Designing *with* and *for* the Visually Impaired: Vocabulary, Spelling and the Screen Reader

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Keywords: user-centered design, e-inclusion, computer-assisted vocabulary learning, visual impairment, auditory feedback, vocabulary acquisition, orthography

Abstract: For visually impaired people it is both usable and effective to study foreign language vocabulary and spelling with an auditory e-learning device. Amongst visually impaired computer users there is a growing preference for the screen reader over the braille line. Unfortunately, this exposes them even less to the written word. However, spelling is considered one of the biggest challenges for visually impaired people who study a foreign language. Existing computer-assisted vocabulary learning software is often designed for sighted users and information is lost when they are accessed with a screen reader. This paper discusses the successful evaluation of a prototype of an auditory vocabulary and spelling trainer (AVoS) and explains how essential it is to involve the target group in the development process. The paper presents the results of an online survey amongst 88 adults with visual impairments in Germany. The survey clearly indicates who would benefit from an auditory vocabulary and spelling trainer and which features would make it usable.

1 INTRODUCTION

Reading text on the screen is not the same as having it read aloud by text-to-speech technology. While the content is available in both cases, orthographic information is lost when text is read by a screen reader. This is disadvantageous to visually impaired people. In the second language (L2) classroom, especially spelling is often challenging for the visually impaired (Couper, 1996), (Moodley, 2004), (Nater and Thäle, 1994). For sighted people it is easy to encounter written words in a foreign language. A learner of English, for example, can choose from a great selection of printed learning materials, they can read newspapers and books, and have access to English websites. For the visually impaired, however, this is a different story. Materials in braille are expensive as they need to be printed with special printers. Due to the limited demand, not everything can be converted to braille. When it comes to language learning, Boguslaw speaks of a "great shortage of materials suitable for learners requiring non-visual methods" (Boguslaw, 2000, p. 1). Computer technologies are hence a true blessing for those with vision problems. With assistive technologies such as a screen reader or a braille line (device displaying embossed writing), visually impaired people can access a great deal of internet content and software applications just like sighted users. However, the screen reader is commonly perceived as more usable than the braille line because it is faster and requires no extra hardware (Moodley, 2004). This creates a dilemma: visually impaired users have difficulties spelling in a foreign language yet they often access foreign language in a way that hides spelling. What is more, computer-assisted vocabulary learning (CAVL) software—as a way to specifically address orthographic shortcomings—is often designed for sighted users. So whether CAVL programs are accessed with a screen reader or a braille line, the user experience for the visually impaired is altered. Shinohara has analysed how blind persons interact with technology and finds that "[...] functional equivalence might not account for the meaning of the mode of interaction for particular users of specific contexts." (Shinohara, 2009, p. 66).

This explains the need for a customised CAVL software that focuses on two important aspects for visually impaired language learners: (1) *usable access mode*, that is, have a primarily auditory output and an optional braille output, and (2) *efficient learning strategies*, that is, focus on L2 vocabulary and orthography. Just how would a CAVL program teach spelling via the auditory channel? Is this perceived as usable by the target group? Following a user-centered design approach, AVoS, an auditory vocabulary and spelling trainer, has been developed, yielding very promising results in a first prototype evalution (Stein et al., 2010). It highlights orthographical errors through means of prosodic enhancement. To ensure usability for the target group, they have been involved in the design process.

This paper motivates the development of AVoS by providing a clear profile of the needs of the target users. Section 2 describes the situation of visually impaired CAVL users from a didactic and usability point of view. Section 3 discusses the methodology adopted in the development of AVoS in which the target users play a central role. Section 4 presents the results from a first prototype evalutation and from an online user survey conducted amongst 88 visually impaired adults. Section 5 concludes the paper by summarising the main results and providing insights for future research.

2 MOTIVATION

This section describes which features make a CAVL program successful for language learners, especially when they are visually impaired. It further discusses didactic and usability aspects, hence justifying the central importance of involving target users in design process of an auditory CAVL tool.

2.1 Computer-Assisted Vocabulary Learning For the Visually Impaired

Explicit vocabulary study is an efficient way of increasing proficiency in a foreign language (Laufer, 1997), (Nation and Newton, 1997). It allows to study form and meaning of words simultaneously. This method allows to define a clear learning goal and measure progress—two features that keep the learner's motivation high, as demonstrated in various studies (Bandura and Cervone, 1983), (Lord, 1982). Moreover, explicit vocabulary study allows to repeat words in spaced time intervals in order to ensure long term retention (Ebbinghaus, 1885), (Pimsleur, 1967). A model that allows for this type of explicit vocabulary study is Leitner's "hand-computer", a comparted box with flash cards. The target language is written on one side of the card, the definition on the other side (Leitner, 1972). This model works well for all language learners and there are various CAVL programs that make use of this system such as Phase 6 (Gorin, 2011) or Vokker (Vokker, 2010). There are even programs that are specifically designed to be used by visually impaired users such as the vocabulary trainer recommended by the German braille line manufacturer Papenmeier (Papenmeier, 2011). However, all programs that have been reviewed by Stein (Stein, 2010) have one of two shortcomings. (1) *Contents and learning strategies:* spelling—as an integral part of vocabulary study—is not addressed adequately. (2) *Navigation and usability:* the program is not screen reader friendly or not usable when the output mode auditory. Subsections 2.2 and 2.3 discuss these issues in more detail.

