutor. Students were presented with spoken words (pronounced by the computer), which they were asked to spell using the computer keyboard. Feedback was provided in one of two ways. One feedback condition, ''knowledge of results'', merely indicated whether or not the word was spelled correctly. In case of an incorrect spelling, they were asked to try again. After four attempts, the student was presented with the correct spelling, without being asked to try to spell the word again. We do not know of any empirical study that investigated the effectiveness of this type of feedback. The other feedback condition, ''informational feedback'', was tailored after a visual-dictation procedure that has been proven successful in previous studies with normally achieving students and students with learning difficulties (van Hell, Bosman, & Bartelings, 2003; van Leerdam et al., 1998). If, in this condition students had made a mistake, they were presented with the correct spelling of the word. After they had studied the spelling for a few seconds, it was removed from vision, and they were asked to try again. Fitzgerald, Fick, and Milich (1986) showed that a visual-dictation procedure on the computer was as effective as the more traditional write-and-check procedure. The spelling-training program contained all six aspects that appear to be required for effective spelling instruction; further details of the program will be presented in the Section 2.

### *1.2. Knowledge of results vs. informational feedback*

The distinction between 'knowledge-of-results feedback' and 'informational feedback' is a common one in the literature (e.g., Cohen, 1985; Geis, 1986; van der Linden, 1998). In case of knowledge of results, students receive information whether the response or answer that has been provided is correct or not. This kind of feedback generally provides students with relatively limited information regarding the underlying knowledge structure. In the present study, students were told that the spelling they had produced was either correct or incorrect; only after four attempts were they presented with the correct model, without the need to correct their wrong spelling. Informational feedback does provide the learner with at least some information as to what is wrong. Informational feedback can have several different forms: Presenting the right answer, referring to a definition, repeating a specific part of the instruction, pointing out the rule that should be applied, providing a new textual explanation, a demonstration, or a combination of these forms. In our study, we provided the speller with the correct model immediately after they had made their first incorrect attempt at spelling the word, which enabled the student to determine the error in their spelling and correct it as well.

Informational feedback is generally more effective than just providing knowledge-of-results feedback (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Cohen, 1985), but there are situations in which informational feedback can in fact be detrimental. For example, when it does not add to the students' knowledge base or when it slows down the instruction and learning process (Cohen, 1985). Moreover, a more limited form of feedback may be more beneficial in case of retention and transfer (Sims-Knight & Upchurch, 2001). Generally, however, it is believed that only a small number of students with high-cognitive capabilities are able to benefit from a more limited form of feedback. According to Geis (1986) and van der Linden (1998), informational feedback is particularly effective for students who have little pre-knowledge. It is therefore an interesting question whether or not students with relatively good spelling skills are actually capable of using the

information provided in the more limited feedback condition. Knowledge-of-results feedback may elicit a more active learning style in the good speller that enhances the students' involvement in the task, whereas in the poor spellers this task might just be too taxing, causing them to learn less than in a condition that provides the location of the error as in informational feedback.

### 1.3. Knowledge transfer

Any proper training brings about learning the materials that have been studied. Efficient training, however, also leads to learning beyond the materials studied when the knowledge base has a shared underlying knowledge structure. Training programs that allow students to generalize their knowledge acquired during training to new materials are highly valued. Research has shown that (spontaneous) transfer is remarkably uncommon in many domains of academic learning (e.g., Boeckaerts & Simons, 1995; Ellis, 1992). It has been argued that students first need to acquire transfer strategies before they are able to put their generalization skills into practice (Griffin, 1995; O'Sullivan & Pressley, 1984).

The present study also investigated whether different feedback conditions affect incidental learning of spelling differently. Incidental learning is reminiscent of implicit learning, which refers to a situation in which a person learns about the structure of stimuli in their environment without the intention to do so, and in such a way that it is usually hard to express what exactly this knowledge structure is (Berry, 1997). Thus, the learner has no real intention to learn, it simply happens. Effects of implicit learning are visible on transfer items. Implicit learning in the domain of spelling is presented by Steffler (2001) and Kemp and Bryant (2003) in English, and Pacton, Perruchet, Fayol, and Cleeremans (2001) in French. Bosman, van Hell, and Verhoeven (2006) showed that young Dutch students with and without learning difficulties were capable of generalizing spelling knowledge they had acquired to materials not studied.

Two important findings related to implicit learning are relevant in the present context. One, implicit learning shows smaller population variance than explicit learning, thus fewer individual differences are expected in case of implicit-learning tasks (Reber, Walkenfeld, & Hernstadt, 1991). Two, implicit learning is, unlike explicit learning, largely unrelated to measures of high-level cognitive functioning (Reber et al., 1991). This suggests that differences between good and poor spellers are more prominently visible on explicitly learned words, and diminished or absent on novel words (i.e., words not studied).

### 1.4. Dutch orthography

As said, transfer is limited to a knowledge base with a shared underlying knowledge structure. Thus, with respect to orthography, transfer can only occur on words that share a particular spelling structure. In Dutch spelling curricula, analogy spellings are an example of a set of words that share a spelling structure. Analogy spellings refer to grapheme–phoneme relationship in words that are not prototypical Dutch, and at the same time they are shared by a larger set of words. For example, the initial phonemes [sj] in CHOCOLADE [*chocolate*] and in CHANTAGE [*blackmail*] have identical initial graphemes CH. Students who become aware of the fact that particular phoneme–grapheme relationships belong to one category, may use their skill to apply analogy reasoning to determine the spelling of a word that contains a similar aspect.

Another example of a set of Dutch words that share knowledge structure are 'rule-based' spellings (e.g., Bosman, 2005). These words require the acquisition and application of a set of spelling rules. For example, the Dutch phoneme [a] can be spelled with either AA or A; the word [pal] is spelled PAAL (*pole*), whereas its plural [pal'n] is spelled PALEN. This is the result of a spelling rule that states that vowels in open syllables reduce to one (see for details Bosman, de Graaff, & Gijsel, 2006). Mastering this rule is one of the major tasks of Dutch students in Grade 2.

