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ORIGINAL RESEARCH

Assistive technology as reading interventions for children with reading impairments with a one-year follow-up

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ABSTRACT

Purpose: This pilot study investigated the possible transfer effect on reading ability in children with reading difficulties after a systematic intervention to train and compensate for reading deficiencies by using applications in smartphones and tablets. The effects of using assistive technology (AT) one year after the interventions were completely studied. School related motivation, independent learning and family relations were also considered.

Method: 35 pupils aged 10–12 years participated. They were assessed five times with reading tests. The participants, their parents and teachers were surveyed with questionnaires regarding their experience of using AT. The data from the assessments were analyzed with paired *t*-tests and Wilcoxon signed-rank tests. The data from the questionnaires were analyzed using content analysis.

Results: The paper shows that using AT can create transfer effects on reading ability one year after the interventions were finished. This means that reading impaired children may develop at the same rate as non-impaired readers. Also, increased school motivation and an increase in independent learning and family effects have been shown.

Conclusions: This paper provides implications in how to facilitate reading impaired pupils' learning process and realizes the need to challenge the concept of reading to change to fit modern means of gaining information.

➤ IMPLICATIONS FOR REHABILITATION

- Children with reading impairment could benefit from assistive technology in regards of their reading development process and increase their chances of not falling behind peers.
- Assistive technology as applications in smartphones and tablets may aid children with reading impairment to have an equal platform for learning in school as their peers without reading difficulties.
- Assistive technology could facilitate the information gaining process and subsequently increase motivation to learn and increase interest in reading activities.
- Assistive technology had wider effects on its users: stigmatizing situations when leaving the classroom for special education were avoided and positive effects on family life were noted.

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Several studies in the past two decades have drawn attention to assistive technology (AT), but the technological progress in this area, as in society in general, has by far exceeded the work of scientists. Rapid advances in the development of technologies to assist people with reading impairment and/or dyslexia have not been followed at the same pace by investigations that have evaluated the technology and its impact on the people using them. The AT available today is remarkably smaller in scale, easier to operate and portable in a sense that has never been possible before. New technologies are changing our societal structures as well as everyday life, especially for people with disabilities.[1]

As reading impairment, like many cognitive or other disabilities, is invisible in character, it can generate experiences of social stigma causing a reluctance to use accommodation or an avoidance of situations, such as academic activities, where reading is required.[2–4] However, technology can redefine traditional concepts of learning accommodation by offering people with reading difficulties an easy access to written/printed material.[5–7]

The simple view of reading (SVR) is a model for describing reading ability that includes two components: decoding as the technical part of understanding written communication, and comprehension, referring to the ability to make inferences and creating meaning, that is, to understand.[8–10] Thus, in this study, decoding and reading comprehension are regarded as constituting reading ability. Literacy is a concept that can be understood in a wider context, ranging from the basic ability to read [11] to a more abstract level implying a social process and a multimodal phenomenon alluding to create meaningfulness and understanding in a given situation and context.[12] A new contemporary definition of literacy may be useful after new technological means for accessing printed material have been invented. However, in this study, we have investigated the transfer effects in decoding ability after using AT. Our starting point was to study if there was a positive outcome for reading-impaired children's reading ability after using AT in a systematic and structured intervention program. Furthermore, we investigated the impact on the pupils' perceived benefits from using

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AT in learning and everyday life and their self-reported motivation for school after using AT.

Assistive technology for reading impairment

Accommodations whose purpose are to facilitate gaining access to printed information for the reading impaired with the help of technology often go by the name of AT,[13–16] even though a generally agreed definition among scientists has not yet been found.[17] In an anthology by Edyburn [5] regarding AT and interventions the following description was presented: *AT has the potential to enable people with disabilities to live, learn and work more independently through the application of specialized technologies that reduce, eliminate, or minimize the impact of a disability* (p. 1).

Reading impairment, especially dyslexia, is often described as a dysfunction in the individual's phonological processing system. From this perspective, it becomes a disability that shows substantial resistance to improvement.[18–20] This dysfunction will typically materialize by difficulties in decoding written words, which indirectly leads to difficulties in reading comprehension and spelling.[20,21] Consequently, a reading-impaired individual will have to make an extra life-long cognitive effort when engaging in reading activities. Jacobson [22] showed in a longitudinal study that decoding problems seemed persistent for reading-impaired children in comparison with a control group despite a period of individual remediation in reading. Thus, to improve literacy by solely practising reading skills and trying harder has shown not to be completely helpful to overcome reading difficulties, especially not for those with dyslexia.[23]

Reading interventions and at

Many studies have focused on the effectiveness of reading interventions through phonological training for students of different ages with reading disabilities and/or dyslexia.[24–30] Fälth et al. [29] concluded in their study that to perform effective interventions they should not be conducted over a long period of time and the assignments and practices should be alternated continuously. We were inspired by these findings in designing the interventions in this study.

To our knowledge, few studies have focused on smartphones and tablets with applications as tools for increasing reading ability. Most studies within this area have few participants with a non-randomized selection procedure.[31] Also, to our knowledge, few studies have taken into account the wider implications of using AT as well as the results on reading skills.

Different kinds of AT have offered alternative means to access printed material for children with dyslexia and/or reading impairment.[6,15,16,18,32–36] Various computer programs such as Kurzweil®, constituted doable methods for gaining access, for instance, to printed material for persons with reading impairment by listening to it instead of having to read it. However, this was language-specific and costly.[7] Today, information can be gained by listening to texts being read aloud *via* a text-to-speech application. An application is a small software program to be used in mobile devices such as a smartphone or a tablet. Many websites and versions of operative systems in computers, tablets and smartphones are now offering a text-to-speech application as standard equipment. The applications in IT devices can be used on texts in a variety of languages. Many, if not most, technologies are designed to reduce obstacles created by difficulties with decoding, rather than increasing the individual's existing cognitive strengths.[37]

