A Tablet Game to Target Dyslexia Screening in Pre-Readers

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Abstract
Using serious games to screen dyslexia has been a successful approach for English, German and Spanish. In a pilot study with a desktop game, we addressed pre-readers screening, that is, younger children who have not acquired reading or writing skills. Based on our results, we have redesigned the game content and new interactions with visual and musical cues. Hence, here we present a tablet game, *DGames*, which has the potential to predict dyslexia in pre-readers. This could contribute to around 10% of the population that is affected by dyslexia, as children will gain more time to learn to cope with the challenges of learning how to read and write.

Author Keywords
Dyslexia; Screening; Detection; Pre-Readers; Serious Games; Computer-based Assessment; Universal Screening; Language-Independent; Visual cues; Musical cues; Gamification

ACM Classification Keywords
K.4.2 [Computers and Society]: Social Issues—*Assistive technologies for persons with disabilities*; K.3 [Computers in Education]: Computer Uses in Education—*Computer assisted instruction*

Introduction

Around 5% to 15% of the world population are affected by dyslexia: a *specific learning disorder* [1]. While visual and auditory difficulties might cause troubles in writing and reading, the general intelligence of a person with dyslexia is not affected. Nevertheless, school failure and frustration is part of the daily routing for children and parents until the child is finally diagnosed.

Children with dyslexia (CWD) are, until now, mainly distinguished by their reading and writing mistakes compared to their peer group. Hence, screening pre-readers needs new indicators. Current approaches to screen pre-readers require expensive personnel (*i.e.,* a professional therapist) or special hardware (*i.e.*, MRI machines). Our work tries to simplify the screening of dyslexia for pre-readers.

First, we created a web-based prototype *MusVis* (mainly for desktops) and conducted a study which served as a proof-of-concept with students from 7 to 12 years old ($n = 178$) [12]. We addressed the participant's feedback as well as the game usage data and created a new application for pre-readers that: (a) simplifies the musical game-play; (b) provides musical content that is perceivable by pre-readers; and (c) uses input methods that are adequate for pre-readers. The major changes were done mostly on the musical part of the game as well as for the adaptation of the input method, *i.e.*, for a tablet instead of a desktop.

In this demo, we present the new tablet application *DGames*, with new game interactions and new content. We will use the game to measure the children's performance to conduct an online user study to distinguish pre-readers with and without dyslexia.

Related Work

The phonological skills deficiencies associated with phonological coding deficits are probably the reason for dyslexia [20]. Therefore, investigations on the visual and auditory perception of dyslexia in relation to language acquisition of pre-readers [8], *rapid auditory cues* with infants, and *visual-spatial attention* [3] on kindergarten children are conducted.

Different games [4, 16, 10] or approaches [19] aim to screen children with dyslexia mainly related to linguistic knowledge. The *AGTB 5 –12* aims to screen pre-readers but is only available for the age of 5 till 12. The Cronbachs Alpha is between .58 and .98 for children at the age of five till eighth [7]. We could not find any other published accuracy of the prediction process for pre-readers. The approach for pre-readers needs to be simple (*e.g.,* tablet vs. desktop) and should not assume existing knowledge of literacy or phonological awareness.

We are combining findings from previous literature, which are known to cause troubles for CWD, to create a game environment to find solid differences for predicting dyslexia in the future. At the same time, the game should be fun and not too difficult. We expect people with dyslexia to take more time and interact differently with the game than the control group.

Game Content

The game *DGames* is a major revision of the game *MusVis* [12]. Both games aim to detect differences in the perception of children with and without dyslexia while playing with musical and visual cues. Only the interaction for the visual part and eighth visual cues are duplicated from *MusVis*. We derived the new design of the game *DGames* from the pilot study and implementation of *MusVis* [13, 12]. All changes are reported below.

Although children (age 8 till 12) and their parents gave very positive feedback on the game-play and content, parents of pre-readers reported difficulties in the interaction of the game. These parents reported, that their children had difficulties in understanding the game-play and distinguished the very short and similar sounds of the musical part. Most of them quit the game because of that. An example quote from a dad of a boy (4 years): *he was overwhelmed by the game. He could not distinguish the sounds and just touched randomly on any card.* Also, the input method, *i.e.*, computer mouse was not adequate for younger children.

To be able to target pre-readers, we changed from a desktop to a tablet device, as well as, recreated completely the musical content and interaction. Additionally, results from *MusVis* and *Dytective* [16, 17] showed that CWD did not make more mistakes while playing games, in spite that CWD are diagnosed by the amount of written errors they make. Therefore, also non-related linguistic visual and musical content is added to evaluate the game interaction itself. Each game part (musical and visual) has 16 rounds which are counter-balanced with *Latin Squares* [2].

Content Design with Visual Cues
The main changes from *MusVis* [12] are (a) adding non-linguistic content, (b) tablet adaptation (*e.g.*, double click), and (c) video introduction to the game.

The visual part has 8 stages and 16 rounds. Each stage is assigned to one visual type: ***symbol, z, rectangle, face, fruit, kitchen, plant & animal*** and four visual cues for each stage are presented (see Figure 1, where the first four visual types are duplicated from *MusVis* [12]). One visual cue is the target which the participants need to find and click (see Figure 2, a). The other three visual cues are *distractors* for the participants. Each stage has two rounds with first a 4-squared (see Figure 2, b) and then a 9-squared

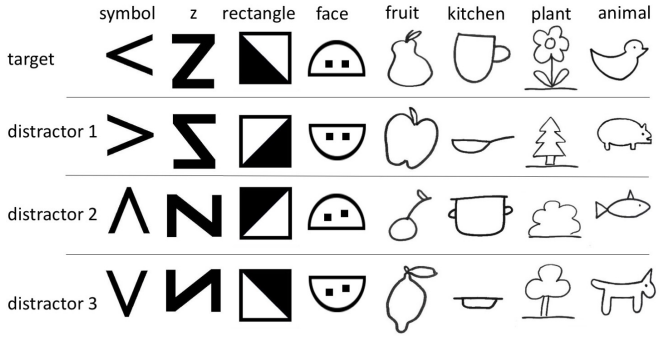

Figure 1: Overview of the designed visual cues. The figure shows the target cue (top) and distractor cues (below) for the eight different stages (*symbol, z, rectangle, face, fruit, kitchen, plant, animal*) of the visual part of the game *DGames*.

design (see Figure 2, c). The target and all three distractors are displayed in the 4-squared design. In the 9-squared design, the target is displayed twice as well as the distractor two and three. Only distractor one is displayed three times.

