Chapter 5

Effects of CCTV training on reading performance

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Abstract

Objective
To investigate the effectiveness of training in the use of closed-circuit television (CCTV) on reading performance in visually impaired patients.

Methods
In a multicenter masked randomized controlled trial, 122 patients were randomized either to a treatment group that received usual delivery instructions from the CCTV supplier combined with concise outpatient standardized training, or to a control group that received delivery instructions only. The main outcome measure was reading performance, which was obtained by measuring reading acuity, reading speed, reading errors, column-tracking time, and technical reading, approximately 2 weeks after patients had received their CCTV and 3 months later. Videotapes of all measurements were rated by 2 investigators. Training effects were analysed with linear mixed modeling.

Results
There were no statistically significant differences in results between the treatment and control group. However, introducing a CCTV increased reading acuity (mean difference [MD] 0.93 logRAD; p <0.01) and maximum reading speed (MD 15 wpm; p <0.01), and decreased the number of errors (MD 0.33; p=0.04), compared to reading without CCTV. Average reading speed (p=0.05), number of errors (p=0.04) and column-tracking time (p=0.01) improved over time.

Conclusions
Prescribing a CCTV and the delivery instructions by the suppliers seemed sufficient to improve reading performance. Additional training in the use of this device did not result in further improvement. Based on these results, outpatient low-vision rehabilitation centers may consider reallocating part of the training resources into other evidence-based rehabilitation programs.
Introduction

Low-vision rehabilitation aims to overcome visual disability by prescribing vision-enhancement devices, teaching patients adaptive skills, and making environmental changes. A closed-circuit television (CCTV) is an electronic vision-enhancement system, which is mainly prescribed to patients with severe low vision and may contribute to overcome reading disability. Training and practice in the use of CCTV is reported to significantly improve reading performance, for example reading speed and reading duration. Analyses of reading performance are useful to measure the impact of visual disability and the success of recommended therapy. However, despite the known benefits of training, it remains unclear whether the improvement in reading ability accrues from training provided by the low-vision therapist or from the patient practicing on his or her own. Studies investigating this question had various limitations, such as using a within-patient design, whereas a higher level of evidence is obtained by conducting a randomized controlled trial (RCT). To our knowledge only 2 RCTs have been conducted on CCTV reading performance and their results were inconclusive regarding whether training and familiarity with CCTVs had contributed to improvement in reading performance. One of these studies focused on only a few young subjects, whereas, in the other, experience with CCTV was not defined and only a 2-minute training program was offered. Therefore, the results of these latter studies may have low generalizability. Furthermore, most studies were conducted in inpatient facilities, whereas most low-vision rehabilitation programs in the Netherlands, and probably other countries as well, are based on outpatient care. Although, a recent RCT showed that the treatment effect of a limited outpatient low-vision training program was comparable to that of inpatient training, this may not be true for CCTV training alone. Goodrich et al. compared a minimal CCTV training program (which may be similar to programs of outpatient low-vision clinics) with more extensive programs, showing smaller treatment effects for the minimal program.

In the Netherlands, training in the use of CCTVs was previously based on the rehabilitation professional’s expertise. Since evidence-based practice is increasingly imposed by society (e.g., government and health insurance companies), low-vision rehabilitation centers aimed to combine scientific evidence and their expertise into a standardized training protocol. After developing the protocol, this multicenter RCT was conducted to investigate the effect of a concise outpatient training program on CCTV reading performance, which was the primary outcome of this study. Measures of visual functioning are important as they relate to quality of life and prolonged independent living; therefore, quality of life and task performance in daily living were considered to be secondary outcomes and are reported separately.
Methods

Design and patients
Detailed information on the methodology of the trial, randomization process and intervention are described elsewhere \(^2\) and are summarized here.

Patients were screened for eligibility and received written and verbal information about the study. They were invited to participate in the study by low-vision specialists at 9 sites of 3 major multidisciplinary rehabilitation centers (MRCs) in the Netherlands. Inclusion criteria were: age ≥18 years, a prescription for a stand-mounted CCTV, ability to speak and understand Dutch, and no absolute indication of cognitive deficits. Randomization was performed by a colleague not involved in the study, using a computer-generated allocation scheme based on blocks of two, stratified by the 9 sites. The assignments were sent by email to coordinators at the MRCs after informed consent was obtained from the participants. The study protocol was approved by the Medical Ethics Committee of the VU University Medical Center, Amsterdam, and conducted according to the principles of the Declaration of Helsinki.