A third set of words, spellings with ambiguous phoneme-to-grapheme relationships, do not share spelling structure. These spellings are idiosyncratic, because there is no way to deduce the proper grapheme for a particular phoneme, other than rote memorization. Many Dutch words contain ambiguous phoneme–grapheme relationships. Often, a phoneme has at least two and sometimes even four different graphemes. For example, the Dutch word [sAus] (*sauce*) contains the phoneme [Au], this phoneme has four different graphemes OU, AU, OUW, and AUW. The proper spelling is SAUS. Generally, most words only contain one or two ambiguous phoneme–grapheme relationships, leaving the remaining phonemes consistent in their sound-letter spelling. An English example is the phoneme [i], which spelled EE as *beer* and EA as in *fear*.

These spelling categories are not based on exhaustive linguistic principles, but are rather the result of experience from educational practice. These spelling categories were used in the present experiment for two reasons. One, all students were familiar with these types of spelling categories, and therefore have a high level of ecological validity. Second, they allowed us to study the differential effects of transfer. Only analogy and rule-based spellings are expected to reveal a transfer effect. Students may incidentally learn about the rule underlying some of the spelling aspects or detect analogies in new words, because these spelling difficulties share an underlying structure. It is unlikely, however, that transfer will occur on words with ambiguous phoneme–grapheme relationships because each new word with an ambiguous phoneme–grapheme relationship is a case of its own.

### 1.5. Spelling proficiency

Spelling is a more difficult skill to master than reading (Bosman & Van Orden, 1997), and students who appear to read relatively adequately may still be atrocious spellers, whereas the opposite is rarely seen (e.g., Frith, 1980). In what respect do good spellers differ from poor spellers? Radebaugh (1985), for example, showed that good spellers had a larger set of strategies available than poor spellers. Unlike poor spellers, who mainly used phoneme-to-grapheme conversion, good spellers also applied breaking down the words in larger units and they said that they also used visual imagery. Note that good spellers do not necessarily have a better visual-sequential memory per se, only when it concerns verbal materials (Giles & Terrell, 1997). Gerber (1984), however, maintains that contrary to widely held opinion, spelling errors of students with spelling difficulties are not qualitatively different, they simply make more errors (see also, Bosman & Van Orden, 1997; Kamhi & Hinton, 2000).

More and more researchers acknowledge that the same phonological deficit that underlies poor reading is responsible for poor spelling (e.g., Perfetti, 1997; Kamhi & Hinton, 2000). For reasons explained in Bosman and Van Orden (1997), we believe that a mild phonological deficit may affect spelling performance leaving reading relatively unaffected, whereas a more severe phonological deficit affects both skills. It is therefore not

surprising that in a regular classroom more students appear to be delayed in spelling than in reading. Although performance differences do (and probably always will) exist among students, the main issue for educators is to keep these differences to an acceptable level. The scientific question that emerges from this is: do poor spellers require a qualitatively different instructional approach than good spellers? This issue has not received a great deal of attention.

In most studies and for obvious reasons, only poor spellers receive a particular treatment, but it precludes an answer to whether an instruction method affects good and poor spellers similarly. Gettinger (1993) showed that an error-correction approach applied to Grade-3 students, reminiscent of the procedure investigated in the present study, yielded substantial effects. It remained unclear, however, whether low-achieving and high-achieving students benefited equally. Gerber (1986) revealed that a similar approach was indeed beneficial for students with learning difficulties (more specifically, spelling difficulties). Van Oudenhoven, Siero, Veen and Siero (1982) conducted an experiment with Grade-3 students and showed that both high and low achieving spellers benefited equally from positive feedback. To add to the knowledge regarding effective instruction, the present study was developed to assess the potential differential role of feedback in students with good and poor spelling skills. Feedback is an important aspect of proper spelling instruction, but it is unclear what kind of feedback is required, and whether or not spelling proficiency interacts with the nature of feedback. Informational feedback might be effective in both good and poor spellers, whereas good spellers might also profit from a more limited form of feedback, like knowledge of results.

### *1.6. Research questions*

Three major hypotheses will be put to test each addressing a major aspect of learning, that is, training, transfer, and efficiency. The first hypothesis concerned the effect of training on words that were learned during the training. Both training conditions are expected to enhance spelling performance in second-graders, but more so in the informational-feedback condition than in the knowledge-of-results feedback condition. As explained above, informational feedback uses more effective feedback, and the experiment is carried out with young inexperienced students who are expected to particularly benefit from this kind of feedback. However, we expect students with good spelling skills to profit from both conditions, whereas students with poorer skills are expected to benefit from the informational-feedback condition only, because they require qualitatively better feedback. An additional issue that was explored were differential effects of training on learning different types of spelling difficulties, that is, rule-based spellings, analogy spellings, and spellings with ambiguous phoneme–grapheme relationships.

The second hypothesis pertained to the issue of transfer. The first question that was put to test was whether transfer occurred at all. If so, it was expected that transfer would only occur on words that share an underlying structure, that is, on rule-based and analogy spellings, but not on spellings with ambiguous phoneme–grapheme relationships. An additional issue was the potential differential effect of spelling level on the presence of transfer.

The third and final hypothesis concerned training efficiency. The program kept a logfile of each of the students during training, which made it possible to keep track of training

development. We expected informational feedback to be more efficient than knowledge-of-results feedback. More specifically, we expected more words to be studied and fewer attempts needed to spell a word correctly in the informational-feedback condition than in the knowledge-of-results feedback condition. After all, in the former condition students are presented with the correct model, which enables them to find the error on their first attempt, whereas in the latter condition, students have to figure out what the error is without the correct model visible, which may require more than one trial in the knowledge-of-results feedback condition. The differential effect of spelling level will again be investigated.

## 2. Method

### 2.1. Participants

Forty Dutch-speaking students (19 girls and 21 boys), with a mean age of 89 months ($SD = 5.1$), attending Grade 2 of a regular-primary school in the Netherlands took part in this experiment. They all received a spelling pretest. The score on the pretest was used to create matched pairs. One of each pair was randomly assigned to one of two experimental training conditions, that is, knowledge-of-results feedback or informational feedback (details below). A $t$ test for independent samples revealed that the to two groups did not differ significantly from each other on the pretest, $t(38) = -0.35$, $p = 0.73$. Table 1 lists the scores on the pretest of all students who took part in the training and the mean scores of each of the groups.

