Criteria for the Dyslexic Games: A Systematic Literature Review

Nur Azzah Abu Bakar[1,*], Noraziah ChePa[1], Laura Lim Sie-Yi[1]

[1]School of Computing, College of Arts & Sciences, Universiti Utara Malaysia, 06010 UUM Sintok, Malaysia

*Corresponding Author nurazzah@uum.edu.my

Abstract:

The advancement of technology has witnessed the increasing use of game-based intervention and it is proven beneficial for people with specific learning disorder such as Dyslexia. Initially developed for entertainment, a game is generally considered a tool with the key features of challenge, motivation, and rewards which add more fun and excitement to Dyslexia teaching and learning. Many game applications have been developed in the area; each incorporates several criteria to meet the specific needs of the dyslexics. To date, these criteria are still dispersed in numerous publications, leading to the duplication of basic games that have previously been developed by others. This study aimed to identify the dispersed criteria by adopting PRISMA approach in the systematic literature review, and analyze them to formulate a comprehensive guideline for future design and development of the dyslexic games. Five main databases were chosen which are Scopus, ACM Digital Library, EBSCO-host, Wiley and Web of Science (WOS). Out of 551 articles that have been screened, only 50 articles were eligible to be analyzed based on the relevancy to the criteria, and only 23 articles were included in the study after further screening. A total of 135 criteria were identified with some redundancies, and were further classified into four categories: device and platform; features; interface and gameplay. These criteria can be utilized by the educational game developers as reference when designing the dyslexic games. A better dyslexic-friendly games could be produced when the developers design it with their special learning needs in mind.

Keywords: Dyslexia; Dyslexic game; Dyslexia intervention; Systematic literature review; Specific learning disorder

1. Introduction

Dyslexia is one type of specific learning disorder (SLD) that results from an unexpected phonological deficit [1]. Neuro-imaging research suggests that Dyslexia is associated with differences in a network of regions implicated in typical reading development [2]. Brain imagery studies have shown that Dyslexia is neurologically based; people with dyslexia have not developed the network in the brain that is typical of successful readers [3]. The cognitive phonological deficit theory proposed that reading difficulties of the dyslexics is directly and exclusively caused by a cognitive deficit that is specific to the representation and processing of speech sound [4]. These deficits can be observed from the symptoms such as difficulty counting syllables in words or difficulty recognizing rhymes which lead to the eventual difficulties with learning to read [5]. Other indicators to Dyslexia include reverse letters sequence, difficulties learning cursive writing and slow reading. As of 2020, it is estimated that between 5 to 20% of the world population struggle to read due to Dyslexia [3]. In 2017, the Dyslexia Association of Malaysia reported 10% of the school age children in Malaysia were affected by the disorder. The percentage shows an increase from 2014 in which 53,685 students with learning disabilities have been involved in formal education and from that total, 0.03% or 1,681 students have been involved in the Dyslexia classroom program [6]. Earlier study conducted by Socio-economic and Environmental Research Institute of Penang has identified 9.4% of children in Grade One elementary schools in Penang as having learning difficulties, and 92.3% of these children were found to have severe reading disabilities [7].

Dyslexia affects individuals throughout their lives. However, its impact can change at different stages in a person's life. It can seriously affect a person's self-esteem [8]. Dyslexia students sometimes feel dumb", frustrated, lonely, humiliated, and academically less competent than they really are. They may get very frustrated and are at risk of developing mental health problems such as anxiety and depression. Despite this, Dyslexia is not related to intelligence or lack of desire to learn. There are evidences that Dyslexia is also associated with health difficulties. Auto immune disorders, allergies, autism and schizophrenia are common amongst families where there are learning disabilities [9]. It is observed in Richardson [10] that the dyslexic children with the most severe symptoms of fatty acid deficiency (rough skin, dry skin and hair) have the most severe reading, spelling and short-term memory difficulties.

Games have been used as one of the intervention methods for Dyslexia. The literatures reporting these games revealed several criteria the developers incorporated into their games in order to cater the specific needs of the dyslexics. This study gathers the criteria that were dispersed in the literatures. The aim is to produce a standard guideline for the dyslexic games from this collection of criteria. The needs or preferences of the dyslexics differ from that of the normal children [11,12]; therefore, careful consideration should be given to these needs when designing and developing games to assist them in reading. The dispersed criteria are difficult and time consuming to refer to, and minimum effort has been put to date to consolidate them for quick and easy reference. The guideline developed in this study serves as a reference for the developers to develop a more dyslexic-friendly games in the future.

2.   Background of the Study

Reid [13] suggests that difficulties in literacy acquisition for dyslexics are due to lack of phonological awareness, problems to recognize words and understand spelling rules, visual spelling errors, confusion between letters and words caused by similar-sounding words, omissions of words, parts of words, as well as individual letters and sounds. In other words, their literacy skills is at word-level reading and spelling [14]. The dyslexics have difficulties in identifying phonemes and the exchanging of letters occurs very often during the spelling process; they also often mixed-up the letters of 'b-d', 'u-n', 'm-w', 'g-q', 'p-q', and 'b-p' [15,16]. Evidence of their great difficulties in writing, poor skill of spelling, oral and written vocabulary and also weak in arranging the content of the compositions is also found in Awang Bolhasan [17]. Besides, previous studies also found that children with dyslexia are significantly slower at naming colors, digits and letters, thus suggesting that children with dyslexia have persistent, and unexpectedly severe problems in naming speed for any stimuli [18]. Details of the difficulties in spelling, reading and writing faced by most dyslexic children can be found in Hussin [15].