Intervention
All participants received the usual instructions from various suppliers when the CCTV was delivered. Suppliers were unaware of the trial, which means that their instructions were not bound by a predefined protocol and may differ between participants from none to basic instructions for operating the CCTV. \(^2\) Participants in the treatment group also received training in the use of the device from low-vision therapists of the MRCs, which offered outpatient rehabilitation services. To develop a standard training program, information was collected by studying literature, observing training in the use of CCTVs, discussing the content of the program with professionals and organizing focus and discussion groups with low-vision therapists. Due to time and budget constraints the protocol was not tested on CCTV users. However, the final content of the protocol did not differ much from daily practice at the MRCs. Therefore, the trial represents the effects of CCTV training as it is given by these centers. The standard training protocol focused on various aspects such as: ergonomics (e.g., posture, working distance), basic operating instructions (e.g., on/off switch, magnification, image contrast, tracking skills), reading (e.g., basic assignments as well as newspapers, books, medicine bottles), writing (e.g., crossing boxes, writing on virgin and zoned paper, filling in checks and forms), looking at pictures and photographs, and practicing hobbies. Once a week, two 30-minute sessions (separated by a break of 15-30 minutes) were scheduled at the patient’s home. Active training and easy-to-difficult strategies were used throughout the program. \(^7\) Training was given hands on with direct feedback to the participants, \(^7\) until they had practiced with every assignment or until no further improvement could be attained. \(^2\)
Change in reading ability was investigated using several tests to measure reading acuity, reading speed, technical reading skills, and column-tracking time. In both groups, tests were administered during home visits after patients had received their CCTV (mean = 13 days post delivery). After these baseline measurements training was started in the treatment group; patients in the control group did not receive training during 3 months. Three months after the baseline measurements, all tests were repeated. To enable objective measurements, videotapes were used to register the time spent reading and to record reading errors while participants were reading aloud. The tapes were rated by 2 masked investigators who were unaware of the treatment allocation, in contrast to participants and trainers. Participants in the control group did not receive training in the use of their CCTV. However, for ethical considerations, training was also offered to all patients in the control group after their follow-up measurements were completed.21

**Main outcome measures**

Primary outcomes (i.e., reading acuity, reading speed, and reading errors) were assessed with the Dutch version of the Radner Reading Charts (RRCs).23-26 The charts consist of logarithmically scaled, highly comparable sentences.23 First, patients were asked to read one of the charts without using optical aids (except for their own correction). Second, patients were asked to read another version of the 3 charts using their CCTV. Participants were instructed to adjust the CCTV settings to get a clear image of each of the print sizes. In both cases participants were asked to read at their preferred reading distance, which was verified several times during the procedure with a tape measure. Participants were instructed not to correct any reading errors. The errors were counted by marking each syllable that was read incorrectly. Reading acuity was defined as the smallest print size patients were able to read. Reading time was measured with a stopwatch. Reading speed in words per minute (wpm) was based on the number of words in each sentence and the reading time ((14 words x 60 seconds) / reading time). Maximum reading speed was considered an objective measure of the best reading performance attainable by the patient.27 Since low-vision patients show fluctuating reading speeds across print sizes,26,28,29 a reading plateau frequently does not exist. Therefore, maximum reading speed was defined as the fastest reading speed achieved at any of the print sizes. Average reading speed was defined as the mean of all reading speeds at the different print sizes. The linear magnification used was measured and the effective magnification was calculated ([linear magnification x print size x 40 cm] / reading distance).

Because magnification reduces the amount of text displayed at one time, patients may have difficulty understanding their reading materials. Therefore, one of the secondary reading performance outcomes was the test ‘Technical Reading’.30 This test is normally used in primary school. It was included to measure technical reading, which is fundamental to reading comprehension. If patients do not recognize words in a text, they have a difficult time understanding them. Moreover, they might be so
busy with word recognition that they can devote little attention to the meaning of words, sentences and text. Therefore, poor word recognition may lead to inadequate reading comprehension.31 The test consists of 140 words with ascending word length. In 90 seconds patients read as many words as possible. As the words were printed in 4 columns (column length 23.3 cm, separated by 2.1 cm) the time to track from 1 column to the next was also measured, by taking the time necessary to track from the bottom word of 1 column to the top word of the next column.

