Exploring Types of On-Demand Reading Assistance for Elementary School Students

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Figure 1: The reading assistant offers three different support visualizations for the difficult word selected by the reader: syllabication, explanation and base form.

ABSTRACT

The ability to read is an essential skill for participating in modern society, yet almost 20% of all third- and fourth grade students in Germany do not have a sufficient level of reading performance. Computer-based learning assistants provide a promising approach for wide-spread reading support, however, it is unclear which types of assistance visualization are effective in overcoming reading difficulties. We present a prototype of an interactive online reading assistant for self-directed learning. This prototype comprises tools for adjusting the text display as a whole, as well as assistance visualizations for individual words (syllabication, explanation and base form). In a formative user test with five primary school students, we gather feedback regarding the general acceptance of the application, differences between the assistance types and suggestions for further improvement. In addition, we provide guidelines on how to adjust the evaluation procedure to better match the intended user group in the future.

CCS CONCEPTS

• **Social and professional topics → Children**; • **Applied computing → Interactive learning environments**; • **Human-centered computing → Accessibility systems and tools**; *Empirical studies in visualization*; Participatory design.

KEYWORDS

Reading difficulties, learning to read, assistance systems, augmented reading, support visualization

1 INTRODUCTION

Reading represents a core skill, enabling not only academic achievement [2], but also full participation in a literate society [6, p. 23]. It is thus all the more unexpected that as many as 18.9% of all German fourth graders did not possess a sufficient level of reading proficiency in 2016 [5]. Similarly, in the 2018 PISA study, 20,7% of German teenagers only reached the lowest competency level in reading [10], showcasing the persistence of these difficulties when not addressed. The widespread nature of these problems does not allow for adequate one-on-one tutoring for at-risk students. Around two thirds of the elementary school students that lack in reading ability do not get any additional school-based reading assistance [5].

One solution may lie in computer-based learning assistants. These have shown to improve concentration, motivation and reading endurance [13]. It is theorized that their main benefit is an increase in reading motivation. This increase in motivation and concentration yields positive results in regards to their later learning success. Moreover, learning independently in addition to school lessons improves the students ability to self-teach [3].

In this project, we utilized the benefits of computer-based learning assistants and self-teaching for remediation of reading difficulties by implementing an online textbook with interactive assistance tools, as can be seen in Figure 1. We especially focus on the impact of different types of support visualizations on a number of indicators of reading motivation and success. In this manner, we aim to gain an empirically founded understanding of which types of assistance visualization are most beneficial in regards to learning to read.

We outline the creation of a modular, online reading assistance app. The system is designed in an extendable manner to enable rapid prototyping of more visualizations in the future. In this way, the system can be used as a framework to be iterated upon, especially to reflect feedback from participants and to include further suggested visualizations. In addition, we showcase how the system can be used report preliminary findings from a small number of first user tests

2 RELATED WORK

There have been a number of research projects that aim to enhance the reading process by automatically detecting the reading behavior of a child and adapting the text display accordingly. *Gary* is an application that combines gaze tracking with text-to-speech output [12]. The gaze tracker is used to detect the current position of the reader in the text and read aloud the passages along with the silent reading of the user. This is to improve the reader's performance on comprehension questions after reading a novel text. A different project investigated the use of gaze tracking to provide localized reading assistance [7]. Unusual gaze paths are interpreted as the user have trouble reading a word, which cues the application to provide an asssistance visualization for that word. This was shown to significantly improve the reading motivation of the students. Ribero et al. enhanced the reading experience by augmenting the readers environment with digital media enrichments [11]. The audio-visual enhancements have been developed in cooperation with elementary school children. Tests that evaluate support for early readers are yet to be done. Other systems use the readers peripheral field of view to provide them with additional information to the text [1]. While the user is reading a text, a projector is used to display images in the periphery of the reader. They concluded that the information shown in the peripheral field of view could be provided to the reader without distracting them or decreasing comprehension. Benefits of the system for novice readers had not been tested.

Additionally there has been research in the brain-computer-interface domain to assist children in reading [4]. *FOCUS* aims to use EEG data to detect a decreased level of concentration and subsequently displays an exercise for the student to regain their attention. During a study with 24 elementary school students, the context-based display of lessons increased the concentration levels of the students.

While several such systems, that automatically detect reading difficulties and give additional information, have been proposed, these all use different visualization methods. It is not clear, which of these methods (or other, yet to be proposed methods) are beneficial in general.