Children with Dyslexia will have the most trouble when learning to represent sounds with letters because this needs a two-way mapping between phonology and written symbols [19]. They need to understand how sounds and letters interact; this requires them to be familiar with phonological concepts and phoneme-to-grapheme relationship. The target word must then be divided into its key sounds, which must then be consecutively represented with symbols [19]. What makes this exacerbated is the fact that spelling, unlike reading, is difficult to use context. In her study, Snowling [20] discovered a substantial difference between the type of spelling mistakes made by the dyslexics and a control group. They made 'phonetically unacceptable' errors that may not be recognized as the word due to the absence of phonetic similarity. This suggests that children with Dyslexia might not have had their phonological representation develop; instead, they use letter naming strategies to spell words with regular phonology.

With regard to reading, Ehri [21] suggests that in order for students to strengthen their sight word reading skills, they must study and use their understanding of the alphabet. According to Goulandris [22], lexical processing, or the ability to recognize words quickly and accurately, is a symbol of skilled reading. In the context of Malay language, a study by Lee and Wheldall [23] reveals both syllable awareness and phoneme blending are significant predictors of word recognition; when the readers have inefficient syllable segmentation, oversimplification of syllables, insufficient grapheme-phoneme knowledge and inefficient phonemic code assembly they will make errors in reading.

Game-based interventions have been proven beneficial in healthcare domain to treat patients with depression, brain injury, cerebral palsy and upper limb injury [24-27], especially when the therapy or rehabilitation process involves young patients. Recent decades have witnessed the increasing use of digital game as tools for treatment of dyslexia. Games are used for diagnosis or early detection of the disorder [28-31] as well as for intervention [32-39]. Other studies [37,40] use gamification approach by utilizing some game elements (such as scores or rewards) in non-game context or the so-called application. Initially developed for entertainment, a ''game'' is generally considered to be an activity with the key features of challenge, motivation, and reward, thus adding more fun and excitement to dyslexics teaching and learning. There are several off the shelve board games such as Zingo Sight Words, Scrabble Junior, Brainbox ABC, Monopoly Junior and Alphabet Lotto. Several online or digital games have also been made available for IOS or Android users including Draw Something, Hanging with Friends, Anagram Scramble, ABCya, Chicktionary, Boogle Bash, Knoword and Word

Whomp. Different strategies are used in these games such as draw out a given word, spell a complex word, create ambiguous word to puzzle others, make out words from a given set of letters, find word while beating the time allotted, and complete words by conjecture based on the word's definition and first letter. Only anecdotal information about these games available, thus little is known about how these strategies succeeded in helping the dyslexics improve their reading skills. Some of these games, however, are not dyslexic-friendly as they require the dyslexics to spell complex words with tricky letter combinations, spell the long words when they are still struggle with the shorter words, or create ambiguous words to puzzle others. None of these are easy for the dyslexics. The standard guideline that specifies the suitable design to be applied in games for the dyslexic may help the developers from repeating the same mistakes.

3. Methodology

This study employed Systematic Literature Review (SLR) by adopting PRISMA approach in conducting SLR [41]. This study has focused on five main databases which are Scopus, ACM digital library, EBSCOhost, Wiley, and Web of Science (WOS). Four main processes that have been carried out in the searching process are *identification*, *screening*, *eligibility*, and *data extraction and analysis*. The first phase is about determining the keywords to be used for searching. In this context, keywords related to reading disabilities and the affected group, which are the children are basically relied on. The use of game intervention in treating the affected age group are also used in the searching. All keywords that have been used specifically for the database involved are listed in Table 1.

Table 1. Keywords and searching information strategy

Database	Keywords Used
Scopus	TITLE-ABS-KEY ((dyslexia OR ("reading disabilities" AND (child* OR kid))) AND (game OR "game intervention"))
ACM	[[Publication Title: dyslexia] OR [[Publication Title: "reading disabilities"] AND [[Publication Title: child*] OR [Publication Title: kid]]]] AND [[Publication Title: game] OR [Publication Title: "game intervention"]] OR [[Abstract: dyslexia] OR [[Abstract: "reading disabilities"] AND [[Abstract: child*] OR [Abstract: kid]]]] AND [[Abstract: game] OR [Abstract: "game intervention"]] OR [[Keywords: dyslexia] OR [[Keywords: "reading disabilities"] AND [[Keywords: child*] OR [Keywords: kid]]]] AND [[Keywords: game] OR [Keywords: "game intervention"]]
EBSCO host	TI ((dyslexia OR ("reading disabilities" AND (child* OR kid))) AND (game OR "game intervention")) OR AB ((dyslexia OR ("reading disabilities" AND (child* OR kid))) AND (game OR "game intervention"))
Wiley	"(dyslexia OR ("reading disabilities" AND (child* or kid))) AND (game OR "game intervention")" in Title, Abstract and keyword
WOS	TS=((dyslexia OR ("reading disabilities" AND (child* OR kid))) AND (game OR "game intervention"))

For screening of the relevant articles, several conditions for inclusion and exclusion have been defined. Type of literature, language, and subject area are among the criteria that have been included. Criteria and its eligibility terms are defined in Table 2.