### 2.2. Materials and procedure

The words that were used for the spelling training were selected from the learning materials used in second grade. To ensure that the students knew the meaning of these words the 'Unaniemenlijst alleen Nederlands' (Kohnstamm, Schaerlaekens, de Vries, Akkerhuis, & Froonincksx, 1981) was used. This is a list of Dutch words indicating the average percentage of students who know the meaning of a word from that list at a particular age. In the training, only words were used of which at least ninety percent of the students were expected to know the meaning. Homophones, words with multiple spellings were excluded from the stimulus set (a Dutch example of a homophone pair is HEI and HIJ, an English example is DEER and DEAR). Only words that could be spelled in one way were used in the training. Finally, it was required that each word contained at least one spelling difficulty. In this context, a spelling difficulty refers to a part of the word in which spelling errors are to be expected.

Based on the selection criteria above, a list of 200 words was composed that was used on the pretest. The set contained words with ambiguous phoneme–grapheme relationships, rule spellings, and analogy spellings (see introduction for a description of each of the categories). The set of 200 words was divided in two randomly constructed lists of 100 words each. One half of the students (one class) was asked to write down from dictation the words from List A containing 100 words, whereas the other half of the students (the other class) had to write down the words from List B which consisted of the other set of 100 words. The test was administered in the classroom setting allowing sufficient time to write down each word.

Table 1
Number of practised words and pretest and posttest descriptive statistics in both conditions

| Feedback condition | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Knowledge of results | | | | | Informational feedback | | | | |
| Student | Practiced | Pre | Post | Diff | Student | Practiced | Pre | Post | Diff |
| 1 | 100 | 83 | 80 | −3 | 1 | 69 | 82 | 86 | 4 |
| 2 | 100 | 55 | 85 | 30 | 2 | 100 | 81 | 92 | 11 |
| 3 | 69 | 51 | 81 | 30 | 3 | 100 | 53 | 83 | 30 |
| 4 | 100 | 50 | 81 | 31 | 4 | 100 | 52 | 90 | 38 |
| 5 | 65 | 43 | 71 | 28 | 5 | 76 | 49 | 76 | 27 |
| 6 | 12 | 27 | 44 | 17 | 6 | 38 | 31 | 62 | 31 |
| 7 | 19 | 27 | 35 | 8 | 7 | 57 | 29 | 66 | 37 |
| 8 | 64 | 15 | 52 | 37 | 8 | 47 | 19 | 36 | 17 |
| 9 | 25 | 13 | 28 | 15 | 9 | 34 | 14 | 41 | 27 |
| 10 | 14 | 12 | 29 | 17 | 10 | 38 | 13 | 43 | 30 |
| 11 | 16 | 12 | 24 | 12 | 11 | 19 | 12 | 26 | 14 |
| 12 | 19 | 11 | 15 | 4 | 12 | 31 | 11 | 36 | 25 |
| 13 | 25 | 11 | 35 | 24 | 13 | 100 | 10 | 59 | 49 |
| 14 | 25 | 10 | 21 | 11 | 14 | 44 | 10 | 42 | 32 |
| 15 | 19 | 9 | 18 | 9 | 15 | 27 | 9 | 22 | 13 |
| 16 | 15 | 7 | 12 | 5 | 16 | 10 | 8 | 3 | −5 |
| 17 | 15 | 6 | 25 | 19 | 17 | 32 | 7 | 28 | 21 |
| 18 | 15 | 5 | 31 | 26 | 18 | 20 | 6 | 27 | 21 |
| 19 | 13 | 2 | 14 | 12 | 19 | 29 | 3 | 25 | 22 |
| 20 | 18 | 1 | 7 | 6 | 20 | 15 | 3 | 12 | 9 |
| *Mean* | 37.4 | 22.5 | 39.4 | 16.9 | *Mean* | 49.3 | 25.1 | 47.8 | 22.7 |
| *SD* | 32.3 | 22.3 | 26.2 | 10.9 | *SD* | 30.8 | 25.0 | 27.2 | 12.7 |
| *Min.* | 12 | 1 | 7 | −3 | *Min.* | 10 | 3 | 3 | −5 |
| *Max* | 100 | 83 | 85 | 37 | *Max* | 12 | 82 | 92 | 49 |

Following this session, each word received a score based on the percentage of students that had spelled the word correctly. Subsequently, the words in both lists were ranked according to difficulty. The 25 words on which performance was worst as well as the 25 words on which performance was best were discarded. This selection resulted in a list of 50 words for each class. In a subsequent session, each class received the 50 words that were selected on the basis of the performances of the other class. Performance on the 50 words selected from the first session and performance on the 50 words from the second session resulted in a total number of 100 words, which provided the score on the pretest.

For the training, a spelling-software program (i.e., DICTO) was used that was specifically developed for this experiment. DICTO provided two different ways in which spelling could be practised (see below). Four desktop computers were used in the experiment. DICTO was installed on four computers that had Windows-95 or a more recent version installed. Each computer required a 3.5-inch disk drive, because the program automatically made backups of the students' 'progress-file' on both the hard disk and the disk drive. Headphones were used during the training so that more than one student could work independently in the same room.

*Knowledge-of-results feedback*: One group of students practised the spelling of the words by means of the 'knowledge-of-results feedback' program that was part of DICTO. They heard a word through the headphones, which they subsequently had to type on the computer. After typing the word, the students were required to press the space bar. When the word was typed correctly a small picture with a 'thumbs up' pictogram was displayed. Then, the computer dictated the next word. When the word was typed incorrectly it was colored red. Students could now perform a certain number of edit actions in the word. An edit action was defined as a non-alphanumeric keystroke that was preceded by an alphanumeric keystroke. When for example the word 'werd' had to be corrected into 'word' and the student pressed the left arrow key four times and the delete key once to place the cursor at the 'e' and to delete this letter this was counted as one edit action. After two edit actions the student heard the word to be typed again. When the word was still not spelled correctly after four edit actions the correct word appeared on the screen. After a few seconds the correct word disappeared and the student heard the next word to be typed. Note that the student was not asked to copy the word after s/he was finally presented with the correct model.