Data analysis
Differences between characteristics of patients in both trial arms, and between responders and non-responders, were analysed with chi-square tests and independent samples t-tests. To make sure that the reading performance measurements were conducted accurately, patients were videotaped during test performance and, for example, reading speed in wpm or number of reading errors were rated afterwards by 2 independent investigators. Therefore, the first step in the data analysis was to evaluate interrater reliability, which determines whether the same value is achieved if a measurement at a certain time point is performed twice by different observers, and is estimated by an intraclass correlation coefficient (ICC). A linear mixed model was used to determine the ICC. Treatment allocation and time (baseline or follow-up) and their interaction were considered fixed effects. Subjects and raters, their interaction and their interactions with time were considered random effects. The contributions of the random effects as expressed by the variance components were calculated as percentages. The relative contribution of the subject and subject x time variance components to the total variability determined the interrater ICC.32

Linear mixed modeling also allows for a simultaneous comparison of dependent observations within and between groups over time and is suitable to assess treatment effects, defined as the treatment allocation x time interaction, of the trial.33 Analysis of treatment effects was based on the intention-to-treat principle. However, to compensate for patients who did not receive the intervention as allocated, analysis was repeated per protocol (rearranging untreated patients from the treatment to the control group and vice versa, see also Figure 1). Furthermore, reading performance might interact with a variety of factors. Therefore, gender, age, visual acuity, working distance, linear and effective magnification, diagnosis, living situation, presence of co-morbid conditions, previous use of low-vision aids (LVAs), previous visits to an MRC, self-reported maximum reading duration, depressive symptoms at baseline (obtained with the Center for Epidemiological Studies - Depression scale)34 and the number of training sessions were added to the mixed model analysis one at a time, to investigate differential effects. To correct for multiple testing, interactions with a p <0.01 were considered statistically significant.

In addition to analysing the interrater reliability and treatment effects, linear mixed models were used to estimate secondary effects of reading with and without a CCTV
and change in reading performance from baseline to follow-up. Since analysis was based on the method of maximum restricted likelihood, missing data at follow-up were considered to be missing at random.\textsuperscript{35,36} Data at both time points add to the preciseness of estimates. Therefore, all available data on measurements made at baseline (n=114) and follow-up (n=106) were used in the analysis. Effect sizes were calculated for the treatment effects.\textsuperscript{37} All analyses were performed in SPSS version 15.0.

**Results**

**Response and patient characteristics**

Between April 2008 and August 2009, 168 patients were screened for eligibility and invited to participate in the study. Three patients were ineligible, 1 patient died before consenting and 42 patients did not want to participate. Of the 122 remaining patients, 62 were randomized to the treatment group and 60 to the control group. Eight participants dropped out of the study prior to the baseline measurements, leaving 59 participants in the treatment group and 55 in the control group (Figure 1). Eight patients (4 in each group) did not participate in the follow-up measurements, which were performed until January 2010. Reasons for loss to follow-up were: physical or mental inability to participate (n=8), delay in CCTV delivery (n=2), too much effort (n=3) and unknown reasons (n=3). Table 1 presents the baseline characteristics of patients in each treatment arm; there were no significant differences between the groups. However, there was an age difference between patients who completed the study (n=106, mean age 76.5 years) and patients who discontinued during the study (n=16, mean age 82.6 years; \( p < 0.01 \)).
Figure 1. Chart showing the progress of participants through the phases of the trial.

- Assessed for eligibility and invited to join the study (n=168)
  - Excluded (n=46)
    - Patients died before consenting (n=1)
    - Patients who did not meet the inclusion criteria (n=3)
    - Patients who refused to participate (n=42)
  - Randomized (n=122)
    - Allocated to treatment group (n=62)
      - Discontinued study prior to baseline measurements (n=3)
      - Received allocated intervention as assigned (n=49)
      - Did not receive allocated intervention as assigned (n=6)
      - Unknown (n=4)
    - Allocated to control group (n=60)
      - Discontinued study prior to baseline measurements (n=5)
      - Received allocated intervention as assigned (n=52)
      - Did not receive allocated intervention as assigned (n=2)
      - Unknown (n=1)
  - Discontinued study prior to completion of the trial (n=4)
  - Completed 3-month follow-up (n=55)
    - Included in intention-to-treat analysis (n=59)
    - Included in per-protocol analysis (n=51)
    - Discontinued study prior to completion of the trial (n=4)
    - Completed 3-month follow-up (n=51)
      - Included in intention-to-treat analysis (n=55)
      - Included in per-protocol analysis (n=58)

In the intention-to-treat analysis all patients who performed a baseline measurement were included. Patients who discontinued the study prior to these measurements were excluded. As analysis was obtained by the method of restricted maximum likelihood, patients who discontinued during the study were kept in the analysis. These patients were considered missing at random; excluding them would have biased the study’s results. In the per-protocol analysis, two patients who did not receive intervention as assigned in the control group were added to 49 patients who did receive intervention as assigned in the treatment group. Six patients who did not receive the intervention were removed from the treatment group and added to the control group. For 5 patients it was unknown if they had received the intervention as assigned, they were excluded from the per-protocol analysis.
Table 1. Baseline characteristics of the study population by treatment allocation.

