Validity and Player Experience of a Mobile Game for German Dyslexic Children

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Abstract

Approximately 4–10% of the German population suffer from developmental dyslexia, influencing children's educational, personal, and social development negatively. Digital interventions have shown great promise to additionally support dyslexic children outside of school or learning therapy. We present the results of a mobile serious game for German dyslexic children to improve reading and spelling performance with special emphasis on syllable stress awareness. We evaluate player experience and investigate the relationship between real-life literacy skills and in-game data of 63 children who played the game at home for 9–10 weeks within the scope of a randomized controlled field trial. Results indicate positive player experience and a completion rate of 75% indicates the feasibility of unsupervised digital game-based interventions. Moreover, real-life reading and spelling proficiencies correlated significantly with processing times and scores measured in-game, providing first evidence of the game's validity.

CCS Concepts

•Applied computing \rightarrow Computer games; Interactive learning environments; •Human-centered computing \rightarrow Empirical studies in HCI;

Author Keywords

Digital Game-Based Learning; Player Experience; Dyslexia

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Figure 1: Game 1 "Stress Pattern".



Figure 2: Game 2 "Open and Closed Syllables".



Figure 3: Game 3 "Orthographic Marker".



Figure 4: Game 4 "Spelling".

Introduction

Dyslexia is one of the most frequent learning disorders, affecting 4–10 % of the German population [27, 28]. The learning disorder negatively affects educational, personal, and social development of children [2, 8], thus appropriate interventions are needed to prevent negative consequences in the long run. Mobile and computer-based interventions have shown great promise to support the acquisition of reading and spelling for dyslexic primary school children (e.g., [3, 6, 10, 19, 24, 37]). Game elements used in digital interventions can explicitly address negative feelings such as frustration, demotivation or boredom [9], and support successful learning [5, 42].

Despite the importance of playful digital interventions to deliver high player experience and to balance game play with educational effectiveness and quality of learning [1, 4, 20, 34], these factors have not been studied systematically, i.e. beyond short questionnaires or observations.

In this article, we propose a mobile serious game for German dyslexic children called "Prosodiya". We investigate player experience as well as the validity of our pedagogical approach based on the results of 63 primary school children who played the game at home during a period of 9–10 weeks within the scope of a randomized controlled field trial. Consequently, we specifically address i) if the proposed game delivers high player experience, ii) if such playful digital interventions are feasible for use at home, and iii) whether we can find preliminary evidence of our pedagogical approach to improve reading and spelling by analyzing in-game times and scores.

This article starts with an introduction to the game, followed by the results and discussion of our study. We conclude with an outlook to future data analyses and game development.

The Game

Prosodiya [15] is a mobile serious game based on recent empirical findings and evidence-based interventions (e.g., [17, 38]). Prosodiya differs from similar games in that it trains syllable stress awareness, which highly correlates with reading and spelling skills [39] and is impaired in dyslexic children [11, 18, 25]. One explanation is thought to be found in the association between stress and German orthographic markers. Vowel length markers, i.e. graphemes marking long or short vowels, generally occur in stressed syllables [41]. Mastering the complex orthographic rules to mark long and short vowels is a major difficulty for German children [22, 23].

The focus of Prosodiya is primarily on spelling acquisition by training the awareness of linguistic features related to syllable stress and linking these features to orthographic regularities of German orthography. By shifting children's attention to relevant areas of words, Prosodiya aims to clarify the association between syllable stress and orthographic marking, such as vowel or consonant doubling, to learn how such syllables are spelled. Figure 1 - Figure 4 display the four games used in the intervention for the word Katze (cat), whose short vowel is marked with the graphemes tz. In the first game, children rebuild stress patterns of words by dragging and dropping cartoon blobs onto platforms, a big green blob for stressed and small yellow blobs for unstressed syllables. The second game is a novel variant of vowel length distinction tasks. Children additionally need to decide whether the stressed syllable is open (ends with a long vowel, big red blob with an open mouth) or closed (vowel is closed by a consonant, big blue blob with its mouth shut), see Figure 2. The recognition of orthographic markers, i.e. spelling of long and short vowels, is the subject of the third game (Figure 3). In the fourth game



Figure 5: In-game map of the game. Glass blossoms are used as level symbols.



Figure 6: One week of the training plan in the sticker book.

(Figure 4), children finally spell words and thereby foster their previously acquired knowledge.