Cheung and Slavin,[34] in performing a meta-analysis of 20 high-quality studies, concluded that AT had a small impact on the participants' reading achievement and that small-group interventions indicated better results than interventions with larger groups of students. Though the effect of AT interventions was small, it was still positive and, due to the small sample sizes of the studies, the results should be interpreted with caution. This meta-analysis also indicated that early interventions are essential for struggling readers, since younger readers seemed to increase their skills more than older ones.[34] The importance of an early detection of reading impairment and of swift interventions to support and/or increase reading ability has been argued for within the research fields of reading, dysfunctional reading and dyslexia.[5,14,17,20,38–40] Archer et al. [17] conducted a meta-analysis of the field of AT interventions for the reading impaired. Thirty-eight studies were found and the overall results indicated a small but positive effect. In this research, to overview the importance of training and support for the teachers who performed the interventions was emphasized in order to reach positive results of the interventions on reading skills. Roberts and Stodden [41] reviewed studies that had investigated the effectiveness of AT in both younger and older students. This review indicated that using AT as compensation for reading difficulties was effective and that having text read aloud facilitated reading comprehension.[41] In the meta-analysis studies mentioned above the absence of studies containing large, randomized samples with control groups and systematically performed and controlled interventions were discussed.[17,34]

Several other authors within the field of reading interventions where AT is used to enhance reading skills in reading impaired and/or dyslexic individuals have called out for more studies adhering to more rigorous scientific standards.[6,14,16,31,32]

In the above studies, interventions have been conducted where the main focus was on training aspects of the reading process such as reading rate, accuracy and reading comprehension. In this study, we focused on probable indirect transfer effects on reading ability, i.e., decoding and comprehension, from using AT as well as taking the clinical and practical implication of using AT into account.

The impact of at on the user

AT may increase, compensate for or support the ability to read but also increase motivation to engage in reading activities.[14,33,35,39,41] In many countries, the standard curriculum favours reading as the main way of gaining knowledge, which makes the ability as well as the motivation to read pivotal achieving grade-level academic goals.

Gregg [6] points out that technology may redefine traditional concepts of learning. In the context of the present study, this implies that gaining information does not necessarily have to be understood as the reading of texts but could, for instance, mean listening to a webpage on your smartphone or on your tablet.

White and Robertson [42] conducted a study in Canada using tablets (iPads) as AT. Their group of subjects comprised children aged 8–10 years with reading difficulties.

Though the sample size was small ($n = 5$), the results showed positive outcomes for interventions using applications in tablets (iPads).

This study also took into account the overall experience of using iPads as AT, both for the children and their teachers. The results indicated an improvement in reading skills, reading comprehension, an increase in motivations not only for reading skills but also for academic activities in general as well as an increase in

participation and social interaction, since behaviours like emailing were generated. White and Robertson claim that "there were gains for the students beyond the increase in reading fluency and comprehension" (p. 6), referring to the impact on the students' sense of independence, motivation and participation on equal level with their peers. White and Robertson's [42] study indicates that users of AT may generalize the benefit of AT from reading support to participation in social areas.

Gasparini and Culen [39] made a university student use reading–facilitating applications such as text-to-speech in a tablet (iPad) in their case study. The results showed that using the iPad became enjoyable for the student, increased self-confidence in her university studies and made her overall attitude toward AT increasingly positive. This study also included a small group of children with and without reading difficulties who worked with their iPads in order to improve the aspects of their reading skills such as memory and comprehension. Although the study indicated positive results, due to small sample size no firm conclusions could be drawn. However, as Gasparini and Culen [39] point out, "the introduction of the iPad in the elementary class has, in general, been a success in particular, it offers clear support to some children with reading difficulties" (p. 33). The authors could also see that the stigmatization associated with using AT diminished, which enabled the user to attain higher self-confidence within the academic area.[39]

Social and community involvement

The accessibility of written material for the reading impaired made possible by AT may also increase the user's independence, in academic as well as social contexts and lead to increasing community involvement.[13,37–39,41–43] Community involvement may be seen as an important aspect in a democratic nation. Today, several governments publish important information on the Internet or in other text forms, which excludes the reading-impaired part of the population.[1] However, this may raise questions of equality regarding access to AT, which may be due to the socio-economic status of the individual and the nation.[1] Certain social behaviours of great importance for the young such as chatting on the Internet or using social media such as Facebook may be accessible and possible with AT. Barden [37] found in his study that young people with reading difficulties quickly adapted Facebook and learned to interact on an equal level with others. Robert and Stodden [41] showed in their review of AT studies that even the most impaired individuals could benefit from using AT and concluded that this may have beneficial impact on self-esteem and self-confidence. Gasparini and Culen [39] found similar results. In the present study, a questionnaire was distributed to the pupils, their parents and their teachers in order to investigate the aspects of motivation, independence and self-confidence in academic situations.

Abandonment of at

Several studies have reported that AT devices are often abandoned by their user.[13,44–46] One reason claimed for this is the social stigma that the user may feel while using AT.[39,42,43] Another discontinuance factor is the failure to individualize AT to meet the needs of the user.[37,39,41,44,48]. On the other hand, individual motivation and involvement for using the device [44,46] as well as continuous technological support to teachers, parents and users,[13,46] have shown in previous studies to decrease discontinuation. Dawe [13] stated almost a decade ago that technology was "seeking simplicity" in the form of small, portable devices that would, above all, avoid social stigma. Tablets with applications seem to have met some important aspects of these suggestions.[39,42]

Clinical significance

To fully seize the impact on the individual from using AT in academic situations as well as the mundane aspects of life, we used the concept of clinical significance. This concept is most commonly used to describe the broader effects of psychotherapy, since the effects of psychotherapy may be difficult to grasp in psychometric assessments.[47] Jacobson et al. [48] argued that a comparison between the statistical means of two treatment conditions does not provide any information on the "practical importance of the test" (p. 338). Instead, they suggested that researchers should calculate the clinical significance of the statistical change to be able to determine whether "the post-test level of functioning places the client within functional limits with respect to the clinical problem" (p. 346). In this study, we have been inspired by the approach of clinical significance as defined above when investigating the impact of the use of AT in everyday life of the user and of psychological aspects as motivation to learn and independence.

Aim

The aim of this pilot study was to investigate the possible transfer effect on reading ability in children with reading difficulties after a systematic intervention to train and compensate for reading deficiencies by using applications in smartphones and tablets. We also aim to investigate the effects of using these applications one year after the interventions were completed as well as the clinical and practical implications of using applications like AT.