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>Treatment Group (n=59)</th>
<th>Control Group (n=55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years): mean (SD)</td>
<td>75.4 (12.3);</td>
<td>78.6 (12.8);</td>
</tr>
<tr>
<td></td>
<td>range [38.9 - 94.4]</td>
<td>range [34.4 - 95.7]</td>
</tr>
<tr>
<td>Gender: % female</td>
<td>61.0</td>
<td>58.2</td>
</tr>
<tr>
<td>Education (years): mean (SD)</td>
<td>9.8 (2.8);</td>
<td>9.9 (3.0);</td>
</tr>
<tr>
<td></td>
<td>range [5 - 16]</td>
<td>range [6 - 16]</td>
</tr>
<tr>
<td>LogMAR visual acuity*: mean (SD)</td>
<td>0.90 (0.38);</td>
<td>0.86 (0.32);</td>
</tr>
<tr>
<td></td>
<td>range [0.05 – 2.15]</td>
<td>range [0.22-1.52]</td>
</tr>
<tr>
<td>LogRAD reading acuity†: mean (SD)</td>
<td>0.95 (0.28);</td>
<td>0.90 (0.27);</td>
</tr>
<tr>
<td></td>
<td>range [0.46 – 1.90]</td>
<td>range [0.41 – 1.47]</td>
</tr>
<tr>
<td>Social status: % living alone</td>
<td>44.2</td>
<td>51.9</td>
</tr>
<tr>
<td>Independent living: %</td>
<td>87.0</td>
<td>82.7</td>
</tr>
<tr>
<td>Co-morbidity: % with co-morbid conditions</td>
<td>69.2</td>
<td>75.0</td>
</tr>
<tr>
<td>Previous use of LVAs‡: % with LVAs</td>
<td>82.7</td>
<td>92.3</td>
</tr>
<tr>
<td>Delivery-time CCTV (days): mean (SD)</td>
<td>47.1 (42.0);</td>
<td>40.3 (26.8);</td>
</tr>
<tr>
<td></td>
<td>range [3-231]</td>
<td>range [3-107]</td>
</tr>
<tr>
<td>Time delivery - baseline (days): mean (SD)</td>
<td>13.2 (8.1);</td>
<td>12.1 (6.0);</td>
</tr>
<tr>
<td></td>
<td>range [1-41]</td>
<td>range [4-31]</td>
</tr>
<tr>
<td>Time baseline – follow-up (days): mean (SD)</td>
<td>96.8 (9.1);</td>
<td>104.2 (28.9);</td>
</tr>
<tr>
<td></td>
<td>range [85-134]</td>
<td>range [81-260]</td>
</tr>
</tbody>
</table>

Primary cause of visual impairment§: %
- Age-related macular degeneration: 61.4
- Diabetic retinopathy: 5.3
- Glaucoma: 3.5
- Cornea disease: 7.0
- Cataract: 5.3
- Other: 17.5

SD=standard deviation;
* Visual acuity of the best eye as assessed during visual function tests at the MRCs; Snellen ratings were converted to the LogMAR scale.
† Binocular reading acuity in LogRAD as assessed during the first home visit, note that small differences in acuity are expected based on the variance in testing conditions in the patients homes.
‡ Low-vision aids.
§ Cause of visual impairment in the better eye according to the patient’s ophthalmologist distilled from the referral letters.

**Delivery of CCTVs and instructions**

The mean delivery time of CCTVs was 6.2 (range 0.4-33) weeks. In the treatment group 86% of the patients received instructions from the supplier at delivery compared with 91% in the control group. Patients received instructions in switching on the CCTV (100%), magnification (96%), reversing the image contrast (92%), focussing (81%), operating the X-Y table (91%) and additional techniques (24%). On a Likert-type scale, 88% of the patients perceived these instructions as good or very good. Results were similar in both groups.
Interrater reliability
The interrater reliability for the measurement of reading acuity, reading speed, reading errors, column-tracking time, and number of words read on the test technical reading was high, that is the ICC range was 0.92-1.0 (Table 2).

Treatment effects
Intention-to-treat analysis did not yield any treatment effects of CCTV training (Table 3). Although patients in the treatment group showed more progression from baseline to follow-up on most performance measures, the differences did not reach significance. In contrast, per-protocol analysis tended to favor improvement in the control group for maximum and average reading speed (mean difference [MD] -2.07 wpm; p=0.72 and -2.24; p=0.52, respectively) and column-tracking time (MD -0.33 sec; p=0.84). Results for reading acuity, reading errors and the number of words read on the technical reading test remained approximately the same. Both analyses showed no treatment effect.