Prosodiya's overall narrative is about the deliverance of the eponymous world from a mysterious fog that has arisen (Figure 5). Little inhabitants called "Kugellichter" (spherical lights), the game's protagonists and pedagogical agents, call for the children's help. To redeem the inhabitants from their sorrowful lives, only children, accompanied by the Kugellichter, can disperse the suppressing fog by mastering linguistic challenges. Progressing through the course of the game, parts of Prosodiya are saved, and new regions await the children with challenges to be mastered.

Evaluation

In this article, we evaluate the general validity and player experience of Prosodiya. A detailed evaluation of individual game elements is reported in [14].

Participants

In total, 137 German primary school children from second to fourth grade (age range 7–10 yrs.) took part in a randomized controlled field trial with a waiting control group design. We recruited children with (suspected) dyslexia or very low reading and/or spelling proficiencies. Additionally, any interested second grader was encouraged to sign up to participate in a chronological age-matched control group regarding literacy skills to further evaluate player experience. Based on spelling and reading proficiency assessed in pretests, we pseudo randomly assigned 69 children to the first intervention group and 68 to the waiting control group.

In this article, we evaluate the data of the first intervention group whose training ended in May 2018. Six children were excluded from data analysis due to not finishing the intervention or data loss. The remaining 63 children was comprised as follows: 23 second (m=13, f=10), 29 third (m=20,

f=9), and 11 fourth graders (*m=8, f=3*). As 13 children answered a preliminary version of the questionnaire without items of the Game Experience Questionnaire (GEQ), respective subscales of game experience are evaluated based on the results of 50 children (18 second [*m=8, f=10*], 23 third (*m=15, f=8*), and 9 fourth graders [*m=7, f=2*]).

Materials

Game and training plan. A version of the game – as described above – with a mainly linear course of play was used due to our research questions. Therefore, adaption was limited to the number of level repetitions and word selection. A training plan of 8 weeks in the form of a sticker book with a set of 40 stickers was used to keep the children on track. The sticker book depicted for each training day and week the levels to be practiced, see Figure 6. Each page corresponded to one training week and was in line with the map used in the game (Figure 5). Due to school holidays during training, we deployed more levels than displayed in the sticker book. We deployed in total 80 levels. The training plan officially ended at level 66, labeling the rest as bonus. To avoid binge-playing and loss of training effect, content of a new training week was unlocked on Monday mornings. During the intervention phase (9-10 weeks), children were given a tablet and were asked to play the game at home 5 days per week, 20 minutes per day following the training plan.

Reading, spelling, and syllable stress awareness. Read-

ing and spelling skills in pre- and post-tests were assessed using standardized classroom tests of spelling [30, 31, 12], reading speed [26] and individually administered standardized tests of reading fluency [29]. Syllable stress awareness was assessed using an individually administered paper version of the game "Stress Pattern" (Figure 1).

Overall Impression

How much did you like Prosodiya?

Usability

- Did you quickly understand how to play the game?
- Do you think the game is easy to use?
- Did you always know what to do while playing?
- In the different exercises, was it always clear to you what you had to do?

Self-efficacy

- How much did you learn in this game with regard to reading and spelling?
- · Did the game help you to learn to read?
- Did the game help you to learn to spell?
- Did the training increase your confidence in German classes?
- How often do you think about the things that you learned in the game when you don't know how to spell a word?

Intention to use

 Would you like to continue playing with Prosodiya?

Likelihood to recommend

Would you go tell a friend Prosodiya is a good game?

Game or homework

 Do you think Prosodiya is more like homework or more like a game?

Table 1: Questions for additionalsubscales of player experience.

	items iGEQ	item+	$\alpha_{\rm iGEQ}$	$\alpha_{\rm iGEQ+}$	α^*
Positive affect	[1,14]	4	.76	.79	.80
Competence	[17,2]	15	.62	.66	.83
Immersion	[3,27]	12	.75	.82	.81
Challenge	[26,3]	1	.70	.74	.74
Negative affect	[16,9]	7	.50	.25	.71
Tension/Annoyance	[29,24]	2	.65	.79	.82

Table 2: Cronbach's alpha of the items used from the iGEQ (α_{iGEQ}) and iGEQ+(α_{iGEQ+}). Item number refers to an item's number in the core GEQ [12].

Player experience. Player experience was evaluated based on a subset of a questionnaire of 69 questions.