Method

In the present pilot study, 35 children participated. This project took place during fall 2011 and spring 2012. One year after the interventions had finished, in spring 2013, the participating pupils were assessed a final time and a questionnaire was distributed.

Participants

The participants ($n = 35$) were 23 boys and 17 girls between 10 and 12 years of age. Eleven of the participating pupils had received a dyslexia diagnosis prior to entering the project. Ten had a recognized reading and writing impairment, and the remaining participants had documented difficulties of the type described above. In the present study, 10 of the participants attended school year 4, 15 school year 5, and 10 school year 6. It should be noted that in Sweden most children start school at the age of 6.

In this pilot study, participants were selected by inviting schools representing a mix of rural and urban locations to the project. At each school, a special education teacher selected pupils with reading and writing problems documented from previous reading and writing results in their ordinary educational program. Pupils were included that showed results at 0.5 SD or lower below the expected level at an equivalent chronological age in comparison with a norm group. The results were based on one or more word recognition, non-word reading and word reading tests. Pupils that had been previously diagnosed with dyslexia were also included. Although the cutoff level for inclusion may seem low,

previous research has motivated this by arguing that avoiding false negatives in an educational setting is preferable to ensure that interventions will be attained by those who need them.[49] Furthermore, AT interventions could also be beneficial for pupils without reading disabilities.

In the final assessment, which took place one year after completing the interventions, 18 students, their parents and teachers participated. Changing schools, and consequently teachers, as a natural progression in the Swedish school system was the most common reason for not completing the follow-up assessments.

Permission was given to conduct the study by the Central Ethical Review Board National in Sweden (Dnr 2011/89-31).

Instruments

The pupils were then assessed with the "Läskedjor" word chains and sentence chains tests [50] the "LäSt" non-word and word reading test [51] and the "which picture is correct?" test.[52] These tests, which are commonly used in Sweden, contain aspects of reading that have been included in many international studies when evaluating reading and writing disability and dyslexia.[53–55] The results were compared with a norm group, provided by the tests' manuals, for the purpose of estimating the pupils' suitability for participating in the project. The norm group for word chains and sentence chains consisted of 2246 pupils in school years 4–9,[50] while the norm group for LäSt comprised 1043 pupils in school years 1–6, equally distributed by gender and school year. Both norms groups were equally distributed by gender and school year. This test is also commonly used to assess older pupils.[51]

Word chains is a test focusing on the decoding part of the reading process.[22] The child is requested to scan words written without interword space, with three words at a time in each chain. This test targets an "alphabetic–phonemic strategy in word recognition for younger children" (p. 82).[22]

Sentence chains is a test measuring aspects of semantics and syntactic. The task is to scan four unrelated sentences written together without any dots or other punctuation. The target is to mark with a pencil where the dots between the sentences should be.[50]

The word chains test had test–retest correlations with an interval of 3 months between measurements of $r = 0.85$, and the sentence chains test had a test–retest reliability of 0.80.[50]

LäSt is a non-word and word-reading test that consists of lists with increasingly longer non-words and words. The child has to read aloud as many of these as correctly as possible during 45 s. The test includes two test versions (A and B), the results of which were added up.[51] The test–retest reliability coefficient in this test was calculated by assessing pupils in school year 4 twice within a month. Adding the A and B versions, the reliability for non-word reading was 0.74 and 0.78 and for word reading was 0.91 and 0.88.[51]

Which picture is correct? [Vilken bild är rätt?],[52] was used to test the reading comprehension of the pupils. The pupil is presented a short sentence and four pictures, only one of which illustrates the meaning of the sentence. The child is to mark the corresponding illustration. In this study, the test was used in a within-group design. Norm data for grades 1–3 are available.

Several questionnaires were distributed concurrently with the assessments. They focused on how participants used AT as accommodations to assimilate and communicate texts and how this affected the participants in everyday life, in school and on aspects such as motivation and sense of independence. The questionnaires also comprised an evaluation of the participation in the project. The majority of the questions offered five response alternatives: strongly agree, agree, disagree, strongly disagree and either.

Examples of questions with response alternatives:
I'm looking forward to learn about how to use the applications
I use the smartphone/tablet on a daily basis in school
I can read text messages from friends

Some of the questions were open:
Examples of open questions:
What do you think was the best thing about using the smartphone/tablet?
What do you think was the worst thing about using the smartphone/tablet?

Procedure

The participants were assessed 5 times to closely follow their reading skills progression, as illustrated in Figure 1.

At T2, questionnaires were distributed to pupils to survey their previous experiences with AT. At T4, the evaluation questionnaires were distributed to participants and their teachers. The follow-up questionnaires were administered at T5, one year after the interventions had finished, to teachers, participants and their parents. The pupils were asked if and to what extent the smartphone or tablet was used in an academic setting or at home. The parents were presented questions about their opinions regarding accommodations such as the applications, how they perceived their child's participation in the project, and how the parent(s) estimated what effect participating in the project had on the child's reading development.

Special education teachers performed all the assessments and interventions. In some cases, the assessor had no previous relationship to the child, while in other cases the pupil and assessor had met in educational settings before the project. The intervention program instructed the participants to use the smartphone/tablet in school as well as at home. In school, the special education teachers met the participant four days a week for five weeks.

Interventions

The interventions were performed during 5 weeks. The pupil and the teacher met 4 times a week, ~40–60 min each time, noting the time at every session. The mean time of an intervention was 47 min ($n = 33$, *SD* 9.74). The average number of sessions was 18 ($n = 33$, *SD* 2.55). The applications used were not specifically construed to fit the project but were available in applications stores.

Time	Week 1	Week 5	Weeks 11-15	Week 16	Week 21	1 year
Activity	Assessment 1	Assessment 2	Interventions	Assessment 3	Assessment 4	Assessment 5
	Inclusion	Pre test		Post test	Evaluation	Follow-up

Figure 1. Study design: assessments and interventions using applications in smartphones or in tablets as AT assessment in project week.

This was in line with one of the ambitions of the project, which was to illuminate the easy accessibility of AT.