Table 2. The inclusion and exclusion criteria

Criterion	Eligibility	Exclusion
Literature type	Journal (Research articles)	Journals (systematic review), book series, book, chapter in book, conference proceeding
Language	English	Non-English
Subject Area / Categories	Computer Science	Other than Computer Science

The searching also focused on literatures with empirical data such as journal articles, research articles, and review articles. To prevent difficulty of translation, only English articles are included. For relevancy, articles with related to the focus are selected which are related to the use of intervention games that involve children with reading difficulties. For this phase, 10 articles have been removed. Main focus of eligibility phase is to identify the eligible articles to be included in the study based on the criteria explained earlier. To achieve this, the identified articles were reviewed and thoroughly analyzed. Focus is given on the targeted objectives. To identify the details, abstracts were reviewed before the articles were

thoroughly analyzed. Figure 1 illustrates the processes involved by adapting PRISMA method. At the beginning, 551 articles were screened from the databases to be further reviewed. Ten out of this number were duplicate articles and have been removed for the next process. 541 articles were further screened based on the relevancy to the criteria. However, only 50 articles are eligible to be analyzed. After further screening, there were only 23 articles the be included in the study. Data extraction and analysis phase focuses on extracting and analyzing key details from the 23 articles that have been chosen. Various types of data are extracted from these articles; proponents of the criteria, year of study, game title, and the criteria of the game. The list of the extracted criteria is covered in findings section.
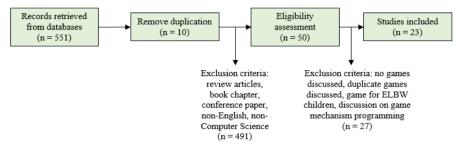

Figure 1. Adoption of PRISMA [41] approach in article selection

4. Findings and Discussion

A list of extracted criteria from the existing works that have utilized game as an alternative intervention tool for the dyslexics over the last five years are depicted in Table 3. The criteria are sorted based on the proponent's publication year. The main medium of language used in the games are English, Spanish and German.

The findings gave initial insights into the special learning needs of the dyslexics. For example, the font type and size which are deemed appropriate for the dyslexics are *Arial*, *Courier*, *Helvetica*, *Open Dyslexics* and *Verdana* and the range of size is between 14 to 26 [42-45,59,60], with appropriate character, line and paragraph spacing as well as the column width to fit the appropriate characters in line [43-45]. One article suggested to focus on lowercase letters [59] as they are more challenging to the dyslexics compared to the uppercase letters. The other frequently mentioned criterion is simplicity, be it the simple and easy interface, instruction, object (figures, images), navigation, installation, narrative or gameplay [42,47,52,54-60,63,64]. Besides simple, the narrative, instruction and gameplay must also be kept short [49,52,59]. Audio/voice/musical cue is also deemed significant in games for the dyslexics [48,51,54]. It serves two functions, i.e., as stimuli to help the dyslexics to focus, and to help them understand the instructions or narrative, as they always have difficulties with text. Use of animations and symbols are also considered better than the written explanation [43,44]. Characters in a form of cute-creature, funny, animated cartoon, teacher-like and avatar are attractive to the dyslexics, especially when they can make friend with them [47-53,64] throughout the game. Several previous works suggested that these characters should be unisex, thus it can cater both genders of the dyslexic children [47,52]. These characters can be part of fun and fantasy setting of the game [49,52,64].

One major element of games is rewards. Games for the dyslexics should also include rewards for their achievement [43.44,49,52,54,56,61,62,64]. The common forms of rewards in games are points or scores; Vasalou *et al.* [49] even suggested to use photo collection as rewards. Another major element of games is challenges [50,53,64]. Challenges should be provided at the right level and match with the skills gained by the dyslexics, and must also adequate. As many suggested that games should have different difficulty levels [43,44,46,49,54-55,57,61-63], there are possibilities to apply appropriate challenges to different levels. In term of competition, both previous works [55,64] agreed that the dyslexic game needs no companion. However, this is contradicted with Rello *et al.* [45] who suggested that the game should allow multiplayers or competition with computer.

Providing feedback is necessary [52,54-56,61,62,64] since the game is meant for educating the dyslexics. There are several studies agreed on instant or immediate feedback [55,61] while the other suggested that feedback should be given when the game ends [54]. Feedback can be provided in various forms such as audio and animated objects. There are mixed opinions on whether the game environment should be in 2D [47,50] or 3D [48], yet it must be interactive [49,60,64]. The aesthetic element of the game such as the color of text and background also need attention [43,44,47,52,59]. Comfort colors are more friendly to children; colors such as black, grey and crème are suggested as appropriate to be used in text and background. There are several other criteria being reported in the literature, i.e., the game must have clear goal [60,62,64]; must have continuity or progression [49,52,55]; touch-based [42,50,55] and multiple or limitless attempt [46,54,56,64].