First, we evaluated 19 questions from the Game Experience Questionnaire [16] (GEQ) using a 5-point word and color coded rating scale (Figure 8). We refer to the 19 questions from the GEQ as the iGEQ₊ that was composed of the in-game GEQ (iGEQ) and 6 additional questions from the GEQ's core module. The GEQ is intended to measure the subscales *Positive affect, Competence, Sensory & imaginative immersion, Challenge, Flow, Negative affect,* and *Tension/Annoyance,* see Table 2.

The iGEQ₊ adds one additional item to all subscales except flow. The items as well as Cronbach's alpha for the subscales of the iGEQ and iGEQ₊ are shown in Table 2. Due to an increase in Cronbach's alpha, we kept the additional item for all subscales except *Negative affect*, which resulted in a severe decrease of Cronbach's alpha.

In addition to the iGEQ₊, we evaluated 12 self-constructed questions covering the children's *Overall impression* of the game and the subscales *Usability*, *Self-efficacy*, *Intention to use*, *Likelihood to recommend*, and whether Prosodiya feels more like homework or like a game, see Table 1. Likelihood to recommend is inspired by the net promoter score by [36], which is one of the simplest loyalty measures.

We used either a 5-point Smileyometer [35] (Figure 7), a bipolar rating scale, or the same scale used for the iGEQ₊.

Procedure

First, we administered the pre-test (T1) involving tests of spelling, reading speed and fluency, and syllable stress awareness. Second, children of the first intervention group performed 9–10 weeks of training. The waiting control group did not play the game and thus is not considered in the current analysis.Third, the post-test (T2) was administered similarly to T1. In addition, children of the first inter-

vention group answered the questionnaire, for which we explained to the children that they now have the chance to express anonymously what they think about the game with no right or wrong answers. We explained the rating scales of the questionnaire and provided explicit examples for positive and negative items with mock-up questions to identify possible careless responses (e.g, "I like chocolate" vs. "I hate gummy bears"). Moreover, preliminary tests indicated that children had problems reading and understanding the questions due to their lack of proficient reading skills and unfamiliarity with such questionnaires. Thus, we read aloud each question individually and clarified posed questions to ensure that everyone understood the items. We continued with subsequent questions after every child had answered the previous one. Answering the guestionnaire took approximately 20 minutes. Upon completion, children were rewarded with flexible pencils and small toy dinosaurs.

Results

Answers of the questionnaire were transformed into values 1 to 5. Answers with no clearly selected options were excluded. If children put marks between two options, we kept and transformed the answer into a floating point value.

Player experience. Mean values of subscales were considered to reflect player experience. We used a conservative approach of analyzing each subscale by conducting one sample Wilcoxon signed rank tests against the middle value of the subscale's 5-point Likert scale (3 = moderately). Descriptive results and inferential statistics are summarized in Figure 9 and 10.

Children's ratings of the game on the subscales *Positive affect*, *Competence* and *Immersion* of the iGEQ₊ were significantly higher than moderately. In contrast, ratings of the *Tension/Annoyance*, *Negative affect*, and *Challenge* sub-







Figure 8: 5-point color and word coded rating scale.



Figure 9: Results of player experience based on the iGEQ₊ and one-sample Wilcoxon signed rank test compared to μ =3.



Figure 10: Results of player experience subscales and one-sample Wilcoxon signed rank

test compared to μ =3.

scales were significantly lower than moderately, see Figure 9. Ratings of the *Flow* subscale did not differ significantly from moderately, see Figure 9. Children reported a significantly positive *Overall impression*, rated the game's *Usability* to be very good, and reported a feeling of *Selfefficacy*, indicated by ratings significantly higher than moderately, see Figure 10. In addition, children reported that they would likely recommend the game to a friend and continue playing the game themselves. Finally, children rated Prosodiya to be more like a game , as reflected by ratings significantly above "neither homework nor game".

We correlated the variables of literacy skills assessed in pre-tests with the subscales of player experience. We opted for Spearman's rank correlation due to non-normal distribution of the data. Results are reported in Figure 11.

In-game measures. Children on average played on 27.9 (SD = 11.5) out of the recommended 40 days, spent on average 494 min. (SD = 194) playing, reached on average level 68.6 (SD = 17.5), and practiced on average 160.6 levels (SD = 47.4). Out of 63 children, 47 (74.6%) fulfilled their training plan and reached level 66 or higher. Children spent on average 3.1 min. (SD = 0.8) and scored on average 139.6 (SD = 5.4) out of 150 points per level consisting of 10 tasks. They solved on average 8.3 (SD = 0.8) out of 10 tasks per level at the first go.

