


Prosodiya – A Mobile Game for German Dyslexic Children

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Abstract. Approximately 4–10% of the German population suffers from developmental dyslexia. The learning disorder affects educational, personal, and social development of children in a negative way. Mobile serious games have the potential to support dyslexic primary-school children in addition to school support and learning therapy. We propose such a mobile serious game called “Prosodiya”, with the help of which dyslexic children can improve their reading and writing performance. Prosodiya includes innovative and evidence-based interventions that focus on improving the awareness of linguistic features related to syllable stress. We report the results of a pilot study of a preliminary version of the game. Results indicate that the children enjoyed playing the game, that their motivation was maintained, and that they wanted more levels.

1 Introduction

Developmental dyslexia is one of the most frequent learning disorders [24]. Affected children suffer massively from an impaired literacy acquisition – compared to their classmates, they acquire reading and writing skills in a much slower pace and not as proficient [29]. Usually, they lose motivation for the learning process as well as faith that they will ever be able to develop a comprehension of literacy language [2]. If these children do not receive appropriate treatments, negative consequences in the long run may arise, such as poor graduation and

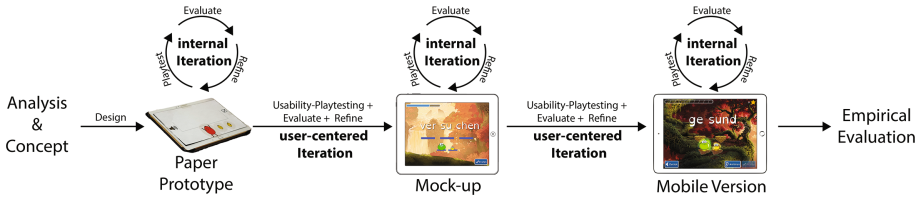


Fig. 1. Exemplary Iterative Children-Centered Game Design Process (ICCGD) for the game “stress pattern”.

higher chances to drop out from school, resulting in poor employment prospects or unemployment [10]. Overall, the learning disorder has a negative impact not only on mental health but also on social and cultural participation [1]. Serious Games have the potential to address the aforementioned difficulties. In shaping an individual’s learning curve, they boost motivation [11], and lead to successful learning processes (cf. [5]). With the great advantage of independence of time and location, mobile games can additionally help the children to overcome their learning disorder outside of learning therapy and classrooms – serious games for dyslexic children have been proven to have positive effects on the process of literacy acquisition (e.g., [4, 18]).

In the first part of this article, we present such a mobile serious game for dyslexic children aged 6–12. Focus of this game called “Prosodiya” is on well-founded user-centered development, on the adaptivity of the digital interventions, and on embodied training. To the best of our knowledge, Prosodiya adds two novelties to the field of serious games for dyslexic children. First, it is the first digital therapy approach that focuses on improving the awareness of syllable stress and associates the stressed syllable’s linguistic features to orthographic principles of the German orthography. Second, it is the first mobile game supporting embodied training using sensor-based gesture recognition.

In the second part of this article we present the results of a pilot testing a preliminary version of the game. Focus is on user experience and usability, but the impact on literacy development is also considered.

2 Prosodiya

To avoid failure caused by losing focus on the target audience, we particularly emphasized the involvement of primary-school children as the end user. We followed an approach called iterative children-centered game design (ICCGD, see Fig. 1) during the whole development process. The ICCGD combines the two familiar approaches of user-centered design [22] (UCD) and iterative game design [12] (IGD).

Prosodiya is based on recent empirical findings and on evidence-based interventions (e.g., [17, 27]). For example, a main component is training phonological awareness as children with dyslexia often struggle with this basic skill [6, 32].