Table 3. The extracted game criteria

Proponent	Year of Study	Game Title	Criteria of the Game			
[42]	2008	Talking Book/C	• REGUL is used	• Simple interface		
[43,44]	2013/ 2014	Dyseggxia/M OB/TAB	• Touch-based • Pedagogical-based • Distractor-based (multiple choice) • Text guideline provided • Frequent error words are used	• Level of difficulties • In-game achievement/rewards • Achievement shared in social media • Animations and symbols instead of written explanation	• Level of difficulties • Grey scale in font (10%) • Grey scale in the background (90%)/black color pairs • 18-26 fonts size	• Character spacing (+7%) • Line spacing (1.4) • Paragraph spacing (2) • Column width (77 character/line) • Present of parents
[45]	2016	Online Chess/W	• Full instruction provided (rule) • Training/practice • Testing	• Multiple players column width not wider than 60 characters per line	• Text in black on creme background • Compete with computer	• Arial typeface • Minimum font size of 14 points
[46]	2016	Dytective/W	• Frequent error words are used • Focus on specific languages • Shapes and visual features	• Timed-based (25s) • Limitless attempt scores	• Text in black using a mono-spaced typeface Courier	• Level of difficulty • Minimum font size of 14 points
[47]	2016	En Plein/VR	• 2D-game-like environment • Plain background	• Virtual bookcase and objects • Plain and brilliant colors	• Intuitive environment	• Cartoon-avatar (unisex) • Simple geometric figure
[48]	2017	NeuroVirtual 3D/V/VR	• Nonconventional tasks • 3D-icon-based interface	• Customize several virtual environments voice-guide to visual stimuli shown on the blackboard	• Instruction before task • Allow them to work in a virtual environment similar to the real one	• Hand-raise respond • Quiet room • Present of teacher
[49]	2017	Words Matter/TAB	• Two difficulty levels • Pedagogical approach • Practices provided • More holistic • Enjoyable • Meaningful play experience	• Continuity (the game world and player progress are persistent) • Discovery (mini games can be triggered through encounters with game characters in the world) • Narratively	• Sociality (players earn game characters as friends and strengthen friendships essentially as a form of game asset)) • Familiar casual game mechanics • Short duration of gameplay	• Aesthetics and fantasy (heroic role) • Interactive navigation (using avatar making friend with character) • Photo collection as rewards
[50]	2017	Pathss etc.	• Collection of games • Accessible from any device • Touch interface	• Distractors training • Game is fun • Adequate level of challenge	• Cue stimuli are used to have the player focusing on the target • Progressively more difficult	• 2D graphic design • Image-based elements • Distinctive emotion character
[51]	2018	DGames/TAB	• Tablet adaptation • Present of Parents • Buttons are disabled until the auto-play is done	• Play all sounds again-button (repetition) • Recognizing visual with musical cue	• Instructions in video or audio media • Controlled layout to avoid zoom effect	• Icon-based • Non-related linguistic visual and musical content video introduction to the game
[52]	2018	Prosodiya/MO B/V	• Story-based game • Visual aesthetics • Prologue/introduction of game • Narrative (short, simple and fun tutorials) • Incentives	• Game's graphical appearance appealing, consistent, and simple • OpenDyslexic font • Fantasy-themed setting weekly and daily progression system in form of cutscenes	• Features ambient music and lighting elements (atmospheric features, e.g., fog) • Companions (pedagogical agents)	• Child friendly color (unique to induce positive emotion) and shape (round) • Unique unisex character that link to linguistic character and support clear distinction.