The special education teachers that participated in the project received a mandatory two-day course in how to conduct the interventions and make the assessments. Initially, the intervening teachers were taught how to operate a smartphone or a tablet. At the time, smartphones were neither used regularly privately nor as an accommodation in special education in Sweden. Following this technical introduction, an equally detailed instruction session about the applications that were included in the interventions took place. When the special educators were able to operate the applications satisfyingly, the intervention program was introduced. This consisted of specific exercises using the applications to listen-to-texts, creating summaries from the material listened to, practising writing by using a speech-to-text application and one that resounded text while writing. The intervention program also contained exercises in searching the Internet *via* an application that used speech-to-text and playing games to practise literacy skills in a joyful way. Finally, the teachers were instructed to encourage the participants to use applications in their ordinary school setting. On the same occasion, the assessing teachers were given a comprehensive review of all the tests included. On the second occasion, when the teachers had tried the applications for a while, possible problems and challenges were discussed. This last meeting was held as a video call *via* the Internet. For continuous support, all teachers had access during the project to a web page with a forum where they could get information or communicate with the project management.

Applications used

Prizmo is a program that photographs or scans text and reads it aloud, which has shown to be effective in supporting reading skills.[35] The pupils were taught the technical aspects of using this application and then how to use it in comfort in their everyday schoolwork. This application was used at each intervention session to encourage reading behaviour by seeking information, scanning the text and listening to it.

Easy Writer is a word processor application with fewer advanced functions than a regular computer word processor. *Ispeak* has the function of a text-to-speech program. The pupils were able to copy text into the app from other applications and have it read aloud.

SayHi is an application that translates spoken words or written texts into a different language and reads it aloud. Written versions of the recorded information can be saved in a word processor. While using *SayHi,* the pupils practised generating texts in a foreign language without using traditional writing or reading ability.

iTranslate translates written text into a different language. It was used for texts that the pupils had created themselves. Spelling mistakes were corrected and the content was discussed with the teacher. To learn English is obligatory in the Swedish school system from the age of 9.

Dragon Search is an application used to search the Internet by giving search directions in spoken words instead of written texts. The pupils were trained in searching information on the Internet, which is an increasingly common approach to get information in Swedish schools.

Voice Reader Web is an application that was used to have text on websites read aloud. The pupils were encouraged to search for topics within their own range of interests and not necessarily for school-related matters.

Two game applications were used: *Ruzzle*, where words should be found from a given game board with letters on, and *Hang Man*, where the player is to guess a word from a few given letters.

These applications trained the pupils' flexibility and readiness to use different abilities required in reading. The playful way of training aimed to add motivation and a positive attitude toward reading activities.[56]

Daisy reader or *Vod* were two applications that were used to listen to fiction.

Intervention program

Each intervention session contained the following assignments: The pupils were to use the *Prizmo* application to scan and listen to a text from a newspaper, a book or a paper-based printed text of relevance for the pupil. Then the text was to be corrected if necessary and saved in the application. Next, the pupil was to create a summary of this text using *Easy writer/Pages.* At the end of every week, an overall summary was to be made of all the texts that the student had listened to. These summaries were to be sent to the research team. They were then copied and pasted into the *ITranslate* application and were listened to in English. The pupils were to use *SayHi* to record a talk of an everyday event and copy the recording into *Easy Writer/pages.* The participants and teachers were encouraged to make any corrections after the listening. Furthermore, the pupils were to use *Dragon Search* to find something of interest on the Internet, copy the webpage into *Voice Reader Web* and listen to it. In this assignment, the pupils' own interests were to guide the choice of subject. Then the pupils were instructed to compose a summary of the content of the webpage that they had listened to and to paste it into *Easy Writer/Pages.*

Assignments to be conducted at home included: listening to fiction *via Daisy Reader/Vod* at least 10 min a day 4 times a week; summarizing what the sections of a book, fiction book or other content they had listened to was about and using the speech-to-text function in *SayHi*. Then the text was to be copied and pasted into *Easy Writer/Pages*. The following school day the participants were to show their special education teacher this assignment and discuss the literature that they had listened to. The teacher was then able to help the participant with possible corrections of the summary.

Statistical analysis

To relate the results with a norm group and to facilitate long-term follow-up (between T2 and T5), raw scores were transformed to stanine values. The longitudinal changes from T1 to T2, T2 to T3 and T2 to T4 were analyzed on the raw scores with paired *t*-tests for all variables except non-word reading and word reading, where Wilcoxon signed-rank tests were used. Longitudinal changes from T2 to T5 were analyzed using stanine values with Wilcoxon signed-rank tests.

Qualitative analysis

The questionnaires included open-end questions that were submitted to content analysis.[57] The answers were relatively short in comparison with interviews, consisting of a few sentences only. First, the answers were read three times to gain an overview. Then they were coded from the latent content and grouped into categories. The coding was conducted on the basis of how the answers related to one another. Five categories were discerned

Table 1. Test results on reading development assessment between test trials ($n = 35$). presented in stanine values. T5 ($n = 18$).

		Project week									
		1	5	15	21	1 year	1	5	15	21	1 year
		Test 1	Test 2	Test 3	Test 4	Test 5	Test 1	Test 2	Test 3	Test 4	Test 5
		Mean value					Progression[a]				
Activity		Study inclusion T1 M	Pre test T2 M	Immediate post-test T3 M	5 weeks post-test evaluation T4 M	1 year follow up T5 M	Study inclusion	Pre test T2 − T1 P_2	Immediate post-test T3 − T2 P_3	5 weeks post-test evaluation T4 − T2 P_4	1 year follow up T5 − T2 P_5
Word	$n = 35$	1.49	2.20	2.54	2.94			<0.001	0.15	<0.001	
Chains	$n = 18$	1.61	2.44	2.56	3.06	2.53		0.01	0.43	0.01	0.75
Sentence	$n = 35$	1.69	1.94	2.20	2.37			0.05	0.03	0.02	
Chains	$n = 18$	1.72	2.17	2.33	2.61	2.59		0.07	0.086	0.02	0.05
Non-word	$n = 35$	2.18	2.62	2.88	3.25			0.01	0.06	0.01	
Reading	$n = 18$	1.93	2.67	3.25	3.25	2.94		0.02	0.16	0.31	0.04
Word	$n = 35$	NA[b]	2.16	2.44	2.71			NA[b]	0.01	0.04	
Reading	$n = 18$		2.17	2.44	2.50	2.69			0.03	0.38	0.05

[a]Significant at the $p < 0.05$ level.
[b]Non-applicable due to non-performance of tests.