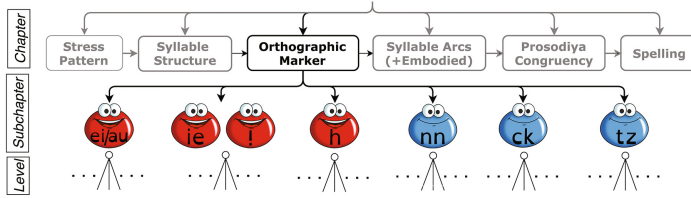


Fig. 2. Structure of Prosodiya. The third chapter (Orthographic Marker) is illustrated in detail. Red blobs refer to open and blue blobs to closed syllables. (Color figure online)

Phonological awareness refers to the ability to deal with the sound system of a language and to detect, distinguish and manipulate segments of a language like syllables, rimes, or even single sounds [20]. It also includes the adequate perception and processing of prosodic features such as syllable stress. Performance in detecting stress highly correlates with reading and writing skills [7, 14, 28] and recent research shows that a shortcoming in syllable stress detection in the context of words or sentences is a very strong predictor of dyslexia (e.g., [7, 14, 21]).

Prosodiya builds on this research and trains stress detection (e.g., Fig. 3a). First, this might boost a child’s ability to segment words into relevant components. Second, children learn to focus on relevant areas in words, as orthographic challenges mainly occur in stressed syllables: In the German orthographic system, there is a strong association between stress and vowel length markers – vowel length markers generally occur in stressed syllables [33]. Prosodiya aims at clarifying this association. It helps children to focus on the stressed syllable and to learn how such syllables are spelled. In doing so, it finally leads to a rule-based orthographic spelling training inspired by the empirically evaluated Marbuger Rechtschreibtraining [17].

Little inhabitants called “Kugellichter” (“spherical lights”), kindred to will-o-wisps, guide the children through the world of syllables and orthography and accompany them through the story: The magical land of Prosodiya is haunted by a mysterious and maleficent fog, causing the inhabitant to live in sadness. Only the children can relieve the world from its sorrow. Prosodiya consists of six chapters, each corresponding to a different linguistic or orthographic challenge for which different mini-games were developed. Each chapter is composed of various subchapters, each targeting a specific level of linguistic or orthographic competence. Each subchapter is again composed of various levels. The levels increase in difficulty in that the target words’ structures get more complex and the objective(s) of tasks get more challenging. The structure of Prosodiya can be seen in Fig. 2. Each part of the game is introduced and instructed by an interactive tutorial that explains game mechanics, imparts linguistic knowledge, and narrates the story. An integrated learner model aims at adapting the game to their individual proficiency, trying to keep up the learning curve, motivation, and fun. We give a brief introduction into the therapeutic process and its games. A further overview with videos is available at <http://youtube.prosodiya.de>.

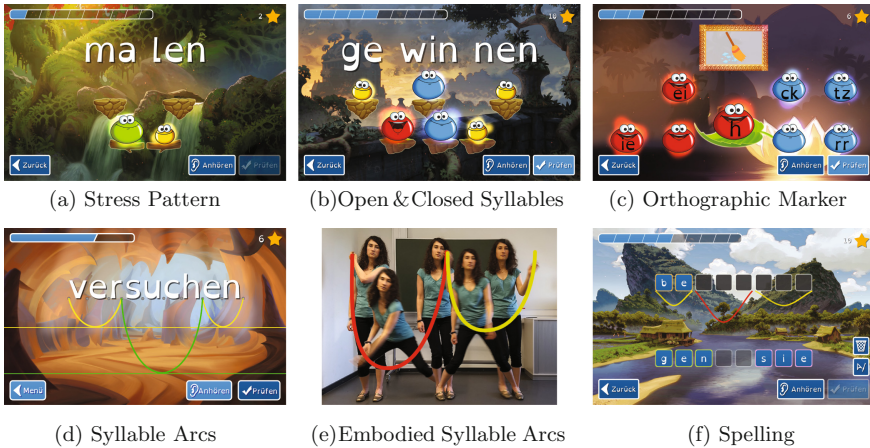


Fig. 3. Exercises of Prosodiya. See <http://youtube.prosodiya.com> for videos. (Color figure online)

In the first chapter, children develop and improve their awareness for syllable stress. They rebuild stress patterns of audio- and/or visually presented words by dragging and dropping cartoon blobs (Fig. 3a, big, green blobs for stressed and yellow blobs for unstressed syllables). This awareness is extended in the second chapter in which the structure of the stressed syllable is explored (Fig. 3b). They additionally have to decide whether the stressed syllable of a word is open (ends with a long vowel, represented by red blobs) or closed (ends with a consonant that closes the syllable and “squeezes” the vowel, represented by blue blobs).