			• Musical score and content • Skills	• Three levels of difficult • Feedback ("Tooltips")	• World map and changes of environment as well as atmosphere • Rewards	• Reminder to continue play
[53]	2018	Jellys/TAB/V	• Adventurous setting • Ancient site	• Cute-creature characters • Challenges	• Narrative instruction • Exploring	• Tapping with rhythm
[54]	2019	Video Games on GDevelop/ MOB/W/C	• Easy install • Basic words only • Frequent error word • Lives (chance of attempts (5)) • Rewards • Instructions	• Training • Help (audio feedback while playing) • Feedback when game end easy to interpret visual representations • Simple interface	• Consistent response to user actions • Customization of game´s multimedia settings, difficulty, and speed • Unobstructed views for the user's current actions	• Intuitive and personalized inputs • Easy to manage controls with an appropriate level of sensitivity and response • Information about the state of the game
[55]	2019	DysPuzzle/M OB	• Difficulty levels available (Freedom to Fail and Freedom of Choice)	• No companion needed Progression (Instant Feedback and Increase of Difficulty)	• Simple flow of game and few option • Touchscreens	• User-interface elements are large enough to be touched • Playful screen
[56]	2019	Spelling Game App/MOB	• Simplicity—activities are grouped in a straightforward menu; elements are legible • Attractiveness—the application is visually attractive • Preview story timeline	• Competition (fair with 5 s countdown) • Exciting gameplay • Unlocking level • Character building	• Tracks achievements, levels, feedback from authors • Practice • 3 attempts • Customized avatar, customized setting (sound, music)	• Possibility to use in any place • Play without the Internet (the result is saved locally) • Rewards for upgrade avatar elements as different word bases
[57]	2019	Nanostray 2/PS etc.	• Point-based • Competition online game	• Greater complexity • Unlock level difficulty	• Training/practice	
[58]	2019	TAB etc.	• Instructions	• Game interfaces with visual search-like qualities	• Easy images	
[59]	2019	Article on game guideline	• Font size = 18-26 points • Font = Helvetica, Arial and Verdana • Use small letter	• Use dark color text on light background • Suggest cream color background Simple navigation	• Consistent theme design (button, instruction, layout) • Simple click	• Character spacing +7% • Simple and short instruction • Drag and Drop
[60]	2020	Spelling Mobile Game/MOB	• Tapping of the letter or buttons to make it easy to navigate • Game goal is introduced	• Simple graphic randomized questions and answers in the assessment level	• Point scores and no minus point • Interactive audio lessons	• Font style Verdana • Font size 18.
[61]	2020	Meister Cody-Namagi/TAB	• Different levels of difficulty • Automatically adapt to the child's abilities	• Training narrative: The training is embedded in a fictional story around	• Reminder to continue play • Immediate feedback. • Rewards	• Training sessions
[62]	2020	LaroLexia/MO B	• Story-based • Points and rewards	• Clear game goals and objectives • Level of difficulties	• Achievement system (number of tries, category, score, and level)	• Feedback
[63]	2020	MusVis/W	• Non-linguistic content like rhythm or frequency	• Language-independent content with auditory (pitch=correlate to language development, sound	• Simple search task • Level of difficulties • Timed-based = 15 s	

			• Selecting the most challenging content for people with dyslexia	duration >350ms)well-known children game			
[64]	2015	APEX and DIESELX/C/V	• Player-centered design • No companion needed • Text and illustration narrative introduction • Interactive video game • Animated cartoons	• Rewards/punishments • Endogenous/intrinsic & exogenous/extrinsic fantasy contexts • Challenges at the right level	• Challenges should match the skills • 3 attempts hard fun (Bushnell's theory - easy to learn but hard to master)	• Funny character • Goal-based • Performance feedback • Meaningful play • Curiosity, interest • Explorative	

Table 4. Categories of dyslexic games criteria

Device & Platform	Interface	Features		Gameplay	
• Touch-based; aaccessible from any device; • Tablet adaptation	• Simple interface; • Grey scale font (10%); • Grey scale in background (90%); • Crème/black color pairs; • 18-26 fonts size; • Character spacing (+7%); • Line spacing (1.4); • Paragraph spacing (2); • Column width (77 character/line); • Column width: 60 characters per line; • Text in black on creme background; • Arial typesface; min font size 14; • Text in black using a mono-spaced; • Courier typespace; min size 14; • Plain background; • Brilliant colors; • Simple geometric figure; • 3D-icon-based interface; • Controlled layout to avoid zoom effect	• Text guideline provided; • Animations and symbols; • Player-centred design • Interactive video game; • Animated cartoons; • Funny character; • Endogenous or intrinsic & exogenous or extrinsic fantasy contexts; • Full instruction (rule); • Shapes and visual features; • Timed-based (25s) 2D-game-like environment; • Intuitive environment; • Virtual bookcase and objects; • Cartoon-avatar (unisex); • Virtual environment similar to the real one;	• Customize several virtual environments; • Voice-guide to visual stimuli on blackboard; • Instruction before task; • Hand-raise respond; • Quiet room; • Enjoyable; • Aesthetics and fantasy (heroic role); • Interactive navigation; • Fun; • Video introduction to the game; • Recognizing visual with musical cue; • Buttons are disabled until the auto-play is done; • Instructions in video or audio media; • Play all sounds again-button (repetition); • Non-related linguistic visual and musical content	• REGUL words; • Pedagogical-based; • Distractor-based (multiple choice); • Frequent error words are used; • Level of difficulties; • In-game achievement/rewards; • Text & illustration narrative introduction; • Rewards or punishments; • Challenges at the right level; • Challenges match the skills; • Bushnell's theory; • 3 attempts; • Goal-based; • Performance feedback; • Meaningful play; • Curiosity; • Interest; • Explorative; • Training/practice, • Practices provided; • Testing; • Compete with computer;	• Multiple players; • Frequent error words are used; • Specific languages; • Limitless attempt; • Scores; • Level of difficulty; • Nonconventional tasks; • Meaningful play experience; • Familiar casual game mechanics; • Short duration of gameplay; • Continuity; • Discovery; • Narratively; • Sociality; • Collection of games; • Adequate level of challenge; • Progressively more difficult; • Cue stimuli to focus on target; • Image-based elements; • Distractors training; • Icon-based

As mentioned earlier, these criteria are dispersed in different articles; having them organized in more meaningful manner could be useful especially for the developers of the future dyslexic games. Further analysis removed the redundant criteria and reduced the number to 96, which were then classified into four main categories which are device and platform, features, interface and gameplay, as depicted in Table 4.