2.2 Didactic aspects

Learning vocabulary requires mastering a word's meaning, form and use (Nation, 2001, p. 27). As was discussed earlier, especially learning the orthographic form of a vocabulary item can be problematic for visually impaired people. First, they are not exposed to the written word as much as sighted language learners. Second, CAVL tools do not adequately address the issue of spelling. There is a tendency to relate orthography to reading and approach the spelling task from a visual point of view. This is reflected in the visual nature of orthographic feedback in many CAVL applications. Specific errors are usually pointed out visually (Stein, 2010). There is evidence that this might not always be the best way. Shuren found that "written and oral spelling share the same central processes [. . .]" (Shuren et al., 1996, p. 52). This means that whether one reads a word or has is spelled out orally, the same parts of the brain are activated. Bosman et al. suggests that oral spelling might be superior in the spelling acquisition process (Bosman and Orden, 1997, p. 10). Arter et al., who more specifically discuss the issue of spelling for children who have visual impairments, come to a similar conclusion, stating that "[f]or blind children and auditory approach would be more appropriate" (Arter and Mason, 1994, p. 20). Other studies discovered that spelling and phonetical awareness are closely related (Bosman and Orden, 1997), (Katz, 1989). This means that spelling errors are usually phonetically plausible. Moreover, in order to spell correctly in a foreign language, one needs to have phonetical awareness in that language. A study by Thomas and Dieter reveals that the best practice for acquiring good orthographic knowledge is writing correct words (Thomas and Dieter, 1987). The interactive nature of a computer program allows to practice writing words and can give immediate feedback in terms of orthographic errors. From what has been discussed above, it seems sensible for this feedback to be delivered via the auditory channel, if visual is not an option.

2.3 Usability aspects

E-learning devices can add to the learning task the dimension of interactivity while the learner can still proceed studying at their own speed. In order to truly benefit from an e-learning program, it must be considered usable, that is, "useful, efficient, effective, learnable, satisfying, and accessible" (Rubin and Chisnell, 2008, p. 4ff.). The most important aspect is probably *usefulness* since no one will engage with a program that does not help them achieve a relevant goal. However, if any of the other aspects is not in place, the user experience is not likely to be a good one. The program must be both *efficient* and *effective*. That is, it must keep its promise and help the user with their task but must do so in a reasonable amount of time. All the while, the program should be *learnable* and *satisfying*, i.e. focus on key elements in a simple and engaging way. The aspect of *accessibility* is especially important when designing software for users who are visually impaired. They have three access modes to the computer, namely, (1) screen magnifier, (2) braille display, and (3) screen reader. A screen magnifier can only be used by those who have some vision left, a braille display only by those who are braille literate, and a screen reader can be used by all visually impaired users. Many who know braille choose to use braille and text-to-speech technology together, i.e. they navigate with a screen reader and read words words with a braille display. Thus, screen content is available to the visually impaired with the help of assistive technology. However, as Shinora (2009) notes "[s]imply replacing one interaction mode, such as the display of text on a screen with a functionally equivalent mode as in speaking text aloud, is not necessarily equivalent from the point of view of user experience." (Shinohara, 2009, p. 66). Hence, navigation and contents of a CAVL application for the visually impaired should ideally be designed for the intended output mode. "[E]xcept for a very limited range of products, 'design for all' is a very difficult, if not often impossible task" (Newell and Gregor, 2000) as cited in (Shinohara, 2009, p. 61). Since the screen reader is experienced as usable by the majority of visually impaired people, it can then be concluded that e-learning navigation and content should be adapted primarily for auditory output.

2.4 Problem Formulation

For CAVL programs to be usable for visually impaired users, they should be fully accessible with a screen reader and still focus on the orthographic form of words. It is didactly plausible to deliver orthographic feedback via the auditory channel. To find out which feedback works best and which additional features render a CAVL application usable for the visually impaired, target users must be involved in the development process. This is why a user-centered-design approach has been adopted in the development of AVoS.