There also exist two commercial applications providing assistance visualizations while reading texts for children. *Leseludi*[1] has the option to mark syllables in alternating colors, though this can only be activated for the full text, not individual words. Similarly, the *Leseo*[2] app offers text-wide syllabication visualizations for texts aimed at beginning readers. In addition, difficult words have the option to display a tooltip, showing an explanation, or the text can be read aloud by playing a previously recorded voice-over. These commercial applications are closest to offering on-demand assistance for individual words. Unfortunately it is unclear how they arrived at the selection of assistance types they offer or whether any of them significantly improve reading performance, as no methodology or evaluation is published.

In summary, there are several systems with various approaches to support the reading process by detecting problems and offering some form of support. However, it is unclear what criteria are being used to select the support measures. To the best of our knowledge, there has not been a systematic study on the effects of different support methods to improve reading performance in children. By developing a system, which provides its supports on-demand, we are able to compare the impact of different assistance types themselves without confounding effects from a detection algorithm. Subsequently we can formulate empirically founded suggestions on which assistance to investigate further for more complex systems.

3 AN EXTENDABLE, ON-DEMAND READING ASSISTANT

To specify the requirements for the initial layout of the system, we conducted semi-structured interviews with four children from second and third grade (3 female, 1 male) that were accompanied by their parents. The participants were volunteers from the extended circle of acquaintances of the researchers and did not receive compensation. The goal of the interviews was to identify candidates for the first set of assistance visualizations that children would be familiar with. In addition, the interviews revealed two features that do not match a pattern of giving support for specific words, but were still requested multiple times. In order to include these findings, support systems were split into two categories: *Tools*, which can be used on the full text, and *Helpers*, which display additional information for a specific word on request.

Both *Tools* and *Helpers* were embedded into a simple web application in which a text could be read. The default appearance of the main text body colors was optimized for legibility [8]. Headings and graphical elements use warm, saturated colors and high contrasts for a child-oriented appearance.

3.1 Tools

The most basic example of a *Tool* is the ability to adjust the font size, which was possible via two buttons in a sidebar. This allows the reader to choose a preferred size for the entire text.

The reading ruler allows the reader to highlight the line they are currently reading. This minimizes the risk of accidentally slipping into an adjacent line. The reading ruler highlights one line by a

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[1] https://leseludi.de/Infos
[2] https://www.cornelsen.de/digital/leseo

changing its background color, while the opacity of the remaining text is reduced (Figure 2).

Figure 2: The reading ruler highlights the current line by decreasing the contrast of the remaining text.
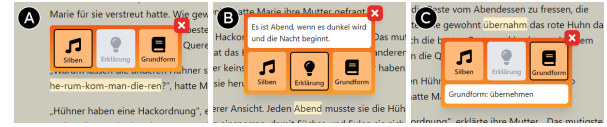
3.2 Helpers

The helper window displays the selection of available *Helpers* when clicking on a word. From there, the different helper visualizations can be activated by the user. This two-step process allows the user to consciously decide on the level of support according to their own competencies and needs. *Helpers* are further divided into two subcategories. Those that change the appearance of the word can alter the word in-line. Whereas visualizations that give additional information related to the word are displayed as an extension of the helper window. Both the exact visualization of the word in-line and the content to display in the extended helper-window can be defined arbitrarily, allowing for the easy extension of the system to include further assistance types. The buttons can also be disabled to indicate that an assistance type is not available for a specific word.

Based on the initial interviews, we identified the syllabication as the most-requested helper. This targets situations, in which the reader would know the word when hearing it, but needs assistance in decoding the written word. In order to keep the word integrated in its sentence, our implementation highlights the selected word and separates the syllables with dashes within the text (see figure 3A; Example: "*favorite*" would get displayed as "*fa-vor-ite*".).

The most common source of difficulty mentioned in the interviews was a lack of understanding of new or rare words. In these cases, the first method employed to resolve those problems was to ask parents or teachers, who would then explain or paraphrase the problematic word. Based on this, the second helper implemented is a short *description* of the word to the user (see figure 3B; Example *"evening": "The time between late afternoon and night."*). Unlike syllabication, this targets situations where the word is completely new to the reader or where they cannot remember its meaning. Due to the larger amount of text to display for the explanations, these are not shown within the text, but rather as an extension of the helper window.

Finally, we implemented a *Helper* to display the base form of the word (see figure 3C). For nouns and adjectives, the base form consists of the nominative singular with its corresponding article. For verbs the infinitive is displayed. For example, the base form of "*brought*" would be "*to bring*". This tool is intended to help readers connect irregular declinations and conjugations back to their more familiar form.