Processing the structure of the stressed syllables provides a basis for acquiring the complex spelling rules that underlie spelling of long vs. short vowels in the German orthography. In the third chapter, children need to find out the spelling of these structures (Fig. 3c). They acquire knowledge about the rules that underlie the spelling of open and closed syllables by playing various minigames that cover the recognition of each of the special orthographic markers (c.f. [15] for a detailed description). In the fourth chapter, they learn to divide written words into relevant components (e.g., syllables) and thus foster their orthographic representation. The traditional intervention “draw syllable arcs” is commonly used to train syllable analysis. In Prosodiya, this training is enhanced by emphasizing syllable stress (children draw outstanding arcs for stressed syllables). This game is also being developed as a so-called embodied training that uses body movement and gestures. In this version, children speak each syllable clearly and loudly, simultaneously do a sidestep, and swing their writing hand from their left to their right shoulder (Fig. 3e). Fitness trackers with built-in accelerometers are used to record and classify the swung stress pattern. We refer to [16] for a detailed description about this embodied training and its implications.

In the last chapter, children foster their previously acquired knowledge by spelling out words using a predefined set of letters (Fig. 3f). This set of letters can - depending on the difficulty - contain distractors.

Table 1. The questionnaires given to children (C) and parents (P).

Question	Response options
Children and Parents	
Q1 C: <i>How do you like Prosodiya?</i> P: —" —	awful ○○○○ great
Q2 C: <i>Did you enjoy training with Prosodiya?</i> P: <i>Did your child enjoy —" —?</i>	not at all ○○○○ very much
Q3 C: <i>Would you like to continue training with Prosodiya?</i> P: <i>Would you continue using Prosodiya for your child?</i>	<input type="checkbox"/> yes <input type="checkbox"/> yes, if new games added <input type="checkbox"/> don't know <input type="checkbox"/> no
Q4 C: <i>Do you think Prosodiya helped you to improve your reading and writing skills?</i> P: <i>Do you think Prosodiya helped your child to improve their reading and writing skills?</i>	<input type="checkbox"/> yes <input type="checkbox"/> don't know <input type="checkbox"/> no
Only Children	
Q5 C: <i>How did you like the graphics?</i>	awful ○○○○ great
Q6 C: <i>How do you like our Kuggelichter?</i>	not at all ○○○○ very much
Q7 C: <i>How did you like the tutorials?</i>	not at all ○○○○ very much
Q8 C: <i>How difficult was Prosodiya?</i>	very hard ○○○○ very easy
Q9 C: <i>Was the task's objective always clear?</i>	<input type="checkbox"/> yes <input type="checkbox"/> sometimes <input type="checkbox"/> no

2.1 Evaluation of a Pilot Study

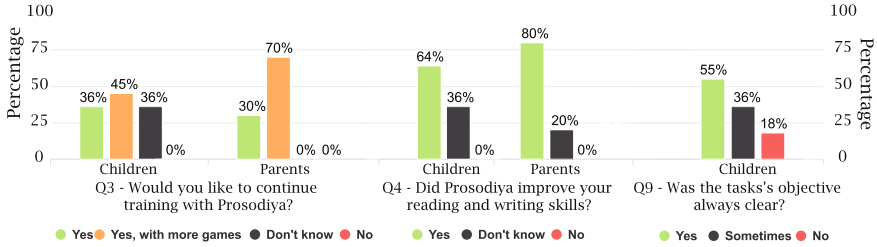
We conducted a pilot study with a preliminary version of Prosodiya in winter of 2015 with 11 dyslexic children from 2nd to 7th grade ($M = 4$, $SD = 1$) aged 7–13 ($M = 9.57$, $SD = 1.63$). Nine of the children were boys and two were girls. The study version contained the first two chapters and a restricted version of the third chapter (different orthographic markers were introduced in one and the same game – not in separate games as in the current version). In total, it consisted of 29 levels and covered 220 words. The children spent an average time of 192.6 min ($SD = 70.69$) training in-game during a period of six weeks.