3 METHODOLOGY

In order to address the needs of the visually impaired target group, the primary output mode of CAVL programs should be auditory but still be able to teach orthography. It is important to involve the users in the design process to make sure the solution is for them. How can an orthographic error be corrected via the auditory channel? Is this as efficient as the visual highlighting of errors is for sighted users? More importantly, is this option *usable*? Who would benefit from an auditory vocabulary and spelling trainer and how? Answers to these questions can best be found in collaboration with the target users. There are two strands of research that require user involvement. First, the target user must be adequately described. Second, the program must be evaluated in terms of its usability aspects. We have adapted a user-centered design approach following the suggestions by Rubin at al. (Rubin and Chisnell, 2008, p. 12ff.). One cycle in the design process describes the following four steps:

Step 1: define goal / concept

Step 2: implement the idea

Step 3: conduct user test

Step 4: evaluate the results

In the development of AVoS, the cycle has been completed one and a half times already. The remainder of this paper reviews the findings from the first cycle and describes the transition between steps 1 and 2 of the second cycle.

4 USER-CENTERED DESIGN IN THE DEVELOPMENT OF AVOS

The goal is to design a usable CAVL software for the visually impaired. This means that the primary output mode should be auditory. In terms of content, there should be a good balance between addressing vocabulary items with regard to their meaning and their orthographic form.

4.1 First cycle (completed)

The key objective of the first cycle in the development of AVoS was to evaluate the basic concept of an auditory CAVL application for the visually impaired. Details of this study can be found in (Stein, 2010).

The evaluation of an AVoS prototype took place under controlled testing conditions at the Carl-Strehl Gymnasium in Marburg, Germany. 15 visually impaired pupils from levels 6 to 9 participated in the study, aged 12 to 16. The evaluation was divided into three parts. (1) The subjects were asked to complete a questionnaire to enquire about their vocabulary study and computer usage habits. (2) Test persons worked with the AVoS prototype and completed a pre-test and a post-test to measure their progress. This served to measure both spelling and vocabulary performance objectively. To this end, a randomised and controlled [2 x 2] factorial between-groups design was adopted. The subjects were assigned randomly to one of two orthographic feedback conditions: simple auditory feedback (S-AF) and prosodically enhanced auditory feedback (PE-AF). In the S-AF condition, words were spelled aloud in the case of a spelling error. In the PE-AF condition, words were also spelled aloud in the case of a spelling error but the errors were located by prosodically enhancing their position. (3) The students filled in a questionnaire to report their user experience.

The following gives an overview of our findings from the evaluation upon the completion of the first cycle in the AVoS development.

(1) What are typical vocabulary study and computer usage habits among visually impaired language learners? The test subjects of this study relied extensively on braille reading and list learning when studying foreign vocabulary and orthography. They did not benefit from index cards in braille script or from the auditory output of the PC. Further, subjects singled out spelling as their biggest handicap in the L2 classroom. In terms of mental orthographic representation, they indicated that they picture spelling both haptic and auditorily. When using the computer, the test subjects relied on both the screen reader and the braille display but prefered the screen reader. Spelling errors in computer documents were commonly corrected using the spelling option of the screen reader or the brailler display, again with a preference for the screen reader.

(2) Do test subjects improve their vocabulary and spelling performance when they use AVoS? Does the prosodically enhanced feedback have any effect on perfomance? Working with AVoS improved both vocabulary performance (Pillai's trace: $F(1;9)=129.452$, $p<0.001$ (two-sided)) and spelling performance (Pillai's trace: $F(1;9)=129.898$, $p<0.001$ (two-sided)) significantly between the pre-test and the post-test. The prosodically enhanced auditory feedback (PE-AF) contributed to a significantly larger learning gain for spelling performance than the simple auditory feedback (S-AF) (Pillai's trace: $F(1;9)=5.030$, $p=0.026$ (one-sided)). For vocabulary performance no difference between the two conditions was found. Subjects who received the prosodically enhanced feedback were able to correct their mistakes faster. However, this result was not significant.

(3) Which features of AVoS work well and which could be improved? The test subjects classified the design of the feedback generally as usable, irrelevant of which testing condition they were assigned to. 14 out 15 test subjects indicated that they would like to work with such a tool to study vocabulary and spelling. They pointed out that they found it helpful that the entire word was spelled after a mistake, that words were repeated until they were known, that they had access to several control options, and that they could only move on to the next word once the correct word had been entered. In terms of the general system design, most subjects commented positively on the diversity of the feedback utterances, while some found this feature somewhat annoying. The missing braille line was not a problem, it was rather seen as a benefit by some subjects. The speech synthesis that was adopted received largely negative comments and should ideally be replaced by better voices.