Figure 3: Screenshot of the *Helpers* that provide syllabication (A), explanation (B) and base form (C)

4 EVALUATION

To test the suitability of the system for gathering feedback in the future, we conducted a small usability test. The test was designed to elicit data regarding the overall acceptance of the reading assistant, differences between assistance types and suggestions for further development. The tests were conducted with one parent present using an online video conferencing tool. The parents were asked to not answer in place of their child and children were instructed to use the application on their own, however, in some cases the adults provided support in operating the application.

The participants were volunteers from the extended circle of acquaintances of the researchers and did not receive compensation. The proceedings were approved by the ethics committee of the University of Oldenburg. The participants were informed that they could quit the study at any time.

4.1 Procedure

We provided an abridged version of the short story "Das rote Huhn" by Prue Anderson (around 450 words in length) to be read in our prototype. This story was originally developed for the 2016 IGLU study [5]. To increase the likelihood of mistakes and subsequent use of the reading-assistants, we chose a text of a slightly higher difficulty than usually intended for the educational level of most participants. (Text intended for students at the end of grade 4, contrasted with intended target user group of students throughout 3rd grade.)

At the start of the test, the features and the interface of the application were explained to the participant using an example text. After answering any open questions on the application, the participant was to read the text for comprehension and use the *Helpers* whenever they encounter difficulties. The children were instructed to think aloud and report all their actions, thoughts and plans.

4.2 Data collected

While reading, user inputs were logged by the application for real-time support and later analysis. This included data on which *Helpers* were used how frequently and for how long, as well as line-by-line activation of the reading ruler. Total reading time as a proximate measurement of reading performance can also be extracted in future studies. Due to the small sample size and limited scope of this initial study, the time-based measurements were not evaluated in detail, but are available for future studies.

The test was framed by two interviews, before and after reading. Beforehand, the children rated the expected fun of using the system as a whole via the *Smiley-o-Meter* [9]. This value is then to be compared to the actual fun rating on the *Smiley-o-Meter*, collected after

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the test. Only the difference is considered to counteract the general positive bias in surveying children, based on recommendations from a workshop with the authors of the *Smiley-o-Meter*.

In addition, the post-hoc interview included questions regarding which of the *Helpers* was perceived as most helpful as well as open-ended questions on which aspects of the system worked particularly well or badly. Considering the age of the participants, these open-ended questions are unlikely to elicit many responses, but were still included to provide an opportunity for feedback.

5 RESULTS & DISCUSSION

The prototype was tested with five children (w=5, four third-graders, one fourth-grader) in a remote usability study. One of the participants (p05) did not use any support visualizations during self-directed reading. As they had still experienced all of the assistance types while being introduced to the system, their preference ratings and feedback were included in the analysis. In addition, the activity log malfunctioned for one of the participant (p02), such that their data had to be excluded when comparing the utilization of different assistance types. This aspect of the prototype will need to be improved before future studies.

5.1 Overall acceptance of the reading assistant

We collected the change from expected fun to perceived fun of using the system via the *Smiley-o-Meter*. Coding the lower end of the scale as 1 and the upper end as 5, the average fun rating increased from 3.7 to 4.2. Considering individual ratings, the value increased or remained constant for each participant, no participants rated the experience worse than expected. The generally high acceptance of the assistance system by the participants is also confirmed by 4 out of 5 participants stating that they would prefer to keep using the assistant in the future, as opposed to reading in a conventional book. The main advantages of the application over books mentioned were the possibility to adjust the font size and display the syllabication. In one case it was also mentioned that reading on the tablet has the advantage of avoiding crumpled pages.

One parent also observed that their child had read much longer than they usually would. However, this could simply be based in the setting of having to read the full story to complete the usability test.

5.2 Comparison between assistance types

Assistant utilization: Figure 4 shows the frequency of use of the helpers (syllabication, explanation and base form), with syllabication being by far the most commonly used assistant type. Reasons for this might be the familiarity with the concept of using syllabication to understand a difficult word from its use in school. Additionally, the syllabication might be sufficient in most cases to understand a difficult word, and more advanced help in form of an explanation of the word is not needed.