Although analysis did not yield a treatment effect on any of the performance measures, patients’ characteristics and training-related factors may interact with the outcome measures. Gender, time between delivery of the CCTV and the baseline measurement, as well as the number of training sessions, interacted with average reading speed. Reading speed in females of the control group decreased from baseline to follow-up (MD -2.6 wpm), whereas females in the treatment group improved their average reading speed (MD 10.0 wpm). The opposite was observed in males; reading speed in the treatment group was stable (MD 0.0 wpm), whereas males in the control group improved their average reading speed (MD 5.5 wpm). Also, the more time between delivery and baseline, the smaller the treatment effect. The difference between baseline and follow-up measurements in the treatment group decreased, whereas average reading speed in the control group increased (mean time delivery-baseline=12.7 days, MD 0.9 wpm; p=0.01). Furthermore, the more training sessions scheduled, the lower the average reading rate in the total group (-8.92 wpm per extra session; p <0.01). There were no differential effects of the variables on the other outcome measures.

Effects of reading with and without CCTV
When both groups were taken together, using a CCTV increased the maximum reading speed of 65 patients (57%), whereas the reading speed of 31 patients declined (27%) at baseline. Another 18 patients (16%) could not read the RRCs without the use of a CCTV, but could read them with the device. Furthermore, maximum reading speed increased when reading with CCTV was compared to reading without the device (MD 18.2 wpm; p <0.01; Figure 2A; Table 4). The average reading speed increased as well, which was on the verge of significance (3.43 wpm; p=0.06). Reading acuity improved significantly when patients used their CCTV (MD -0.93 log units; p <0.01) and patients made fewer reading errors (-0.33 errors; p=0.04).
Change in reading performance from baseline to follow-up

From baseline to follow-up patients improved their skills using their CCTV: the mean improvement on maximum reading speed was 4.8 wpm, on average reading speed 3.4 wpm, the number of reading errors decreased by -0.13 errors and the column-tracking time improved by -2.1 sec (Table 4). However, improvements on maximum reading speed and column-tracking time were not significant. In Figure 2B, the data points of both groups, representing baseline (mean 100 wpm) versus follow-up (mean 105 wpm) measurements of maximum CCTV reading speed, lie close to the diagonal, indicating only small changes over time. Although some improvement was seen on most variables, patients showed deterioration on the number of words read on the test ‘Technical Reading 345678’. Because the word length on the second version of the test ascended more rapidly than on the first version, the number of words was corrected for the number of syllables read, resulting in an absolute gain of 21 syllables over time (p <0.01). It is possible that if the word length had been similar in both versions, patients might have read (significantly) more words at follow-up.

Table 2. Data on Interrater reliability.

<table>
<thead>
<tr>
<th>Variable</th>
<th>%subject x time</th>
<th>%subject x rater</th>
<th>%rater x time</th>
<th>%rater x rater</th>
<th>%subject x time x rater</th>
<th>%error</th>
<th>ICC†</th>
<th>SD‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading acuity (logRAD)</td>
<td>60.98</td>
<td>39.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.000</td>
<td>0.20</td>
</tr>
<tr>
<td>Maximum RS (wpm)</td>
<td>83.65</td>
<td>15.54</td>
<td>0.16</td>
<td>0.00</td>
<td>0.00</td>
<td>0.65</td>
<td>0.992</td>
<td>52.58</td>
</tr>
<tr>
<td>Average RS (wpm)</td>
<td>89.19</td>
<td>10.55</td>
<td>0.06</td>
<td>0.01</td>
<td>0.03</td>
<td>0.15</td>
<td>0.997</td>
<td>38.80</td>
</tr>
<tr>
<td>Reading errors</td>
<td>75.30</td>
<td>16.81</td>
<td>1.02</td>
<td>0.00</td>
<td>0.00</td>
<td>6.87</td>
<td>0.921</td>
<td>1.04</td>
</tr>
<tr>
<td>Column-tracking time (sec)</td>
<td>23.07</td>
<td>75.99</td>
<td>0.04</td>
<td>0.03</td>
<td>0.00</td>
<td>0.87</td>
<td>0.991</td>
<td>5.97</td>
</tr>
<tr>
<td>Words technical reading</td>
<td>76.16</td>
<td>22.32</td>
<td>0.02</td>
<td>0.06</td>
<td>0.05</td>
<td>1.39</td>
<td>0.985</td>
<td>27.51</td>
</tr>
</tbody>
</table>