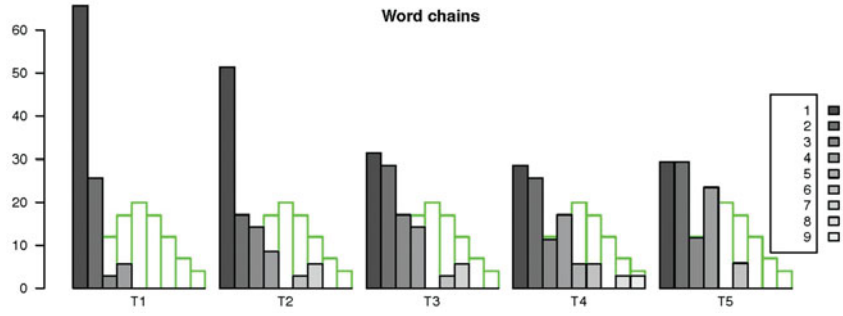

Figure 2. Bar plot of word chains results presented in stanine values together with the norm group values. T1–T4 ($n = 35$) and at T5 ($n = 18$).

from answers that were interpreted as having a similar meaning. Thus, each category had a content that shared cohesion and was given a title representing its content. The content analysis contributed to the investigation in this study as a complement to the statistically analyzed quantitative data. Different sorts of data required distinct methods of analysis. The answers to the open-end question needed interpretation to expand the awareness of how the participants experienced the use of AT in a wider perspective.

Results

First, the results of the assessments and the statistical analysis will be presented with the help of tables and figures. Next, the results of the content analysis of the questionnaires will be presented by category.

Assessment results

At Test Trials One to Four 35 pupils participated and at Test Trial Five 18 pupils were assessed. All tests were compared with Test Trial 2 (T2) and the results are shown in Table 1 and described below.

The results show a statistical significant mean difference between T1 and T2 ($p = <0.05$). Earlier studies have shown that test–retest training effects fade out after the second time the child is assessed.[58,59] Therefore, the second test trial was usedas a baseline for comparisons. All test results are described below:

Word chains showed an overall improvement of test results and a statistically significant difference between T2 and T3 and between T2 and T4.

Follow-up assessment results

18 pupils participated in all the 5 test trials and the results are presented in Table 1. All tests showed statistically significant results ($p < 0.05$) but the test word chains. The progression of the 18 participants in the follow-up test trial is presented below using stanine values. In Figure 2, a bar plot of the participants' improvement in stanine values (1–9) illustrates that 50% of the main group ($n = 35$) and 39% of the follow-up participants ($n = 18$) reached the lowest grade, stanine 1, at T2 regarding word chains, whereas 29% reached stanine 1 at T5 ($n = 18$).

Sentence chains, presented in bar plots in Figure 3, showed similar results, 50% of the main group ($n = 35$) and 39% of the follow-up group reached stanine 1 at T2 and 18% of the follow-up participants got the stanine 1 result at T5 ($n = 18$).

Non-word reading: Figure 4 presents a bar plot of the distribution of the results showing that 30% of the participants in the main group ($n = 35$) and 33% of the participants in the follow-up group ($n = 18$) scored stanine 1 at T2. At T5, 6% of the participants scored stanine 1 ($n = 18$).

Word reading: The results showed statistically significant improvements on all the test trials. As the test was not conducted at T1, word reading could not be analyzed at either T1 or T2. As shown in the Figure 5 bar plot, 50% of the participants ($n = 35$) and 56% of the follow-up participants ($n = 18$) scored stanine 1 at T2 and 38% scored stanine 1 at T5 ($n = 18$).

Reading comprehension: The results showed a statistically significant improvement ($p < 0.05$) on all test trials. Reading comprehension was not tested at T1 or at T5.

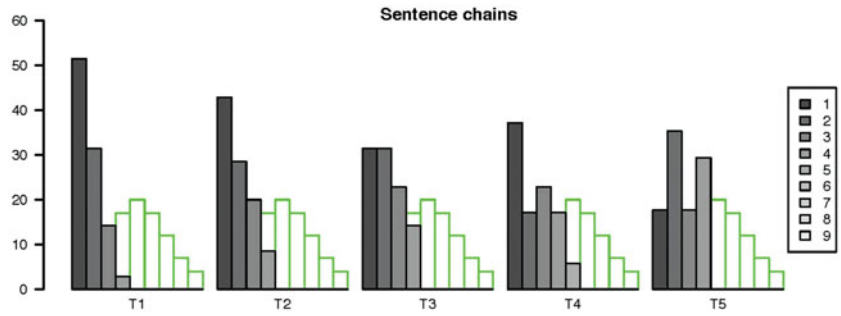

Figure 3. Bar plot of the test results on sentence chains presented in stanine values together with the norm group values. T1–T4 ($n = 35$) and at T5 ($n = 18$).

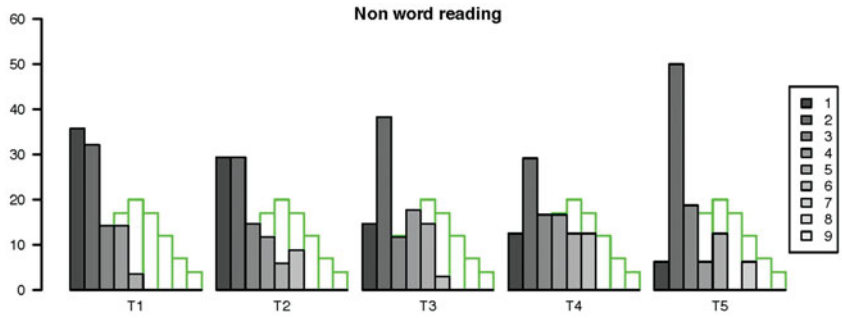

Figure 4. Bar plot over the test results on non-word reading presented in stanine values together with the norm group values. T1–T4 ($n = 35$) and T5 ($n = 18$).