Content Design with Musical Cues
The musical part has for each round a new musical type: ***substitution, omission, phoneme, structure*** (once Spanish and German vowel; Spanish consonant), ***rhyme*** (twice Spanish and German; four times English), ***combinations, & rhythm***. Each musical type has one musical cue target and three musical cue distractors. The new musical cues are designed with the knowledge of previous literature (see Table 1 and the new analysis of the published German errors resource [11, 14]). The matrix shows the relations between our designed musical types and the literature which provide evidence to distinguish a person with dyslexia.

The children click on the *play*-button and can listen to the musical cue target as often as they like (see Figure 3, a). After that a row of four buttons is displayed (see Figure 3, b)

Features	Explanation of the Features	Subs.	Omiss.	Struct.	Phon.	Rhyme	Comb.	Rhythm
Beginning	70% of the spelling errors are at the third position of a word for German and Spanish [15, 11].	x	x	x	x		x	
Length	The average word length for German and Spanish is just above 7 letters [15, 11].	x	x	x	x	x	x	
Simple	For 73.3% of the analyzed words for Spanish the Damerau-Levenshtein distance was 1, which means that only one letter mistakes were made [15]. For German it is even 81.3% [11].	x	x	x	x			
Substitution	The error category *Submission* (exchanging a letter for another one) is frequent for German, English and Spanish [15, 11].	x			x		x	
Omission	The error category *Omission* (leaving a letter out) is frequent in German [11].		x				x	x
Structure	CWD find it more difficult to recall a target item with a similar prosodic structure [5].	x	x	x	x	x	x	x
Phonological STM	CWD showed impairments in the phonological short-term memory (STM) [5].	x	x	x	x	x	x	x
Short-Interval Perception	Copying and discrimination tasks are used to predict phonological awareness [9].					x	x	x
Pitch Modulation	CWD have difficulties in processing pitch patterns [18].	x		x	x	x	x	
Combinations	Discrimination of rise time is related to language processing [6].						x	x
Complexity	CWD have difficulties with *the phonological similarity effect* and the *phonological neighbourhood* when long memory spans are used [5].				x		x	x

Table 1: Mapping of the evidence from literature to distinguish a person of dyslexia to design the musical type for each stage in the musical part of the game *DGames*.

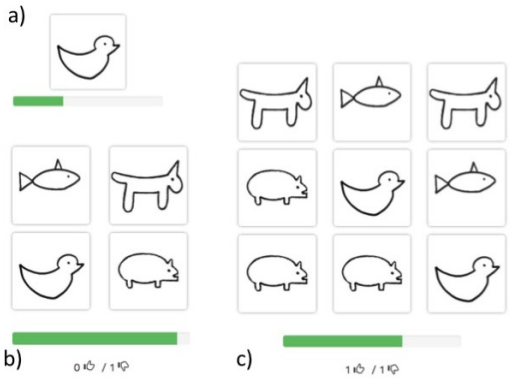

Figure 2: Example of the visual part of the game *DGames* with the priming of the target cue *animal* (a) and then the fourth-squared (b) and nine-squared design including the distractors for each *animal* (c).

and automatically the assigned musical cues for each button are played one after another. The buttons are disabled until the auto-play is done to ensure children listen to all musical cues. The first button/musical cue is never the musical cue target to force a distraction for the player. The order of musical cues is randomly assigned and starts always from left to right and with the *Play all sounds again*-button children can listen to all cues as often as they like.

Implementation Details

Both game parts are developed as a web-application using JavaScript, jQuery, CSS, HTML5 and a backend with a PHP server and a MySQL database to make the game easily adaptable for different devices. The visual part is also implemented with Angular.

Because of the web implementation technique, a double click on a web-application generally *zooms* the application on a tablet. As young children were observed touching the

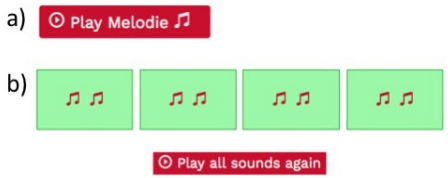

Figure 3: Example of the musical part of the game *DGames* with the priming of the target cue (a) and then the distractors for each musical cue (b).

application very quickly and triggering the *zoom*-effect, this caused interruptions while playing and was not coherent with the experience of using a native tablet application. Therefore, we used a *viewport meta tag* to control the layout settings for mobile devices.

All instructions within the game are presented with video or audio media to address pre-readers. *Android* prevents by default *automatic play of sound or video* and asks for a user interaction. Therefore, we designed the whole game with a sequence that starts with a user interaction followed by audio sounds.

Conclusions and Future Work

The main advantages of the new tablet Game *DGames* makes it playable for pre-readers and should improve the current results for screening dyslexia in young children. Additionally, the game is playable on different devices and the device information are taken into account for the analysis of the differences between the two user groups. To prove our improvements, we plan to conduct a large-scale study in different languages *e.g.* German, Spanish and English.

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