* The sources of variation (i.e., the random effects) were considered to be subjects, raters, their interactions with time and each other, and error. The contribution of each source to the total variability was calculated as a percentage. As time, treatment allocation and their interaction are fixed effects, they are not represented in the table.
† To determine the intraclass-correlation coefficient, the subject and subject x time interaction were added and their relative contribution to the total variability was calculated.
‡ The SD (standard deviation) is the square root of the total variance.
Table 3. Data on changes in reading performance: treatment effect.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Baseline reading performance Treatment group</th>
<th>Follow-up reading performance Treatment group</th>
<th>Difference follow-up vs. baseline Treatment group</th>
<th>Baseline reading performance Control group</th>
<th>Follow-up reading performance Control group</th>
<th>Difference follow-up vs. baseline Control group</th>
<th>Treatment effect</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading acuity (logRAD)</td>
<td>-0.14</td>
<td>-0.13</td>
<td>0.01</td>
<td>-0.10</td>
<td>-0.06</td>
<td>0.04</td>
<td>-0.03 (p=0.43)</td>
<td>-0.15</td>
</tr>
<tr>
<td>Maximum RS (wpm)</td>
<td>102.84</td>
<td>109.35</td>
<td>6.51</td>
<td>97.59</td>
<td>100.76</td>
<td>3.17</td>
<td>3.34 (p=0.56)</td>
<td>0.06</td>
</tr>
<tr>
<td>Average RS (wpm)</td>
<td>64.37</td>
<td>68.20</td>
<td>3.83</td>
<td>61.24</td>
<td>64.24</td>
<td>3.00</td>
<td>0.83 (p=0.81)</td>
<td>0.02</td>
</tr>
<tr>
<td>Reading errors</td>
<td>0.68</td>
<td>0.48</td>
<td>-0.20</td>
<td>0.88</td>
<td>0.82</td>
<td>-0.06</td>
<td>-0.14 (p=0.27)</td>
<td>-0.13</td>
</tr>
<tr>
<td>Column-tracking time (sec)</td>
<td>10.02</td>
<td>8.09</td>
<td>-1.93</td>
<td>9.81</td>
<td>7.54</td>
<td>-2.27</td>
<td>0.34 (p=0.83)</td>
<td>0.06</td>
</tr>
<tr>
<td>Words technical reading</td>
<td>57.72</td>
<td>54.55</td>
<td>-3.17</td>
<td>51.66</td>
<td>47.83</td>
<td>-3.83</td>
<td>0.66 (p=0.86)</td>
<td>0.02</td>
</tr>
<tr>
<td>Syllables technical reading</td>
<td>110.28</td>
<td>132.43</td>
<td>22.15</td>
<td>92.60</td>
<td>111.54</td>
<td>18.94</td>
<td>3.22 (p=0.76)</td>
<td>0.04</td>
</tr>
</tbody>
</table>

* MD = mean difference (i.e., [follow-up minus baseline values in the treatment group] minus [follow-up minus baseline values in the control group]).
Table 4. Data on changes in reading performance for both trial arms (n=114): effect of prescribing a CCTV and time effect.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Reading performance without CCTV (mean baseline and follow-up)</th>
<th>Reading with CCTV (mean baseline and follow-up)</th>
<th>Effect of prescribing a CCTV (MD*)</th>
<th>Reading with CCTV at baseline</th>
<th>Reading with CCTV at follow-up</th>
<th>Changes between follow-up and baseline (MD*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading acuity (logRAD)</td>
<td>0.82</td>
<td>-0.11</td>
<td>-0.93 (p &lt;0.01)</td>
<td>-0.12</td>
<td>-0.10</td>
<td>0.02 (p=0.24)</td>
</tr>
<tr>
<td>Maximum RS (wpm)</td>
<td>79.02</td>
<td>97.27</td>
<td>18.24 (p &lt;0.01)</td>
<td>100.22</td>
<td>105.06</td>
<td>4.84 (p=0.09)</td>
</tr>
<tr>
<td>Average RS (wpm)</td>
<td>60.87</td>
<td>64.30</td>
<td>3.43 (p=0.06)</td>
<td>62.81</td>
<td>66.22</td>
<td>3.42 (p=0.05)</td>
</tr>
<tr>
<td>Reading errors</td>
<td>0.98</td>
<td>0.65</td>
<td>-0.33 (p=0.04)</td>
<td>0.78</td>
<td>0.65</td>
<td>-0.13 (p=0.04)</td>
</tr>
<tr>
<td>Column-tracking time (sec)</td>
<td>NO†</td>
<td>8.87</td>
<td>NO†</td>
<td>9.92</td>
<td>7.82</td>
<td>-2.09 (p=0.01)</td>
</tr>
<tr>
<td>Words technical reading</td>
<td>NO†</td>
<td>52.94</td>
<td>NO†</td>
<td>54.69</td>
<td>51.19</td>
<td>-3.50 (p=0.06)</td>
</tr>
<tr>
<td>Syllables technical reading</td>
<td>NO†</td>
<td>111.72</td>
<td>NO†</td>
<td>101.44</td>
<td>121.99</td>
<td>20.54 (p &lt;0.01)</td>
</tr>
</tbody>
</table>