We used quantitative spelling (DRT 2–5, i.a [26]) and reading tests (SLRT II [25], SLS [23]) to evaluate changes in literacy competence. Two questionnaires (see Table 1) were given to the families after the post-test to assess effects on motivation, enjoyment, and self-efficacy. One was answered by the children and one by their parents. The parents of one child didn't answer the questionnaire.

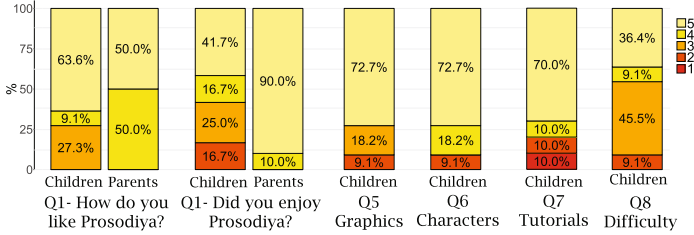
Results

Results of the questionnaires are listed in Figs. 4a and 4b.

Children and parents rated Prosodiya altogether (Q1) with an average of 4.36 and 4.5 out of 5 points. Children enjoyed playing Prosodiya (Q2, $M = 4.0$)



(a) Answers given to the multiple choice questions Q3, Q4, and Q9.



(b) Answers given to the Likert scale questions Q1, Q2, Q5, Q6, Q7, and Q8.

Fig. 4. Results of the questionnaires.

which is in line with the impression their parents reported ($M = 4.5$). Children rated the graphical appearance of the game with an average of 4.36 points (Q5) and its main characters with an average of 4.55 points (Q6). The majority of both children (72%) and parents (100%) would like to continue using Prosodiya (Q3), especially if more games are added (45%, 70%, respectively). Also the majority of both children (64%) and parents (80%) reported that they perceive self-efficacy considering reading and writing skills (Q4).

Children rated the overall difficulty of Prosodiya (Q8) with an average of 3.73 points ($SD = 1.1$) of a scale ranging from 1 (very hard) to 5 (very easy).

The majority of the children (55%) reported that the task's objective was always clear (Q9), 36% reported that it sometimes took some time to figure out the objective and 18% reported that they often had to guess what the task's objective was. One child answered this questions with both of the two latter options resulting in a total response above 100%. The tutorials (Q7) were rated with an average score of 3.82 points ($SD = 0.73$). Two children rated them very low (1 and 2 points) whereas the remaining rated them on average with 4.87 points.

In spelling tests, six children improved their performance in post-tests (DRT 2-5, i.a [26]), only two did not change in performance and one child performed worse. In speeded single word reading post-tests (SLRT II [25]), three children improved, four children did not change in performance and two children performed worse. In speeded reading comprehension tests (SLS [23]), the best improvements were obtained. Almost all children improved with up to 13 points on the fluency scale (a competence level encompasses 9 points). Only one child's performance did not change.

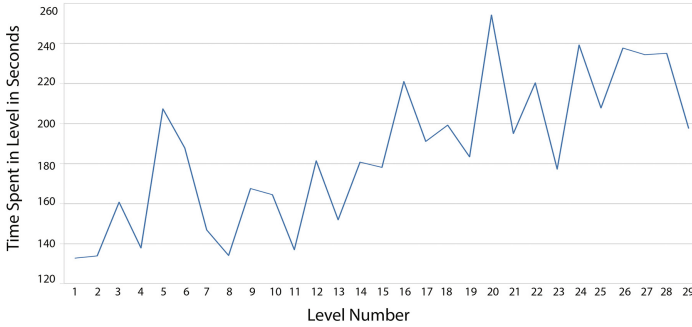


Fig. 5. Average time spent in the different levels. The curve resembles the flow channel used in game design.

Discussion

The results of the questionnaires suggest that both children and parents like Prosodiya (Q1), enjoy spending time playing it (Q2), and are waiting for more content (Q3). The graphical elements of Prosodiya seem to be appealing and match the taste of primary-school children (Q5), which is crucial for serious games [3]. Also the main characters seem to be well received (Q6).