5. Conclusion

In this study, the criteria for designing and developing the dyslexic games have been systematically extracted from multiple sources using SLR approach. The extracted criteria have been summarized into Table 3 and 4. Thus, objectives of the study have been met. Table 4 serves as the preliminary guideline. At times this article is written, the authors have successfully developed a dyslexic game as a proof of concept to the extracted criteria, and used it to gather another set of criteria from the respondents through series of interviews and hands-on sessions. A more comprehensive guideline is targeted next, using both sets of criteria, to serve as a guideline for designing and developing games that meet the specific learning need of the dyslexics.

Acknowledgment

References

[1]   E. Ferrer, B.A. Shaywitz, J.M. Holahan, K. Marchione and S.E. Shaywitz, Uncoupling of reading and iq over time: Empirical evidence for a definition of dyslexia. Psychological Science, 2010, 21(1):93–101. https://doi.org/10.1177/0956797609354084

[2]   D. Mellow and J.D.E. Gabrieli, Cognitive neuroscience of dyslexia. Language, Speech & Hearing Services in Schools, 2018, 49: 798–809. https://doi.org/10.1044/2018_LSHSS-DYSLC-18-0020

[3]   International Dyslexia Association, Dyslexia basics. International Dyslexia Association. 2020. https://dyslexiaida.org/dyslexia-basics-2/

[4]   M.J. Snowling, Dyslexia as a phonological deficit: evidence and implications. Child Psychology & Psychiatry Review, 1998, 3(1):4–11. https://doi.org/10.1017/S1360641797001366

[5]   U. Goswami, Reading, dyslexia and the brain. Educational Research, 2008, 50(2):135–148. https://doi.org/10.1080/00131880802082625

[6]   Special Education Division Ministry of Education, Special Education Data 2014, The Ministry of Education, 2014.

[7]   Socio-economic & Environmental Research Institute Penang, Learning difficulties among Standard 1 pupils in Penang. Penang: Socio-economic & Environmental Research Institute Penang, 2003.

[8]   J. Glazzard, The impact of dyslexia on pupils' self-esteem. Support for Learning, 2010, 25(2):63–69. https://doi.org/10.1111/j.1467-9604.2010.01442.x

[9]   D. Horrobin, A. Glen, and C. Hudson, Possible relevance of phospholipid abnormalities and genetic interactions in psychiatric disorders: The relationship between dyslexia and schizophrenic. Medical Hypothesis, 1995, 45:605–613.

[10]   A. Richardson, Dyslexia, Dyspraxia and SDHC-Can Nutrition Help? Oxford: Dyslexia Research Trust, 2001.

[11]   P. Zoccolotti, M. De Luca, L. Lami et al, Multiple stimulus presentation yields larger deficits in children with developmental dyslexia: A study with reading and RAN-type tasks, Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 2013, 19(6):639–647. https://doi.org/10.1080/09297049.2012.718325

[12]   N. Getchell, P. Pabreja, K. Neeld and V. Carrrio, Comparing children with and without dyslexia on movement assessment battery for children and the test of gross motor development, Perceptual and Motor Skills, 2017, 105(1):207–214. https://doi.org/10.2466/pms.105.1.207-214

[13]   G. Reid, Dyslexia: A Practitioner's Handbook, 5th ed., West Sussex: John Wiley & Sons Ltd., 2016.

[14]   L. Bazen, M. van den Boer, P.F. de Jong, and E.H. de Bree, Early and late diagnosed dyslexia in secondary school: Performance on literacy skills and cognitive correlates. Dyslexia, 2020:1–18. https://doi.org/10.1002/dys.1652

[15]   H. Hussin, Mobile dyslexic specialized digital game-based learning object for learning letters (DOLL), Project Dissertation, UTP, 2012.

[16]   W.M.R. Wan Mohammad, V. Subramaniam, A.Y. Abd Aziz and N. Abdul Rahim, Dyslexia in the aspect of Malay language spelling. International Journal of Humanities & Social Science, 2011, 1(21):266–268. http://psasir.upm.edu.my/id/eprint/22683

[17] R. Awang Bolhasan, A study of dyslexia among primary school students in Sarawak, Malaysia. School of Doctoral Studies (European Union) Journal, 2009:250–268.

[18] A.J. Fawcett and R.I. Nicolson, Naming speed and dyslexia. Journal of Learning Disabilities, 1994, 27(10):641–646. https://doi.org/10.1177/002221949402701

[19] C. Jamieson and S. Simpson, Spelling: Challenges and strategies for the dyslexic learner and the teacher, in M.J. Snowling and J. Stackhouse, Dyslexia, Speech and Language: A Practitioner's Handbook, 2nd ed., England: Whurr Publishers, 2006.

[20] M.J. Snowling, Dyslexia, 2nd ed., Oxford: Blackwell, 2000.

[21] L.C. Ehri, Reading processes, acquisition and instructional implications, in G. Reid and J. Wearmouth, Dyslexia & Literacy: Theory and Practice, Chichester: John Wiley & Sons, 2000.

[22] N.K. Goulandris, Assessing reading and spelling skills, in M.J. Snowling and J. Stackhouse, Dyslexia, Speech and Language: A Practitioner's Handbook, 2nd ed., England: Whurr Publishers, 2006.