* MD = mean difference. The mean difference of prescribing a CCTV is calculated by adding baseline and follow-up values of CCTV performance in the total group and extracting baseline plus follow-up values without CCTV in the total group. The mean difference between baseline and follow-up CCTV performance is (follow-up CCTV performance in the treatment group + follow-up CCTV performance in the control group) minus (baseline CCTV performance in the treatment group + baseline CCTV performance in the control group).
† NO = not obtained without CCTV
Figure 2a. Reading speed with versus without CCTV.

Reading speed with versus without CCTV. Scatter plot representing maximum reading speed obtained with and without CCTV in both trial arms. Note that data points on the y-axis represent patients who were unable to read the charts without CCTV.

Figure 2b. Follow-up vs. baseline CCTV reading speed.

Baseline and follow-up CCTV reading speed were compared; data points on the x-axis represent participants who did not complete the follow-up measurements. The one data point on the y-axis represents a patient who could not perform the reading assignment at the first home visit due to recent physical inability.
Discussion

The study evaluates the effect of training in the use of CCTVs on reading ability. Reading performance (i.e., reading acuity, speed, and the number of reading errors) largely improved in all patients when reading with CCTV was compared to reading without CCTV. Patients also showed improvement in CCTV performance from baseline to follow-up on average reading speed, the number of errors, and column-tracking time. However, since there were no statistically significant differences in treatment effects between both groups, most performance differences appear to be the result of introducing the device, not of training or practice differentials. Likewise, in the RCT of Pearce et al., patients receiving device handling training showed a similar improvement in functional ability compared to patients who did only receive an LVA without additional training in its use. However, in their study, electronic magnifiers were not included. It was expected that handling a relatively complex electronic device would require at least some training. In contrast, Mintz et al. state that one advantage of the CCTV over optical aids is that no specific training is required in its use other than simple technical skills. The results of the present study seem to confirm their statement. Most patients (89%) received training in these skills from suppliers delivering CCTVs and their instructions were well received by many patients. Therefore, these instructions, in addition to effectively prescribing a CCTV to visually impaired patients, might be sufficient to improve reading performance.

In the present study, the improvement in reading ability differed considerably from that reported by others. For example, in the study of Goodrich et al. maximum CCTV reading speed increased within 10 days of training by (mean) 72%, whereas in this study the increase was 5% after 3 months. The variations in results may have been caused by differences in organizational structures, training strategies, and patients’ characteristics. For example, outpatient rehabilitation centers typically provide minimal reading training for either optical aids or CCTVs. In contrast, in residential programs more extended training and practice sessions are scheduled. A recent RCT showed that outpatient low-vision rehabilitation was equally effective in improving reading ability at lower costs compared to inpatient rehabilitation. However, the program focused on more than just CCTV training. Typically more than one low-vision aid was prescribed and home-adjustments were made. As reading training has shown to be a process rather than a single event, the minimal training (mean 2 sessions, range 1-7) offered in our study might have resulted in less impressive results. Similarly, brief training did not provide as great an increase in reading speed as did extended training in the studies of Goodrich et al. However, too much training also had a negative impact on reading speed. Therefore, it was expected there might be a dose-response relationship. However, for each extra session scheduled in this study average reading speed decreased. This is probably due to poorer performers needing more sessions. On the other outcomes this differential effect was not confirmed.
The greatest gain in wpm from baseline (78 wpm) to follow-up (198 wpm) was reported by Lagrow et al. This might be due not only to the extensive 6-week training program that was offered, but also to the strict regulations of their program. Assignments needed to be mastered within time limits or with 90-100% accuracy. However, as their study population consisted of young students, the program is probably not generalizable to older patients. The training program in the present study was designed to deliver patient-centered care, tailored to correspond to individual needs, learning styles and learning rates. For example, in the present study, females seemed to benefit from training as it protected them from a decline in average reading speed. However, on the other outcome measures gender did not interact with the treatment effect; therefore, it cannot be stated that training is only beneficial for women.