*Informational feedback*: This type of feedback constituted another part of DICTO. Students also heard a word through their headphones, which they had to type on the computer by means of the keyboard. When they were finished typing the word, the students pressed the space bar, which resulted in the presentation of the correct spelling of the word on the screen below the student's spelling of the word. The students now had to judge whether they had spelled the word correctly or not by comparing their own spelling to the correct model. The correct spelling of the word was displayed in a different size than the word spelled by the students so that they could not simply mentally align both words. When the students had decided that the word was typed correctly or not they could acknowledge their choice by selecting one of two buttons on the screen with 'Right' and 'Wrong' displayed on them, respectively. They selected these buttons by means of the left- and right-arrow-keys on the keyboard. By pressing the 'Enter' key on the keyboard they confirmed their choice. Subsequently the computer notified them whether their judgment was correct or not. When the word was spelled correctly the students heard the next word. When the word was spelled incorrectly the whole cycle as described in the above was repeated again. When the students misspelled the word four times they heard the next word.

*Information regarding both feedback conditions*: Before the first session, the computer randomized the order of all words for each student separately and created a 'progress file' in which the words were saved. During each session, the computer started with the word at the top of the list in the working file, working its way down. After the first session, the list did not only consist of new words but also of words that were not spelled correctly in one attempt during one of the previous sessions. Thus, each word that was not spelled correctly in one attempt during one of the previous sessions had to be spelled again in a following session.

Words that were spelled correctly in one attempt were not presented again in any of the following sessions. Incorrectly spelled words were on top of the list, maintaining their relative position in the list in regard to other incorrectly spelled words and words that the student had not received so far in one of the sessions. Apart from the progress file the computer also logged the number of attempts that were necessary to spell each word correctly in a session. These logs were stored in a separate file. After seven sessions the

training ended, regardless of the number of correctly spelled words, and irrespective of whether a student had practised all words in the training. The training also ended when a student had practised all words from the list and had typed each word correctly during one of the training sessions. One week after the training had finished all 100 words that were selected for the training and tested in the pretest were assessed again in a posttest. The same spelling-to-dictation procedure was used, in which all participating students spelled all experimental words in a classroom setting, allowing for sufficient time to write down each of the 100 words.

## 3. Results

Prior to the analyses, each student was assigned a spelling level based on the score on the pretest. Students with a score on the pretest between 1 and 19 were designated poor spellers ($n = 26$; 13 in each feedback condition) and students with a score on the posttest between 27 and 83 were designated good spellers ($n = 14$; 7 in each feedback condition). Note the gap in pretest scores between good and poor spellers. A descriptive statistical analysis showed that the overall mean number of practised words was 43.4 ($SD = 31.7$, *min.* = 10, *max.* = 100; *range* = 90). This is an average of about 7 words per session. The range and standard deviation of the scores indicated large differences in performance levels. Only 7 students practised all 100 words to perfection (3 in the knowledge-of-results feedback and 4 in the informational feedback), and 15 students practised between 10 and 20 words to perfection (11 in the knowledge-of-results feedback and 4 in the informational feedback). Table 1 lists the number of words practised to perfection and the pretest and posttest scores of each of the participants.

The results section consists of four major parts. The first analysis investigated the training effect on general performance in pretest and posttest. The second set of analyses concerned the effect of the training on practised words. The third analyses pertained to possible transfer effects, that is, to what extent benefited unpractised words from the training. The fourth and final analyses focused on the efficiency of the training. All analyses provide exact significance levels, *partial* $\varepsilon^2$, and *observed-power* levels computed using $\alpha = .05$.

### 3.1. General training effects

This analysis was conducted to investigate the general effect of the training. For each participant in both the pretest and the posttest, the number of correctly spelled words was computed. Recall that exactly 100 words were used, meaning that absolute numbers are also percentages. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) X 2 (test: pretest vs. posttest) analysis of variance was performed on the number of correctly spelled words. Feedback and spelling level were treated as between-subjects variables and test as a within-subjects variable. The mean scores are presented in Table 1.

The main effect of test was, $F(1, 36) = 106.70$, $p < .0001$, *partial* $\varepsilon^2 = .75$, *observed power* = 1.00. A significant increase in general performance on the posttest of about 20% emerged. The main effect of spelling level was also significant, $F(1, 36) = 124.57$, $p < .0001$, *partial* $\varepsilon^2 = .78$, *observed power* = 1.00. Good spellers had better scores than poor spellers, 62.3 and 18.3, respectively. The main effect of feedback was not significant ($p = .13$); the

effect size was moderately high (Cohen's $d = .33$). None of the interactions reached significant levels. Thus, no differential effect of feedback condition emerged in the two spelling groups.

### 3.2. Training effects

The first analysis pertained to the effects of the training on practised words and whether differential effects of training occurred in good and poor spellers. For each participant in both the pretest and the posttest, the number of correctly spelled *practised* words was computed. Recall again that exactly 100 words were used, meaning that absolute numbers are also percentages. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) X 2 (test: pretest vs. posttest) analysis of variance was performed on the number correctly spelled practised words. Feedback and spelling level were treated as a between-subjects variables and test as a within-subjects variable. The mean scores are presented in Table 2.

All main effects and none of the interaction effects reached significant levels. The main effect test was, $F(1, 36) = 67.98$, $p < .0001$, *partial* $\varepsilon^2 = .65$, *observed power* $= 1.00$. Scores on the posttest were on average 23% higher than on the pretest. The main effect of feedback was, $F(1, 36) = 3.90$, $p < .05$, *partial* $\varepsilon^2 = .10$, *observed power* $= .49$. Students in the informational-feedback condition scored on average 9% better than students in the knowledge-of-results feedback condition. Because feedback did not interact significantly with test, this occurred in both the pretest and the posttest. The main effect of spelling level was, $F(1, 36) = 75.85$, $p < .0001$, *partial* $\varepsilon^2 = .68$, *observed power* $= 1.00$. Spelling performance of good spellers (61.3) was on average 39% better than of poor spellers (22.2). Because spelling level did not interact with test, good spellers outperformed the poor spellers on both the pretest and the posttest. The absence of a significant interaction between spelling level and feedback revealed that feedback did not have a differential effect on the good and poor spellers in this experiment.