[23] L.W. Lee and K. Wheldall, Acquisition of Malay word recognition skills: Lessons from low-progress early readers, Dyslexia, 2011, 17(1):19–37. https://doi.org/10.1002/dys.421

[24] J. Li, Y. Theng and S. Foo, Game-based digital interventions for depression therapy: A systematic review and meta-analysis, Cyberpsychology, Behavior, and Social Networking, 2014, 17(8):519–527. https://doi.org/10.1089/cyber.2013.0481

[25] J. Cheng, C. Putnam, and D.C. Rusch, Towards efficacy-centered game design patterns for brain injury rehabilitation: A data-driven approach. ASSETS '15: Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility, 2015, 291–299.

[26] Y. Li, W. Fontijn and P. Markopoulos, A tangible tabletop game supporting therapy of children with cerebral palsy. Lecture Notes in Computer Science, 2008:182–193. https://doi.org/10.1007/978-3-540-88322-7_18

[27] S.K. Tatla, N. Shirzad, K.R. Lohse, N. Virji-Babul, A.M. Hoens, L. Holsti, L.C. Li, K.J. Miller, M.Y. Lam and H.F.M. Van der Loos, Therapists' perceptions of social media and video game technologies in upper limb rehabilitation. JMIR Serious Games, 2015, 3(1):e2. https://doi.org/10.2196/games.3401

[28] N.A. Bartolomé, A.M. Zorrilla and B.G. Zapirain, Dyslexia diagnosis in reading stage though the use of games at school. 17th International Conference on Computer Games, 2012:12–17. https://doi.org/0.1109/CGames.2012.6314544

[29] L. van Den Audenaeren, V. Celis, V. Abeele, L. Geurts, J. Husson, P. Ghesquière, J. Wouters, L. Loyez and A. Goeleven, DYSL-X: Design of a tablet game for early risk detection of dyslexia in preschoolers. Games for Health, 2013, 257–266. https://doi.org/10.1007/978-3-658-02897-8_20

[30] L. Rello, M. Ballesteros, A. Ali, M. Serra, D.A. Sánchez and J.P. Bigham, Dytective: Diagnosing risk of dyslexia with a game. PervasiveHealth '16: Proceedings of the 10th EAI International Conference on Pervasive Computing Technologies for Healthcare, 2016, 89–96. https://doi.org/10.1145/1235

[31] O. Gaggi, C.E. Palazzi, M. Ciman, G. Galiazzo, S. Franceschini, M. Ruffino S. Gori and A. Facoetti, Serious games for early identification of developmental dyslexia. Computers in Entertainment, 2015, 15(2):1–24. https://doi.org/10.1145/2629558

[32] T. Cuschieri, R. Khaled, V.E. Farrugia, H. P. Mart´ınez and G. N. Yannakakis, The iLearnRW game: Support for students with dyslexia in class and at home. IEEE, 2014. https://doi.org/10.1109/VS-Games.2014.7012167

[33] M.H.L. Abdullah, S. Hisham and S. Parumo, MyLexics: An assistive courseware for dyslexic children to learn basic Malay language. Accessibility and Computing, 2009, 95:3–9. https://doi.org/10.1145/1651259.1651260

[34] P.A. Di Tore, S. Di Tore and G.R. Mangione, Madrigale: A multimedia application for dyslexia and reading improvement gamifying learning experience. IEEE Computer Society, 2014:486–491. https://doi.org/10.1109/INCoS.2014.48

[35] L. Rello, C. Bayarri and A. Gorriz, What is wrong with this word? Dyseggxia: A game for children with dyslexia. ASSETS '12: Proceedings of the 14th international ACM SIGACCESS conference on Computers and accessibility, 2012, 219–220. https://doi.org/10.1145/2384916.2384962

[36] S.Z. Ahmad, N.N.A.A.N. Ludin, H.M. Ekhsan, A.F. Rosmani and M.H. Ismail, Bijak Membaca - Applying phonic reading technique and multisensory approach with interactive multimedia for dyslexia children. 2012 IEEE Colloquium on Humanities, Science and Engineering Research, 2012. https://doi.org/10.1109/CHUSER.2012.6504375

[37] M.R.U. Saputra, LexiPal: Design, implementation and evaluation of gamification on learning application for dyslexia. International Journal of Computer Application, 2015, 131(7):36–43. https://doi.org/10.5120/ijca2015907416

[38] H. Holz, K. Brandelik, J. Brandelik, K. Beuttler, A. Kirsch, J. Heller and D. Meurer, Prosodiya – A mobile game for German dyslexic children, Games and Learning Alliance Conference, 2017.