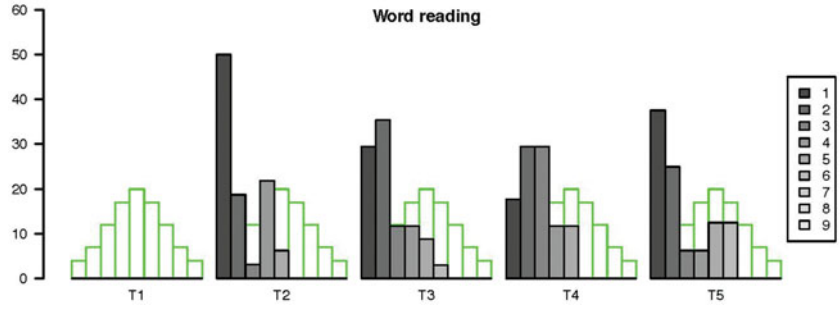

Figure 5. Bar plot of the test results on Word reading presented in stanine values together with the norm group values. T2–T4 ($n = 35$) and T5 ($n = 18$).

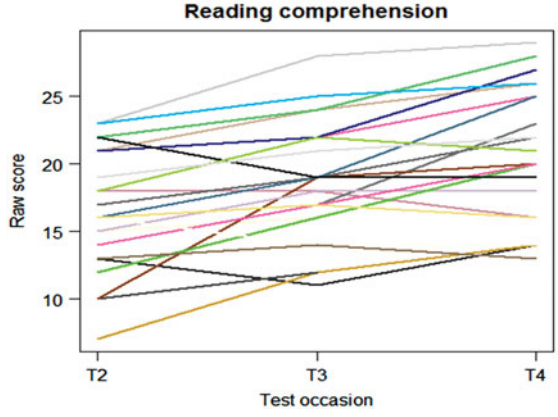

Figure 6. Individual results in raw scores on the reading comprehension test "Which picture is correct"? from T2, T3 and T4 showing a significant progression on group level.

Individual scores are illustrated in Figure 6, which shows raw scores and visualizes the improvement for each individual.

The main results in this study were that children with reading impairment that received interventions with AT showed a decoding development rate one year after the interventions similar to that of non-impaired children, who were represented by a norm group provided by the test manuals. The results also showed that reading comprehension increased significantly from T2 to T4.

Questionnaires

When the interventions were finished, both the pupils and their teachers answered a questionnaire. One year after the interventions were completed the participating pupils, their teachers and parents answered similar questionnaires. Several teachers could not answer, because the pupils had changed schools in pursuance of the Swedish school system. Below the results from the content analysis are presented.

From the content analysis performed on questionnaires from all the assessments five categories were created:

The accessible qualities of the device and the easy features of the applications: According to some of the participants, the easy access to the device, a smartphone or in some cases a tablet, was an important aspect. Pupils reported how easy they thought the applications and the devices were to operate. Both pupils and teachers rated *Prizmo*, the text-to-speech application, as the most useful application. Other highly rated applications were *Ispeak*, *SayHi* and *Easy writer*. One teacher stated: "It was an easy way to

teach the pupil to understand the content in a Swedish or an English text by having it read aloud". Pupils claimed that they were continuingly using the smartphone/tablet in school one year after the interventions had finished.

Inadequate technical experience, ineffective implementation and fatigue

However, technical issues were in focus for some teachers. Insufficient access to the Internet aggravated frustration and obstructed the work with the applications, since many of them required this Internet connection. Further, some teachers referred to their inadequate knowledge about the smartphone/tablet and the applications. One teacher wrote: "(…) some of the apps weren't very meaningful, it was difficult to operate them, I would have needed someone to show me how to do it in real life, now it took time after working hours". In some cases, the pupils had to show the teachers how to operate the device. In addition, teachers reported of inadequate information and insufficient pedagogical strategies for how to integrate the AT into the ordinary curriculum. Time and fatigue aspects were important in this pilot study, since many teachers experienced that the interventions were time-consuming and pupils referred to their exasperation while taking part in the interventions. Besides, the interventions took time from the ordinary curriculum. One teacher stated: "We spend too much time on the project to the detriment of other lessons, too much leisure time has been spent on trying to understand the technique and because of this other assignments have been neglected".

Increase in motivation and independent learning: Being overall enthusiastic about using the AT begin with, teachers still noticed an increase in motivation and independent learning as an improvement for the child after taking part in the project. Teachers also emphasized broader, or secondary, effects, for example an increase in self-confidence. One teacher wrote: "It was easy to use, the pupil has matured, gained self-confidence and is now more reflective over how to spell words". Another teacher wrote: "The pupils got a modern tool that gave them inspiration to work; it was fun to join in"! The pupils described that they had a sense of reading better after taking part in the project, which could be inferred as helping motivation to learn, since so many school-activities are reading-based. All groups of respondents mentioned the discovery of fiction. Having formerly avoided reading activities, many participating children were enabled to discover the world of books on their own and began to consume reading material to a greater extent than before. One teacher wrote: "My pupils read more books. And read whole books"!

Family effects of motivation and independent learning

Parents stated with great emphasis the relief of not having to badger their child about doing homework. They sensed that their child could learn more independently after it had found out how to use the apps in the smartphone or in the tablet and that they did not have to help with the homework. As a consequence of the child's increased independence in learning, the family climate showed improvements. One parent stated:

> It was very positive during the time of the project, he wants to read and listen to books on his own, earlier we really needed to nag on him to do this. This is a modern way to get children interested in books (…).

Another parent stated: "The project has been very good for our child; she became completely independent in doing homework and in studying for exams. We had to read her text aloud before". In addition, independence is closely related to motivation and self-confidence, as mentioned above.