The second analysis was conducted to test differential training effects on the three spelling difficulties, that is, analogy spellings, rule-based spellings, and spellings with ambiguous phoneme–grapheme relationships. To conduct this analysis, an additional dependent measure had to be computed. For each word it was assessed whether it

Table 2
Mean number correct of practised words ($n = 100$)

| | Knowledge of results | Informational feedback | Total |
|---|---|---|---|
| *Pretest* | | | |
| Good spellers | 47.5 (5.2) | 53.1 (5.2) | 50.3 (3.7) |
| Poor spellers | 8.2 (3.8) | 12.0 (3.8) | 10.1 (2.7) |
| Total | 27.8 (3.2) | 32.5 (3.2) | 30.2 (2.3) |
| *Posttest* | | | |
| Good spellers | 65.5 (6.7) | 79.0 (6.7) | 72.2 (4.8) |
| Poor spellers | 28.1 (4.9) | 40.6 (4.9) | 34.3 (3.5) |
| Total | 46.8 (4.2) | 59.8 (4.2) | 53.3 (3.0) |
| Grand Total | 37.3 (3.2) | 46.2 (3.2) | 41.7 (2.2) |

Standard errors are in parentheses.

contained one or more of the three spelling-category difficulties, and subsequently each spelling difficulty of each student was evaluated. The total number of errors was divided by the total number of potential spelling difficulties of each category and multiplied by 100, resulting in percentages correct on each spelling-category difficulty. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) X 3 (spelling difficulty: analogy spellings vs. rule-based spellings vs. ambiguous phoneme–grapheme relationships) analysis of variance was performed on the difference scores of pre and posttest. Feedback and spelling level were treated as between-subjects variables and spelling difficulty as a within-subjects variable. The mean scores are presented in Table 3.

Neither the main effects of feedback ($p = .22$), spelling level ($p = .47$), and spelling difficulty ($p = .19$) nor any of the interaction effects reached significant levels (all $F$'s $< 1$). Thus, no differential effects of spelling difficulty emerged as a result of training, suggesting that performance on all three spelling difficulties increased to the same degree in both conditions and in good and poor spellers alike.

### 3.3. Transfer effects

The first analysis pertained to general transfer effects of the training on the unpractised words and whether differential effects of transfer occurred in good and poor spellers. For each participant in both the pretest and the posttest, the number of correctly spelled *unpractised* words was computed. Recall, exactly 100 words were used, meaning that absolute numbers are also percentages. Note that seven students practised all words to perfection and as a result did not have a mean score on the set of unpractised words. They were, therefore, excluded from this analysis. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) X 2 (test: pretest vs. posttest) analysis of variance was performed on the number correctly spelled unpractised words. Feedback and spelling level were treated as between-subjects variables and test as a within-subjects variable. The mean scores are presented in Table 4.

The main effect of feedback was marginally significant and indicated a slightly better performance of the students in informational-feedback condition, $F(1, 29) = 3.72$, $p = .06$, *partial* $\varepsilon^2 = .11$, *observed power* $= .46$. Because feedback did not interact significantly with test ($F = 1$), the superior performance by students in the informational-feedback condition occurred in both the pretest and the posttest. The main effect of spelling level was significant, $F(1, 29) = 89.59$, $p < .0001$, *partial* $\varepsilon^2 = .76$, *observed power* $= 1.00$; and the main effect of test was, $F(1, 29) = 99.97$, $p < .0001$, *partial* $\varepsilon^2 = .78$, *observed power* $= 1.00$. Because of a significant interaction between spelling level and test, both main effects had to be qualified, $F(1, 29) = 7.39$, $p < .01$, *partial* $\varepsilon^2 = .20$, *observed power* $= .75$. Although both

Table 3
Mean difference scores (posttest–pretest) in percentages of the practised words

| | Knowledge of results | Informational feedback | Total |
|---|---|---|---|
| Analogy | 17.6 (4.0) | 13.5 (4.0) | 15.5 (2.8) |
| Rule based | 22.1 (5.5) | 21.1 (5.5) | 21.6 (3.9) |
| Ambiguous spellings | 19.4 (4.1) | 8.9 (4.1) | 14.2 (2.9) |
| Total | 19.7 (3.0) | 14.5 (3.0) | 17.1 (2.1) |

Standard errors are in parentheses.

Table 4
Mean number correct of unpractised words ($n = 100$)

| | Knowledge of results | Informational feedback | Total |
|---|---|---|---|
| *Pretest* | | | |
| Good spellers | 35.1 (4.7) | 47.0 (4.7) | 41.1 (3.3) |
| Poor spellers | 9.5 (2.6) | 8.9 (2.7) | 9.2 (1.9) |
| Total | 22.3 (2.7) | 28.0 (2.7) | 25.1 (1.9) |
| *Posttest* | | | |
| Good spellers | 56.0 (5.9) | 74.0 (5.9) | 65.0 (4.2) |
| Poor spellers | 22.5 (3.3) | 23.4 (3.4) | 22.9 (2.4) |
| Total | 39.3 (3.4) | 48.7 (3.4) | 44.0 (2.4) |
| Grand total | 30.8 (2.7) | 38.3 (2.8) | 34.6 (2.0) |

Standard errors are in parentheses.

groups of spellers had significantly better performance on the unpractised words in the posttest (good spellers: $t(7) = 5.35$, $p < .001$; poor spellers $t(25) = 8.77$, $p < .0001$), good spellers' performance increased significantly more from pretest to posttest (24.1%) than that of poor spellers (13.7%), $t(31) = 2.77$, $p < .009$.