4.2 Second cycle (partially complete)

The key objective of the second cycle in the development of AVoS is to improve the protoype and allow for more sophisticated user interactions. Again, before doing any implementation work, it is important to re-assess the needs of the target group. From the evaluation in cycle 1, there are indications as to which improvements of AVoS are desirable. However, the evaluation has been conducted among only 15 school children. This explains the need to evaluate a more global demand of an auditory vocabulary and spelling trainer. To this end, an online survey has been conducted, using the barrier-free tool soscisurvey.com. The survey has been completed by 88 visually impaired adults out from which 77 sets of data could be evaluated. The youngest test participant was 10 years old, the oldest was 74 years old and the mean age was 38.4 (SD=13.794). The majority of test subjects had achieved a university degree (29.5 %) or completed high school (16.7 %). Also, most participants specified their braille literacy as "very good" (67.9 %). Test subjects were asked to answer a total of 18 questions concerning their vocabulary learning and computer usage habits, and their usage of vocabulary learning software. Further, in an open-ended question, the subjects could indicate which features were important to them in a CAVL application.

(1) What are typical vocabulary study and computer usage habits among visually impaired language learners? The results from the online survey show that language learners with visual impairments struggle significantly more with acquiring spelling of an L2 vocabulary item than with acquiring its meaning. Consultation of the chi-square distribution χ^2(df=1)=12.737 shows that the probability of observing this difference is significant on a level of $p<0.01$. In terms of finding spelling mistakes in a text on the computer screen, more test participants indicated that they find the mistake from the mispronounciation of the text-to-speech synthesis rather than finding it with the braille display. On a scale from 1 (never) to 7 (always) of how often they apply either method, the mean for the screen reader was 4.59 (SD=1.814) and for the braille display it was 4.19 (SD=2.134). Tested against the middle value 4 (sometimes), the deviation was significant in the case of the screen reader ($t(67)=2.674$, $p<0.01$ (two-sided)). Further, there is a statistically significant correlation between how well visually impaired people know the braille script and how much they like to engage in foreign language study $F(1;72) = 4.052$, $p<0.05$ (two-sided).

(2) Which features are desirable in an auditory vocabulary and spelling trainer among adult learners? 68 test subjects answered this question and mentioned the following features as making a CAVL application usable for them: pronounciation help 48.5%, orthographic feedback 30.9%, screen-reader friendly 25%, context of the vocabulary item 20.6%, flash card method 23.5%, simplicity of the program 19.1%, braille line access 17.6%. Further, some test participants noted grammar help, display of progress, online dictionary, free of charge, and rich contrast for the display.

(2) How can the findings from the user survey be implemented into the AVoS prototype? Based on the results from cycle 1 and the results from the online survey, the following additional features should be included in the next prototype of AVoS:

Pronounciation help. Provide formant text-to-speech synthesis in the according language to allow a more natural pronounciation.

Intermediate pronounciation. Include a function to listen to the word 'so far'. Visually impaired people can easily pick out spelling errors from the misprounounciation of their screen reader. This feature could help them to verify their input easily before submitting their answer.

Braille line access. Usability for screen reader *and* braille display. While the screen reader is often prefered, good accessibility via braille line is also needed.

Context. Present vocabulary in the context of a sample sentence. This could be achieved via external links to online dictionaries.

4.3 Next steps

The results of the online survey give some great insights about the vocabulary learning and computer usage habits of visually impaired adults. Moreover, it provides some valuable information about what features are needed within a CAVL application in order to render it usable to the target group. This shows how important the interaction between the developers and the end users is. It is simply not enough to have theoretical knowledge about the target group.

Following the survey among adult language learners with visual impairments, a survey among visually impaired children and youth will be conducted. This should identify whether their needs in terms of vocabulary learning and computer usage differ. Once the new features are implemented in the next AVoS prototype, it will again be evaluated with visually impaired users. In order to reach a larger group of test subjects, the evaluation would ideally be carried out online. Moreover, it would beneficial to conduct a longitudinal study and compare the effect of AVoS to that of traditional CAVL software.

5 CONCLUSION

It has been discussed that for visually impaired language learners, it is both usable and effective to learn vocabulary and spelling via the auditory channel within a computer-assisted vocabulary learning (CAVL) application. Auditory is the prefered access modality to the computer screen for many visually impaired people. Unfortunately, this makes spellings of words invisible. Yet orthography is a major challenge for many visually impaired people in the L2 classroom. This explains the need for a CAVL tool which is designed specifically for auditory output and can still provide adequate orthographic feedback. In order to design a program that truly reflects the needs of the target users, they must be involved in the development. A prototype of an auditory vocabulary and spelling trainer (AVoS) has been evaluated with 15 visually impaired pupils yielding promising results in terms of the usability of the program. Further, an online survey amongst 88 visually impaired adults provided insights about the vocabulary study and computer usage habits of the target group. It has been found that many people find spelling errors in texts on the computer screen due to mispronounciations of the screen reader. Finding such as these can be used in the further development of AVoS. The overall goal is to provide a CAVL software for visually impaired users that allows them the same benefits sighted users receive from traditional software. This e-inclusion technology could potentially bridge the gap the two user groups in the realm of computer assisted vocabulary and spelling learning in the L2 classroom.

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