Detailed correlations between literacy proficiencies and ingame data of times and scores are listed in Figure 12.

Discussion

The results indicate an overall positive perception of the proposed game and prove its usability and application as an intervention used at home. Inferred from the results of the iGEQ₊, children reported high positive affect and to feel



Figure 11: Spearman's Rank correlation between literacy skills and player experience. Correlations significant on $\alpha=.05$ are colored.

competent and immersed while playing. Furthermore, the children did not perceive negative affect nor did they feel tense or annoyed during game play. Positive engagement has been shown to positively affect learning [13]. The results additionally imply that the game did not overstrain the children but also that it might have been too easy. The low value of challenge could be explained by the high percentage of tasks solved at the first go or by the study version of the game that increased the difficulty gradually to keep training similar across participants and to not overextend poor performers or young children. This might have led to an too easy course of play in general.

The game's moderately value of flow implies room for improvement, which in turn can positively affect learning [21]. The negative correlation between reading and spelling proficiencies and flow indicates that children with lower literacy



Figure 12: Detailed Spearman's Rank correlations between literacy skills and in-game scores and times per game (G). Correlations significant on $\alpha = .05$ are colored.

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This research was funded by the LEAD Graduate School & Research Network [GSC1028], a project of the Excellence Initiative of the German federal and state governments. Heiko Holz is a doctoral student at the LEAD Graduate School & Research Network. skills needed to pay more attention to the game and, thus, experienced higher levels of flow.

In addition, the perception of self-efficacy was reported by the children, which is a central aim of therapeutic interventions [2] and is related to self-awareness of and actual skill increase [7]. The positive correlations between self-efficacy and likelihood to recommend and between self-efficacy and intention to use indicate that the more effective the children perceived the game to be, the more likely would they recommend the game to friends and would play it in future. This is supported by positive correlations between the positive subscales of the iGEQ₊ and self-efficacy, likelihood to recommend, and intention to use.

Moreover, the results indicate that primary school children can use the game very easily, that they would likely keep on playing it, and recommend the game to friends. Generally, perceived ease of use, among other variables, was reported to be an important predictor of learning success and flow in other game-based trainings (e.g., [33]).

Taken together with the training behavior measured by the number of days and the amount of time children spent with the game, as well as that three-quarter of the children fulfilled their training plan, we infer that the game is feasible as an intervention at home and that it was able to engage children throughout the training.

Significant correlations between literacy skills and in-game data of scores and times (Figure 12) provide support for the game's pedagogical approach, i.e. difficulties of children with poor literacy skills were trained. This is in line with previous research providing evidence that in-game measures such as times (e.g., [40]) or scoring (e.g., [32]) may allow for valid assessment of skills and knowledge.

Finally, Prosodiya was overall rated to be significantly more like a game than like homework.

Conclusion and Outlook

In this article, we presented the preliminary evaluation of a randomized controlled field trial of our proposed mobile serious game for German dyslexic children regarding player experience, feasibility of the digital intervention, and first evidence of our pedagogical approach. The results of 63 children from the first intervention group, who answered a questionnaire after playing the game for 9-10 weeks, are overall very promising. The game was perceived very positively while not invoking negative feelings. The results also indicate that challenge and flow of the game can be improved. We may conclude that our game-based intervention can easily be used by primary school children, is likely considered to be a game, engages and motivates children over a longer time period, and that children are likely to recommend the game to friends and keep on playing it. Thus, we may infer that such interventions can successfully be used in field trials outside the classroom or learning therapy. Significant correlations between in-game data of times and scores and real-life literacy skills provide first evidence that our game addresses difficulties of children with poor reading and spelling skills. Importantly, these results are promising as to the validity of our serious game. Taken together, it seems that our game achieved a balance between game-play and learning objectives.

We plan to further investigate in-game measures and aim at increasing the game's flow and challenge, e.g. by continuing the development of an adaptive user model and integration of daily narratives, to keep player experience high over longer period of time. The efficacy of the game regarding reading, spelling, and syllable stress awareness will be evaluated in the near future after the second intervention group has successfully finished its training.

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