The second analysis was conducted to test differential transfer effects on the three spelling difficulties, that is, analogy spellings, rule-based spellings, and spellings with ambiguous phoneme–grapheme relationships. The same measure as in the second analysis of the training data was computed. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) X 3 (spelling difficulty: analogy spellings vs. rule-based spellings vs. ambiguous phoneme–grapheme relationships) analysis of variance was performed on the difference scores of pre and posttest. Feedback and spelling level were treated as between-subjects variable and spelling difficulty as a within-subjects variable. The mean scores are presented in Table 5.

Only the main effect of spelling difficulty reached significance, $F(2, 28) = 4.14$, $p < .03$, *partial* $\varepsilon^2 = .23$, *observed power* $= .68$. The within-subject contrast revealed a significant linear trend $F(1, 29) = 7.49$, $p < .01$, *partial* $\varepsilon^2 = .21$, *observed power* $= .75$. The largest increase in spelling performance occurred on the unpractised analogy spellings, followed by rule spellings, and the least amount of increase occurred on the ambiguous phoneme–grapheme relationships spellings. This effect did not interact with feedback or spelling level (both $F$'s $< 1$), indicating that it occurred in both conditions and in both reader groups. Neither the main effects of feedback and spelling level nor any of the remaining interaction effects reached significant levels (all $F$'s $< 1$). Thus, performance on all three spelling difficulties increased to the same degree in both conditions and in good and poor spellers alike.

### 3.4. Training efficiency

To assess the efficiency of each of the feedback condition during training, three different analyses were conducted. The first analysis investigated the effect of feedback on the number of unique words practised during the training. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) analysis of variance was performed on the number of unique words practised during training. Feedback and spelling level were

Table 5
Mean difference scores (posttest–pretest) in percentages of the unpractised words

| | Knowledge of results | Informational feedback | Total |
|---|---|---|---|
| Analogy | 15.6 (3.4) | 17.4 (3.2) | 16.5 (2.3) |
| Rule based | 12.4 (4.3) | 12.7 (4.0) | 12.6 (2.9) |
| Ambiguous spellings | 8.6 (3.1) | 8.2 (2.9) | 8.4 (2.1) |
| Total | 12.2 (2.2) | 12.8 (2.1) | 12.5 (1.5) |

Standard errors in are parentheses.

Table 6
Mean number of words practised and mean number of spelling attempts for each correct spelling

| | Knowledge of results | Informational feedback | Total |
|---|---|---|---|
| *Number of words* | | | |
| Good spellers | 66.4 (9.0) | 77.1 (9.0) | 71.8 (6.3) |
| Poor spellers | 21.8 (6.6) | 34.3 (6.6) | 28.0 (4.7) |
| Total | 44.1 (5.6) | 55.7 (5.6) | 49.9 (3.9) |
| *Number of attempts* | | | |
| Good spellers | 3.9 (1.1) | 1.1 (1.1) | 2.5 (0.8) |
| Poor spellers | 10.9 (0.8) | 4.3 (0.8) | 7.6 (0.6) |
| Total | 7.4 (0.7) | 2.7 (0.7) | 5.1 (0.5) |

Standard errors are in parentheses.

treated as between-subjects variables. The mean scores are presented in the upper part of Table 6.

The main effect of spelling level was significant, $F(1, 36) = 30.72$, $p < .0001$, *partial* $\varepsilon^2 = .46$, *observed power* $= 1.00$. Good spellers practised significantly more words during training than poor spellers did. Neither the main effect of feedback ($p = .15$) nor the interaction effect ($F < 1$) reached significant levels.

The second analysis investigated differential effects of feedback and spelling level on the number of attempts to spell words correctly. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) analysis of variance was performed on the number of attempts to spell words correctly during training. Feedback and spelling level were treated as between-subjects variables. The mean scores are presented in the lower part of Table 6.

The main effect of feedback ($F(1, 36) = 23.44$, $p < .0001$, *partial* $\varepsilon^2 = .39$, *observed power* $= 1.00$) and the main effect of spelling level ($F(1, 36) = 27.56$, $p < .0001$, *partial* $\varepsilon^2 = .43$, *observed power* $= 1.00$) were significant. The interaction effect between feedback and spelling level reached a marginally significant level, $F(1, 36) = 3.58$, $p < .07$, *partial* $\varepsilon^2 = .09$, *observed power* $= .45$. Subsequent $t$ tests revealed that in both feedback conditions, good spellers needed fewer attempts to spell a word correctly than poor spellers; knowledge-of-results condition, $t(18) = -4.13$, $p < .001$, and informational-feedback condition, $t(14.9) = -4.40$, $p < .001$. Unlike poor spellers in the knowledge-of-results condition, who needed more attempts than poor spellers in the informational-feedback condition ($t(24) = 6.00$, $p < .0001$), good spellers did not, ($t(6.3) = 1.68$, $p = .14$).

Table 7
Mean number of correct spellings at first attempt for each of the seven training sessions

| Session | Knowledge of results | Informational feedback | Total | |
|---|---|---|---|---|
| | | | Good | Poor |
| 1 | 4.2 (1.0) | 4.3 (1.0) | 7.5 (1.1) | 1.0 (0.8) |
| 2 | 5.4 (1.2) | 7.7 (1.2) | 11.1 (1.4) | 2.0 (1.0) |
| 3 | 4.7 (1.3) | 7.9 (1.3) | 10.2 (1.4) | 2.3 (1.1) |
| 4 | 5.1 (1.4) | 8.7 (1.4) | 11.1 (1.5) | 2.7 (1.1) |
| 5 | 3.4 (0.9) | 6.9 (0.9) | 7.6 (1.0) | 2.7 (0.7) |
| 6 | 4.5 (1.0) | 6.2 (1.0) | 7.0 (1.2) | 3.7 (0.9) |
| 7 | 5.9 (1.0) | 5.2 (1.0) | 7.9 (1.2) | 3.2 (0.9) |
| Total | 4.7 (0.8) | 6.7 (0.8) | 8.9 (0.9) | 2.5 (0.7) |

Standard errors are in parentheses.