Assistant ranking: Figure 5 shows the participants' answers to the question "Which assistant did you like best?". In some cases the participants mentioned a second priority in addition to their favorite, such that these were also included in the analysis. For future studies, always asking for a full ranking could give a more complete picture. For the initial user test, syllabication and explanation were
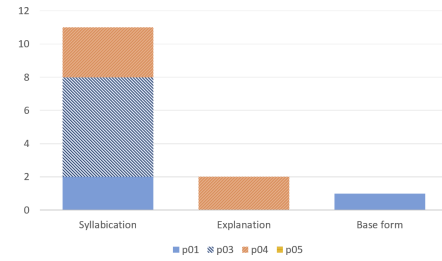
Figure 4: Frequency of use of the helpers by participants (p02 excluded due to incomplete logs)

chosen a similar number of times, showing a more complex picture than the utilization by itself. Despite not being used often in this test, the explanation was still considered as their favorite assistance type by two of the participants. Aside from the *Helpers*, the reading ruler also received a number of votes, highlighting the benefit of its inclusion despite not adhering to the strict per-word-pattern of the other assistance types. The base form was not picked at all and, considering also its low utilization, can likely be removed in future iterations.
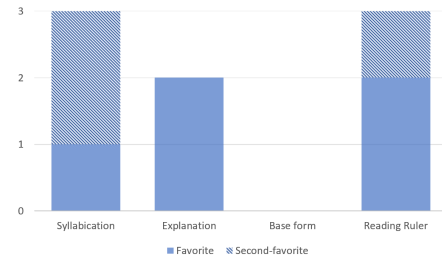
Figure 5: Number of times each assistance type was chosen as best or second-best.

5.3 Feedback and suggestions for further development

Positive features. When asked if there were any particularly good aspects of the application, two of the children told us that they liked the story very much. The reading ruler and the syllabication were each mentioned positively twice. In addition, the possibility of adjusting the font size was also mentioned in one case.

Problems. In most cases the question "In what aspects should the application be improved?" was answered with "None". One participant wished for the addition of horse stories. Another child wished that the application made it possible to read a story in only five seconds.

Most participants also answered that they were never caught of guard by the operation of the application. In one case, a child stated that sometimes instead of using the helpers for difficult words, they just kept reading. This could possibly be counteracted by reducing the amount of effort required to access a helper having it be displayed automatically (cf. [4], [7]). Alternatively, the children

could be informed that help is available by marking especially difficult words to remind them of the option.

Helpers. When asked, the participants did not think of any other assistance types that could be offered by the reading assistant, highlighting the need for a more involved participatory design process. This will need to be decoupled from the evaluation to give sufficient time and energy to the ideation process.

Some parents suggested the use of text-to-speech as a assistance type, as this feature would allow the children to learn the pronunciation of a new word. While not a visualization by itself, this could be combined with further information on how the pronunciation relates to the spelling of the word to reinforce the connection between the two. This would fit into the *Helper* scheme prescribing use of the helper window for additional information, while a pure speech-to-text feature could even be implemented in-line.

5.4 Further observations

Although it was not part of the usability test, some of the accompanying parents gave feedback at the end of the test. Overall, the feedback was positive. One parent described the program as a "great application for kids, with limited vocabulary." They felt that the application could be given to children on their own, so that they can read independently without having to ask someone for help.

While this feedback was valuable, it also has the potential to interrupt the post-test interview with the child. It would be beneficial to include a dedicated interview section for the parents at the very end for further studies. This would both ensure that feedback from parents is collected but also that they wait with providing it until after the interview with the participating child is completed.

6 CONCLUSION

In this work, we present a system to enable children to read texts containing new and complicated words on their own, without relying on the help of their parents or teachers. The system includes both *Tools* for adjusting the overall rendering of the text, such as the reading ruler, as well as *Helpers*, on-demand assistance visualizations for specific words. The latter include syllabication, explanation and a base form of the word, with the system designed to be easily extendable by further assistance types in a participatory design process.

We performed a small usability test with 5 children, both to evaluate the current state of the system, but also to test it's suitability for testing different assistance types.

Regarding the prototype itself, the application was well-received by the participants, with syllabication, explanation and the reading ruler all mentioned as beneficial. Out of the *Helpers*, the syllabication was by far the most commonly used. Only the base form was neither commonly used, not perceived as beneficial, and is a candidate for removal in future iterations. In its stead, inclusion of a text-to-speech based assistance type was suggested.

For further development of the system, there were a number of insights on how to improve the design and evaluation process: While the evaluation did already provide valuable insights into possible improvements, these were partially driven by feedback from accompanying parents, rather than the children themselves. Accordingly, it is recommended to embed the evaluation into a larger participatory design process, such that separate sessions with the children can be dedicated to ideation. These sessions should also include more age-appropriate feedback methods over openended questions to better understand the children's interaction with the prototype. In addition, the role of the parent should be codified in the evaluation process to ensure that their insights are also considered.

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