According to the results of Q8, the perceived level of difficulty seems to be adequately between boredom (too easy) and frustration (too hard). Our goal was to keep the children within the flow-channel, a narrow band between boredom and anxiety [9]. In-game measurements of average time spent in a specific level (Fig. 5) indicate the success of our approach. As the number of tasks for each level was constant, the difference of time spent can be attributed to response times for single tasks - which in turn can be used to estimate the proficiency level of a learner [31]. Thus, the in-game metrics indicate that sequences of tension (more time spent, caused by increased difficulty) and relaxation (less time spent, caused by a higher increase of learner proficiency compared to difficulty adjustment) keep the children in a state of flow. This in turn can have positive impact on learning and player's attitude [19].

The reports to Q4 are important to the area of self-efficacy and self-esteem. Boosting both is a central aim of therapeutic intervention [2]. The perceived high self-efficacy reported by children and parents is related to self-awareness of skill increase and actual skill increase [8]. As pointed out by [3], the absence of or little self-awareness of skill increase must be avoided.

We have analysed the reports regarding the questions whether the games were self-explanatory to a satisfactory degree (Q8) and how the tutorials were rated (Q7). Although the majority answered both questions quite positively, the reports also indicate room for improvement. The reasons for negative reports can be that the tutorials didn't communicate the objective of a game well enough or the fact that sometimes the difficulty affecting game mechanics or objectives was slightly increased between levels without informing the children. We therefore derived and applied three changes: First, we refined the tutorials by splitting

complex domains and addressing the respective domain in much more detail and including more examples. Second, whenever something changes that could have an impact on the children’s answers and behaviour, a brief information is displayed and informs the children of the change and its consequences. Third, we developed in-game tool-tips for each game that explain the game’s objective(s).

Overall, in spelling as well as in reading, approximately half of the children could improve their performance, some of them significantly. About a third did not change in performance and two children performed worse. Overall the best improvements were obtained in speeded reading comprehension tests. These results are promising, considering that our pilot’s duration was only six weeks. A meta-analysis [13] has shown that interventions with a maximum duration of 12 weeks have only small effect sizes and interventions that last more than 12 weeks have a higher mean effect size. The main objective of the present pilot was primarily to investigate user experience and playability, therefore, duration was set to six weeks. But for future work, focus will be set on therapeutical efficacy and intervention phases will be prolonged.

All in all, the evaluation of the pilot study suggests that the version of Prosodiya at that time reaches a satisfactory level in terms of game and therapeutic design. However, it also highlights the limitations of that version, especially in terms of effects of the game on reading and writing performance. The evaluation of the questionnaires provide evidence that our proposed ICCGD is a valid approach for designing serious games for children. It also highlights the drawbacks of the study version that we addressed in the current version.

Limitations

The pilot study had two major limitations with respect to training effects. First, the children spent significantly less time training with Prosodiya than is recommended by [13]. To find empirical evidence for the effects on reading and writing improvement, the intervention period must be extended and intensified. Second, the games were very limited. We didn’t include spelling practice. However, training phonological awareness is assumed only to have an effect on writing performance if combined with spelling exercises (cf. [30]). The crucial core component of spelling was added to the current version of Prosodiya.

3 Conclusion and Future Work

In summary, we presented a mobile serious game for dyslexic children and the results of a pilot study of a preliminary version of the game. Prosodiya introduces various novelties in this area of research. The main contribution of Prosodiya is its unique focus on syllable stress that we derived reasonably. This focus led to the development of innovative exercises based on empirical findings. The pilot study was conducted with 11 dyslexic children. A central feedback in questionnaires was that the children liked playing the game and that they wanted more levels to keep on playing. Overall, they felt that they could improve their literacy skills. This self-assessment was not represented in quantitative reading and spelling tests in which almost half of the children improved after a period of six

weeks, the other half did not show any change in competence, and two children performed worse.

To evaluate the effects of this therapy approach in an improved and most recent version of Prosodiya, a randomized control trial with a waiting control group design is planned starting January 2018. Both a group of dyslexic and unimpaired children from 2nd to 4th grade will practice in total eight weeks with Prosodiya. In the intervention phase, children should practice 20 min per day, 5 days per week. This will result in approximately 800 min of training. Besides the effect of the therapeutic approach on reading and writing, newly introduced elements of gamification will also be investigated.

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