In the third and final analysis, the focus was on the development of the training process. The question that was put to test was whether feedback condition and spelling level affected the number of correctly spelled words at the first attempt differentially during the seven training sessions. A 2 (feedback: knowledge-of-results vs. informational) X 2 (spelling level: good vs. poor) X 7 (training session: 1 vs. 2 vs. 3 vs. 4 vs. 5 vs. 6 vs. 7) analysis of variance was performed on the number of correctly spelled words at first attempt. Feedback and spelling level were treated as between-subjects variables and training session as a within-subjects variable. Mean scores are presented in Table 7.

The main effect of feedback was not significant ($p = .10$), but the main effect of spelling level was, $F(1, 36) = 31.51$, $p < .0001$, *partial* $\varepsilon^2 = .47$, *observed power* $= 1.00$. Good spellers spelled on average more words correctly at first attempt than poor spellers. The main effect of training session was marginally significant, $F(3.3, 117.2) = 2.35$, $p < .07$, *partial* $\varepsilon^2 = .06$, *observed power* $= .60$ (Greenhouse-Geisser corrected, because Mauchly's test of sphericity was significant). The significant interaction effect between spelling level and training session revealed that different developmental paths were visible in two spelling-level groups, $F(3.3, 117.2) = 3.28$, $p < .02$, *partial* $\varepsilon^2 = .08$, *observed power* $= .76$. A significant linear trend was visible in the group of poor spellers, signifying an increase in the number of correctly spelled words at first attempt with increasing training sessions, $F(1, 36) = 4.22$, $p < .05$, *partial* $\varepsilon^2 = .11$, *observed power* $= .52$. The group of good spellers revealed a significant cubic trend; an increase in number of correctly spelled words at first attempt was followed by a decline, which in turn was followed by an increase, $F(1, 36) = 6.61$, $p < .01$, *partial* $\varepsilon^2 = .16$, *observed power* $= .71$.

## 4. Discussion

This study was designed to test differential effects of two types of computer-aided feedback on spelling performance of Dutch students from second grade in the Netherlands: knowledge-of-results feedback and informational feedback. The difference between the two training conditions lies in the nature of the feedback that is given. In the knowledge-of-results feedback condition, the speller is told *that* the word is spelled incorrectly, whereas in the informational feedback condition, the speller is told *what* is spelled incorrectly. Although a number of studies have shown that informational feedback

is generally more effective than knowledge of results (see Section 1), this effect was never studied in the spelling domain.

Before discussing the findings in light of the hypotheses that were posed in the introduction, we discuss some general results. The experiment revealed striking differences among students with respect to the number of words practised to perfection during the seven training sessions. On the high end were seven students who practised all 100 words and at the low end were 15 students who practised 20 words or less. The mean number of words practised was 43, which amounts to about seven words per session. There was also a large gap between the groups. Good spellers had a score of 27% or more correct on the pretest and the poorer spellers had a score of 19% or less on the pretest. Moreover, the number of good spellers was also considerable less than the number of poor spellers (14 and 26, respectively). These numbers reveal that diversity regarding spelling skill is large in this group of students who all attended a regular primary school, justifying the distinction between spellers with a relatively high proficiency and those with a relatively low proficiency. The overall effect of the training was clear. Posttest scores were about 20% higher than pretest scores for both good and poor spellers in both feedback conditions. This suggests that the training did not affect spelling performance of good and poor readers differently or that feedback condition led to performance differences in general.

The first hypothesis pertained to the effects of practised materials. Although both training conditions were expected to enhance spelling performance, we hypothesized that this effect would be stronger in the informational-feedback condition than in the knowledge-of-results feedback condition for the poor spellers and equally effective for good spellers. The results revealed that these effects did *not* occur. Good and poor spellers learned the studied materials in both conditions to the same extent. The only difference was the substantially better scores of the good spellers in both the pretest and the posttet. Moreover, no differential effects occurred with respect to the three spelling difficulties that were distinguished. In short, knowledge-of-results feedback was equally effective as informational feedback with respect to different spelling levels and various spelling difficulties.

The second hypothesis pertained to the issue of unpractised materials. Transfer to new materials occurred in both groups of spellers, but more so in the good than in the poor spellers. As predicted the increase in spelling scores was larger for spellings sharing an underlying knowledge structure, that is, rule-based and analogy spellings, than idiosyncratic spellings (i.e., spellings with ambiguous phoneme–grapheme relationships). Interestingly, the increase in performance on analogy spellings was larger than on rule-based spellings; perhaps, because it is more difficult to deduce the underlying rules than to detect an analogy.

The third hypothesis concerned training efficiency. Informational feedback was expected to be more efficient than knowledge-of-results feedback. This hypothesis was only partly corroborated. There was no difference between conditions with respect to the absolute number of words practised. Only good spellers practised more words than poor spellers. With respect to the number of attempts to spell a word correctly, it was clear that poor spellers in the informational-feedback condition needed fewer attempts to spell a word correctly than poor spellers in the knowledge-of-results condition; no such difference emerged in the good spellers. In both conditions good spellers were more efficient than poor spellers; they needed fewer attempts for a correct spelling. An additional analysis was

performed to investigate the developmental path of each of the speller groups in each of the conditions. During training, poor spellers became increasingly better at spelling words correctly at the first attempt. Good spellers started with a relatively large number of words spelled correctly at first attempt, followed by a one-time session decline, followed by an increase, and again a drop. All in all, however, the overall number of words spelled correctly at first attempt during training was considerably higher in good than in poor spellers.

To summarize, both feedback conditions appeared to be equally effective in teaching students the spelling of words, irrespective of spelling level and spelling difficulty. Both feedback conditions led to transfer to a set of new words, with the effect being stronger in good than in poor spellers. Transfer was best on analogy spellings, followed by rule-based, and worst on idiosyncratic spellings. The poor spellers learned the spelling of words more efficiently in the informational-feedback condition than in the knowledge-of-results condition, whereas for the group of good spellers efficiency was equally large in both conditions.