Aspects of enjoyable ways of compensation: Pupils, teachers and parents stated that, overall, participating in the project was a positive experience. The participating pupils had moderate to little experience of the everyday use of computers and of using text-to speech programs (*Prizmo*) or of recording their own speech and transforming it into text (*SayHi)* in their schoolwork before they entered the project. After they had been introduced to the AT used in the project, fun aspects of using a smartphone and/or a tablet as a compensatory device were reported. Pupils stated that the smartphone/tablet was "fun to work with" or "it was fun"! The children liked learning new ways to get round their difficulties, and teachers discovered new possibilities in the field of special education. One parent wrote: "Participating in the project has been a very positive experience; we don't know what would have happened without it, fantastic"! The enjoyable aspects of this AT may have contributed to the increase in motivation that teachers and parents reported.

Discussion

The main purpose of the present study was to investigate the reading development and the impact of using AT on reading impaired children.

The results show that the group of reading impaired children increased aspects of their reading ability, such as the norm group during one year. The function of a norm group is to estimate an expected development, in this case, in reading progression. Even though the reading-impaired group still show substantial difficulties in comparison to their non-impaired peers, the results can be interpreted as positive outcomes. Stanovich [60] showed in a classic paper about the "Matthew effect" that children with dyslexia or other reading disabilities do not improve their reading abilities at the same rate as pupils without reading difficulties, leaving the impaired children behind at an increasing gap in comparison to their non-impaired peers.[22] However, in the present study the gap between impaired readers and their non-impaired peers remained the same. The children with reading difficulties showed a similar reading progression rate as the norm group. The aim of the interventions was to investigate possible transfer effects on reading ability after using AT. The reading-impaired pupils seem to have improved their reading ability, since the gap has not increased but may have been stabilized in relation to non-impaired peers.

The results of the assessments indicate that the transfer effects on reading abilities were small but possibly existent. If practice were the only solution to reading impairment, our positive results would have been expected already at T3, since it was the assessment made directly after the interventions were finished. Instead, our statistically significant results were also noticeable in later assessments. During the interval between post-test and the follow-up, the participants were allowed to continue to use the smartphone or the tablet with the applications unrestrictedly. The continuous use of the AT may have made them more comfortable with the device and the function of the applications. We assume that the supporting function of the AT in this study led to an increase of text exposure, which gave effect on the later assessments regarding reading skills. One possible reason why reading skills could have improved is that the child has encountered texts to a larger extent than before using applications in reading activities. Cipielewski and Stanovich,[61] referred to text exposure as a factor that accustomed children to reading activities and prepared them for independent reading. Since reading-impaired children

often avoid reading activities, the text exposure becomes small and has little effect. In this study, both parents and teachers stated that the discovery of fiction was a positive outcome from participating in the project. With the help of applications a child can get exposed to texts without having to be involved in technical reading or decoding to the same extent as without AT. Listening to a text and simultaneously looking at it could create secondary effects of training of reading. These relationships will, hopefully, be more stringently investigated in future studies. They may be challenging to conceptualize and operationalize in order to conduct research on what it is that makes a change in the individual, regarding both reading skills and the wider impact of the effect of AT. Edyburn [5] pointed out the lack of outcomes within the research area of AT for reading impaired individuals.

The results from the content analysis as presented in the category *the accessible qualities of the device and the easy features of the applications,* showed that the pupils continued to use the smartphone/tablet as AT during the year after the interventions was finished. There may have been some qualities in the device that made the children continue to use them. Why some pupils did not use the applications after the interventions had finished may be explained by how the smartphone/tablet with the applications was implemented in the pupils' everyday schoolwork, which was expressed in the questionnaires and presented in the second content analysis category. The special education teachers that performed the interventions may have little impact on organizing the ordinary programme of the participants. This may have hindered the use of application devices. Pupils stated in the questionnaires that the smartphone/tablet had other supporting effects in their ordinary school day than that of compensating for reading impairment, for instance an upturn in social status among peers. A more profound analysis of these supporting qualities was not conducted in this pilot study.

The third category of the content analysis contained themes of motivation and independence. The follow-up assessment indicated self-reported increase in motivation, an observed rise in pupils' self-confidence as well as in independence, according to their teachers and parents above all. These results are similar to the study conducted by White and Robertson.[42] The wider impact from using applications as AT could stem from the composition of the AT used in this study: the size, portability and simplicity of utilization. It is almost comparable to wearing glasses for improvement of eyesight or becoming mobile *via* a wheel chair.[5] We can presuppose from the results and narratives by our participants that the use of AT can give a reading impaired child an equated level in educational and social settings. Besides, stigmatizing episodes when going in and out of classroom to special education is avoided.[39,42] In this study, the interventions required one-to-one learning, while the continual use of the smartphone as an AT did not. To leave one's peers in order to receive the interventions may have been activating some feelings of labelling and stigmatization that have been often and thoroughly described in previous studies.[39,62–64] However, using the smartphone or the tablet as an AT in everyday life or in an ordinary learning situation can decrease incidents of stigmatizing when leaving the classroom acts and make the child learn in the same context as everyone else. Excluding potentially stigmatizing special education sessions may have a positive effect on the child's well-being including its self-confidence.[39]

A larger study to systematically evaluate the effects of using AT in smartphones and tablets on reading skills and its relationships with aspects of self-concepts is coveted.

An increased motivation to learn is an important result since reading impaired children may run a greater risk of being non-motivated for school work due to the unproportional amount of effort that may be necessary in comparison to non impaired children while conducting similar tasks. This unrecognized workload may decrease the motivation for a child with reading impairments.[65] Thus, motivation for reading activities could contribute to facilitating learning and taking part in the curriculum for the reading impaired child. The higher the grade, the greater the emphasis on reading as the most important means to acquire knowledge. If the reading activity could be recognized as listening to text-to speech applications as well as using video clips on the Internet the built-in disadvantage that many reading-impaired children have had to face so far may be on the verge of elimination.

The test results and questionnaire data of the present study highlight the importance of an early detection of reading difficulties.[40] The participants in this study were in many ways at the beginning of their reading careers since they were at a fairly young age (10–12 years). It is possible that, because of their young age, they have not yet developed compensating strategies of their own to master or avoid reading tasks in school. Therefore, they may have been open to using AT. If pupils have already created and manifested less effective ways of compensating reading, the AT may lose its compensatory effect. The clinical and practical implications that our participants have reported may also contribute to the notion of the importance of early detection.