There may also be a difference in patients’ characteristics between inpatient and outpatient services. Patients in inpatient services may have more severe vision loss compared to patients in outpatient services; for example the visual acuity of patients in studies by Stelmack et al. and Goodrich et al. was 0.97 to 1.0 logMAR. It can be hypothesized that training is more effective in patients who are more severely impaired; however, differences in acuity compared to our study were small and might not be significant. In one of the studies by Goodrich et al., a brief training group with similar acuity as the population in this study (0.85 logMAR) showed less progression in reading ability compared to extended training groups with lower visual acuity (0.95 and 0.99 logMAR). However, when extended training was offered to the first group reading ability restored to the same level as the extended groups. Therefore, we still think that differences in results comparing our study with others are predominantly caused by differences in the extensiveness of the programs. Also patients in this study used several additional LVAs, which they purchased themselves in stores or had received in previous visits to MRCs. As they could already use an LVA, this might have minimized the effect of training. However, adding use of an additional LVA or previous visit to MRC (32% of patients) to the mixed model analysis, did not cause a differential effect on any of the outcomes.

Furthermore, in the Netherlands, eccentric viewing training is not regularly offered to patients receiving low-vision aids. We acknowledge that eccentric viewing training and perceptual learning might improve reading performance by improving the visual span. In a study by Nilsson et al., over 5 hours of perceptual training improved reading speed wearing high-power spectacles. However, the evidence for perceptual training in CCTV training programs for predominantly elderly patients is not that convincing. Goodrich et al. and Stelmack et al. did offer eccentric viewing training with low-vision aids and found, in contrast to this study, an effect of CCTV and outpatient training, respectively. Yet, they reported it to be unclear which part(s) of the programs used contributed to increasing efficiency in using CCTVs. It would
be interesting for future studies to see if eccentric viewing does improve reading
speed with a CCTV.

Results of the present study remain inconclusive as to whether training improves
reading ability. Although the treatment group showed more improvement on most
reading performance tests than the control group, differences were small and not
significant. One of the limitations of the study might be lack of power. Additional
power analyses based on maximum reading speed were performed and revealed
that, given the estimates on variability (SD=60.3), over 5,000 participants would
be required before a difference of 3.34 wpm would reach significance at the 0.05
alpha level (power 0.8). Moreover, because a treatment effect was not found with
intention-to-treat analysis as hypothesized, the effect of training may have been
underestimated. Therefore, the analysis were repeated according to the per-protocol
principle to see if there would be a treatment effect analyzing patients who did receive
training in the treatment group and those who did not in the control group. However,
it did not change the results of this study and even tended to favor non-significant
improvement in the control group.

Another limitation might be that the tests were administered only (as soon as possible)
after delivery of the CCTV (mean 13 days), whereas in most studies the patient’s first
CCTV use was at baseline. The delay in baseline measurements may result in minimal
changes from baseline to follow-up, so identifying a difference is more difficult. This
was confirmed by analyses of differential effects, which showed that an increase in
time between delivery and baseline measurements caused a decrease in treatment
effect. Therefore, some improvement in reading performance might have already
accrued due to patients practicing with the device prior to baseline measurements.
However, the differential effect was only found for average reading speed and was not
confirmed in maximum reading speed or any of the other outcome measures. Also,
baseline reading speed in our study (mean 100 wpm) might have been close to the
maximum reading speed that could have been reached, since in the study of Lowe et
al., under the best conditions with regard to window width and character size, patients
read mean 100 wpm. Furthermore, 100 wpm is even more than normally sighted
elderly aged 75 and above can read, which suggests that patients may have reached
a ceiling reading with their CCTV. It seems a great advantage of the CCTV, that even
without training in its use, patients can read at levels even faster than normally sighted
peers. This might be explained by the fact that CCTVs can influence other factors that
might reduce reading rate in elderly for example low-contrast vision and illumination.
Conclusion

In conclusion, the present study shows that improvement in reading performance was predominantly caused by introducing the device. In contrast to findings of other studies on CCTV performance, the results of this study strongly suggest that there is no evidence for the benefit of training and that the improvement in reading ability mainly accrues from the patients practicing on their own (starting even before the baseline measurement). The program in the present study was designed in accordance with daily practice at the Dutch MRCs and was considered to be consistent with outpatient training offered in rehabilitation services worldwide. More studies are needed to determine which components of training procedures are necessary, beneficial and actively contribute to increasing efficiency in using CCTVs compared to patients practicing on their own.\textsuperscript{20}
References


41. Nilsson UL, Frennesson C, Nilsson SE. Patients with AMD and a large absolute central scotoma can be trained successfully to use eccentric viewing, as demonstrated in a scanning laser ophthalmoscope. Vision Res. 2003;43:1777-1787.