### *4.1. Quality of feedback*

The general conclusion from our study is that knowledge-of-results feedback can be as effective as informational feedback in learning to spell; a finding not in line with the majority of studies on feedback in general (Bangert-Drowns et al., 1991). What could be the reason for this? An important aspect that requires attention is the way both conditions were operationalised. Knowledge of results provided no clues to the origin of the error during all four trials that a student attempted to spell a word that was auditorily presented. After the fourth attempt, however, the correct spelling was shown to the student. Showing the correct spelling in the end appears to be effective, despite the fact that the student was not able to attempt to spell the word once more. It was only during the following session a week later that the student was asked to try to spell the previously incorrect spelling again. Thus, memory for the correct spelling had to be good. This was apparently the case, because no detrimental effects of this type of feedback emerged. Perhaps students in this condition who had had four fruitless attempts at spelling a word correctly, were determined to remember the spelling, knowing that incorrect spellings did not just disappear, but would turn up in the next session.

The informational feedback condition provided students with information concerning the origin of the error after the first incorrect spelling attempt. This type of information was not detrimental to the learning process either, because presenting the correct model immediately after the first incorrect attempt was equally effective as providing this information after four attempts. Knowledge-of-results feedback may have induced a more active learning attitude in the students than the informational-feedback condition, which could have countered the advantage of being presented with immediate feedback on the origin of the spelling error.

To conclude this paragraph, it is interesting to note that the effect size, that assessed the non-significant difference between the two feedback conditions in the present study, was substantially higher (.33) than effect sizes (0.19 and −.07) reported in Bangert-Drowns et al. (1991) on two studies by Aumiller who compared no feedback with knowledge-of-results feedback.

### 4.2. Implicit learning

Both feedback conditions revealed transfer to words that were not practiced during the training, revealing an important characteristic of effective instruction, namely implicit learning. Interestingly, the level of implicit learning was only slightly less than that of explicit learning. Performance increase from pretest to posttest on unpractised was 12.5% (see Table 5) and on practised words it was 17.1% (see Table 3). Based on the literature on implicit learning (see Section 1, Reber et al., 1991), it was suggested that differences between good and poor spellers should be more prominently visible on explicitly learned words, and diminished or absent on novel or unpractised words. Although there were large overall differences in performance on pretest and posttest between good and poor spellers, learning the spelling of a set of words occurred to the same extent in both groups. Thus no performance differences occurred at all between speller groups on explicitly learned words. Performance differences did occur on the transfer words, indicating an enhanced-transfer effect in the group of good spellers as compared to the poor spellers. Thus, the implicit-learning results from the present study are not in agreement with the general findings obtained in the implicit-learning literature either.

The fact that there was a considerable level of transfer to unpractised items is probably due to the fact that the training forced students to learn a spelling to perfection. Following the conclusion of Gettinger (1993), rather than having students learn a set of words to a pre-established criterion of, for example, 80% correct, our training forced students to learn words to perfection. Gerber (1986) showed that learning to perfection in students with spelling disabilities not only speeded up their acquisition of the spelling of a new set of words, but also induced qualitative improvements in the spelling of new words in general.

### 4.3. Automated spelling monitoring and the educational practice

An important practical goal of the present study was to contribute to the improvement of the educational practice, based on well-informed scientific research, and it aimed at answering the question whether computer-assisted instruction was effective for learning the spelling of a relatively large set of words. Although, the methodological design was not designed to answer the question whether the use of the computer adds additional learning value to traditional classroom activities, the findings suggest that inexperienced spellers, good and poor spellers alike, can learn the spelling of words by means of a computer program that provides some sort of feedback.

The nature of the implemented computer-aided programs has several benefits. One important advantage is that students received immediate feedback. All computer programs can be designed such that they can provide tireless feedback immediately after each response; a clear advantage to conventional paper-and-pencil instruction and a requirement that is obviously impossible to meet for a teacher in a regular classroom. A disadvantage of our implementation is that students did not receive information about the underlying cause of the error. Based on an extensive meta-analysis, Azevedo and Bernard (1995) concluded that effective feedback in computerized instruction should not only involve verification of a student's answer, but also present an explanation as to why the word is spelled incorrectly.

A second benefit is that spelling instruction can be individualized. After all, students do not encounter the same problems nor do they learn at the same rate, a notion that was

corroborated by the results of the present study. The majority of our second graders did not succeed in studying the entire set of words: the least successful practised only 10 words to perfection and the seven most successful studied all 100 words to perfection. Both knowledge-of-results feedback and informational feedback allowed for self-paced learning, allowing for good students to move ahead, and for poor students to keep studying words they had not mastered yet. Earlier research by Gerber (1986) indicated that studying the spelling of words to perfection had great educational value, a requirement that can easily be met when computers are used in classroom activities. A disadvantage of our design was the fact that some students never seemed to manage finding the correct spelling of some of the words and as a result got stuck. In a future program, this aspect should be changed, because it affects the motivation of the students negatively.

A third benefit of computer-assisted instruction is that students' spelling responses are unambiguous: the computer program presents a clear representation of the spelling on the screen and a well-designed program also indicates whether the spelling is right or wrong. A spelling written down with a pencil is not always unambiguous because of students' poor handwriting and it remains uncertain whether or not the spelling is correct until the teacher inspects it. Particularly scribbled handwriting does not allow for proper inspection by the student, whereas typewritten spelling does. A clear picture of the correct spelling may reinforce its mental image, and an indication that the spelling is incorrect may encourage students to correct the spelling and in turn try to provide the proper representation. A disadvantage of having students practicing the spelling of words solely by means of the computer may be that producing the spelling in handwriting becomes difficult, because it is by no means guaranteed that transfer occurs from computer-learned spelling to handwritten spelling.

A fourth and final benefit we raise, although not explicitly researched in the present study, is the fact that students like working with computers (see MacArthur, Haynes, Malouf, Harris, & Owings, 1990; Vaughn et al., 1993). Keeping up motivation and interest is an important prerequisite for any subject students need to acquire, particularly with respect to spelling, because it is one of the least popular topics in primary school; even school teachers rate it as one of their least favoured subjects (Graham, 1983). If we can strengthen the motivation for young spellers to work on spelling half the battle may be won.

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