Aspects of parents' relief at not having to be helping their children with homework was presented in the category *Family effects of motivation and independent learning* and may be an important result. Previous studies have shown that children with reading impairment benefit from family support.[66,67] Clinicians and special educators as well as teachers will recognize the fact that a disabled child may bring certain challenges for the family. Parents of children with reading impairments may recognize endless reminders of reading training and homework. The effect of using smartphones/tablets as AT may relieve parents from their role as an extra tutor and may enable them to focus on other, non-school-related, aspects of parenting. Possible positive effects of this can supposedly be: a better communication between the school and parents; a more independent child that can manage homework without parental involvement, and an increased psychological well-being in the family system.

Clinical significance

The results of this study may be more substantial and have more personal impact on the participants than what the statistical calculations may prove. As in psychotherapy, the effect of an intervention may be other than what is captured by psychometric instruments.[48] Edyburn [5] has mentioned the difficulty of presenting individual outcomes of AT. The reading process is complex in nature, and being reading impaired has far greater implications in the life of an individual than not being able to assimilate information *via* text. In this study, we have shown that important aspects of a young reading-impaired person's forthcoming development, such as self-confidence, motivation to learn, relief of feelings of stigmatization and family relations, can be affected by using AT.

Limitations

As our pilot study probed new areas of research such as using applications for training reading-impaired children, we are inclined to discuss the limitations of the study thoroughly.

Our results show a significant improvement between Test Trial One and Test Trial Two, which can be explained by test recognition effects. However, it may be argued that this will continue to affect the results throughout the assessments. Unfortunately, none of the standardized, practically used, tests available provide five different versions for avoiding this possible effect. As previous studies using *Word chains* and *Sentence chains* have shown that the initial training effect from recognizing test items and test procedure declines after the second time the child has undergone the assessment, the results of the second assessment (T2) were used as starting point in the statistical analysis in this study.[22,59] The test *which picture is correct?* does not seem to create test–retest effects, which is possibly due to its design. To our knowledge, no previous studies have discovered such effects with this test.

We chose an age group including many pupils who changed schools and teachers, in accordance with the Swedish school system, and therefore were lost to the project and made the dropout rate higher than expected for the follow-up assessments. We also had too many applications to work with, which made the training less structured and sequential and less able to reinforce effectively, as recommended by Rose [36] and SBU,[31] since this study was designed before the SBU report was published. In addition, this study was initiated as a pilot study in order to develop and launch a larger, oncoming similar project.

Further, we noticed that both the teachers and pupils experienced fatigue after a month with extensive work involving the interventions. Instead, to increase the program fidelity, a short cessation halfway through the intervention program would have been preferred.[28,29] All these observations will be passed on to a current project with randomized controlled groups and more efficient but not so time-consuming training.

The majority of our participating teachers received one-day real-life training and another occasion *via* a video call. For geographical reasons, a small group of teachers received all their introduction and education *via* a video call. While the project was performed, all teachers had access to a webpage where information was posted. In retrospect, this was not enough for project compliance. The project suffered from dropouts in the one-year follow-up assessments. Furthermore, during the performance of the project, participating teachers showed a disinclination to complete the sessions or the assessments and did not visit the webpage. For complete implementation, the information and education about and within the project may have needed to be more intense and extensive. However, it is prerequisite to put it in the context of the funding and the occupational context granted to the teachers. Since the participating teachers did not receive any monetary remuneration for their contribution, it was impossible to ask for more time than achieved. Besides, one ambition of the project was to stay close to a practical and clinical context.

Another methodological concern to discuss is the concept of literacy. We have aimed to illustrate that the improvement of the reading ability for reading-impaired children is not solely due to extensive training. A complex network of contributory factors has to interact in order to produce a skilful reader. AT can contribute with the individual experience of independence, motivation to learn, text exposure and evasion of stigmatizing shame when a difficulty is apparent in academic and everyday life. With this paper we wanted to illustrate what impact using applications as AT for reading impaired persons can have. However, RCT studies are desirable for evaluating this to secure a body of knowledge, since there are few previous studies that have measured the outcomes of using AT.[5] Researchers could be said to be facing a challenge in capturing all the aspects mentioned above in investigating the use of AT by reading-impaired persons. Assessments or questionnaires are not equipped per se to describe the phenomenon in a way to give it justice and we are yet waiting for an instrument that is.

In this study, several psychometric challenges have been met. We have used traditional pedagogical instruments to test aspects of reading skills, while our ambition was to investigate how well the children could assimilate and communicate text by other means than the traditional reading of decoding and writing with the use of pen and paper and instead with the help of a certain AT. The conceptualization of assimilating text is in its early stage, and we will continue to work on ways to conceptualize, theorize and measure this. In this study, we have combined test results with answers on questionnaires to fully grasp the complexity of the act of understanding and using information presented as text.

Future research

As mentioned above, to our knowledge few studies have been conducted with the purpose of investigating the use of tablets and smartphones as AT for reading-impaired children. Springing from our results we are now conducting a study that aims to investigate the effectiveness of training reading skills with applications using a randomized selection of pupils at different ages that are assessed stringently on several aspects of the process of reading. We are also investigating the role of self-image, teacher involvement, aspects of psychological health and motivation in combination with the use of AT to outline the progression of reading skills.

We would also like to encourage a debate about the claim that time is ripe to re-define the act of reading. If literacy is defined as the act of assimilating and communicating text, which can take place without the act of decoding, the ability to listen to printed material being read aloud will count as literacy. Today, we have a number of different media to choose from to gain knowledge, communicate or acquire information. To our knowledge, there are no scientific proofs that the most effective way is *via* visual channels and, traditionally, by reading printed texts. In the act of reading, we often mean decoding printed text, whether we look at it digitally or in a book. It is reasonable to think that gaining information will grow even more important, no matter how it is done. New means of technology will facilitate this even more in the future, especially for reading impaired people. The concept of reading may be by extended to gaining information, not excluding the act of decoding but including assimilate and communicate texts. This would but correspond more suitably to the way reading impaired people, and perhaps everyone in the next generation, will acquire information. This promoted change of the concept of reading and gaining information will challenge the research field to broaden itself to include these aspects, as well as certain changes in pedagogical visions and obligations will be necessary.

Disclosure statement

The authors report no declarations of interest.

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