[39] M. Ronimus, K. Eklund, L. Pesu and H. Lyytinen, Supporting struggling readers with digital game-based learning. Education Technology Research Development, 2019, 67:639–663. https://doi.org/10.1007/s11423-019-09658-3

[40] D. Gooch, A. Vasalou, L. Benton and R. Khaled, Using gamification to motivate students with Dyslexia. CHI '16: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, 2016, 969–980. http://dx.doi.org/10.1145/2858036.2858231

[41] D. Moher, A. Liberati, J. Tetzlaff and D.G. Altman, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med, 2009, 6(7). https://doi.org/10.1371/journal.pmed1000097

[42] J. Ecalle, A. Magnan, H. Bouchafa and J.E. Gombert, Computer-based training with ortho-phonological units in dyslexic children: New investigations, Dyslexia, 2008, 239:234–239. https://doi.org/10.1002/dys

[43] L. Rello, C. Bayarri and A. Gòrriz, Dyslexia exercises on My Tablet are more fun, International Cross-Disciplinary Conference on Web Accessibility, 2013:8–9. https://doi.org/10.1145/2461121.2461148

[44] L. Rello, C. Bayarri, Y. Otal and M. Pielot, A computer-based method to improve the spelling of children with Dyslexia, 16th International ACM SIGACCESS Conference on Computers and Accessibility, 2014, 153–160. https://doi.org/10.1145/2661334.2661373

[45] L. Rello, S. Subirats and J. P. Bigham, An online chess game designed for people with Dyslexia, W4A '16: Proceedings of the 13th International Web for All Conference, 2016, 28:1–8. https://doi.org/10.1145/2899475.2899479

[46] L. Rello, K. Williams, A. Ali, N. C. White and J. P. Bigham, Dytective: Towards detecting Dyslexia across languages using an online game, Proceedings of the 13th International Web for All Conference, 2016, 29, 1–4 https://doi.org/10.1145/2899475.2899491

[47] M. Goffredo, I. Bernabucci, C. Lucarelli, S. Conforto, M. Schmid, M. M. Nera, L. Lopez, T. D'Alessio and B. Grasselli, Evaluation of a motion-based platform for practicing phonological awareness of preschool children. Journal of Educational Computing Research, 2016, 54(5):595–618. https://doi.org/10.1177/0735633115626881

[48] E. Pedroli, P. Padula, A. Guala, M. T. Meardi, G. Riva and G. Albani, A psychometric tool for a virtual reality rehabilitation approach for Dyslexia. Computational and Mathematical Methods in Medicine, 2017. https://doi.org/10.1155/2017/7048676

[49] A. Vasalou, R. Khaled, W. Holmes and D. Gooch, Digital games-based learning for children with Dyslexia: A social constructivist perspective on engagement and learning during group game-play. Computers and Education, 2017, 114: 175–192. https://doi.org/10.1016/j.compedu.2017.06.009

[50] O. Gaggi, C. E. Palazzi, M. Ciman, G. Galiazzo and S. Franceschini, Serious games for early identification of developmental Dyslexia. Computers in Entertainment, 2017, 15(2):1–24. https://doi.org/10.1145/2629558

[51] M. Rauschenberger, L. Rello and R. Baeza-Yates, A tablet game to target dyslexia screening in pre-readers. MobileHCI '18: Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, 2018:306–312. https://doi.org/10.1145/3236112.3236156

[52] H. Holz, B. Beuttler and M. Ninaus, Design rationales of a mobile game-based intervention for German dyslexic children. CHI PLAY 2018: 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts, 2018:205–219. https://doi.org/10.1145/3270316.3272053

[53] M. Ostiz-Blanco, M. Lallier, S. Grau, L. Rello, J.P. Bigham and M. Carreiras, Jellys: Towards a videogame that trains rhythm and visual attention for Dyslexia, ASSETS 2018: 20th International ACM SIGACCESS Conference on Computers and Accessibility, 2018:447–449. https://doi.org/10.1145/3234695.3241028

[54] G. Gabriel Elías Chanchí, W.Y.C. Muñoz and L.F.M. Sanabria, A videogame as a support tool for dyslexia therapy using the GDevelop platform, ACM International Conference Proceeding Series, 2019:162–166. https://doi.org/10.1145/3364138.3364172

[55] M. Rauschenberger, C. Lins, N. Rousselle, A. Hein and S. Fudickar, Designing a new puzzle app to target Dyslexia screening in pre-readers, ACM International Conference Proceeding Series, 2019:155–159. https://doi.org/10.1145/334428.3342679

[56] P. Dymora and K. Niemiec, Gamification as a supportive tool for school children with dyslexia, Informatics, 2019, 6(4). https://doi.org/10.3390/informatics6040048

[57] S. Franceschini and S. Bertoni, Improving action video games abilities increases the phonological decoding speed and phonological short-term memory in children with developmental dyslexia. Neuropsychologia, 2019, 130:100–106. https://doi.org/10.1016/j.neuropsychologia.2018.10.023

[58] K. Tulloch and K. Pammer, Tablet computer games to measure dorsal stream performance in good and poor readers. Neuropsychologia, 2019, 130:92–99. https://doi.org/10.1016/j.neuropsychologia.2018.07.019

[59] M.A. Che Sulaiman and A. Ban, User interface guidelines for Dyslexic game-based learning on selected usability test method. International Journal of Advanced Trends in Computer Science and Engineering, 2019, 8(1.4):439-445. https://doi.org/10.30534/ijatcse/2019/6981.42019

[60] R.T. Bigueras, M.C.A. Arispe, J.O. Torio and D.E. Maligat, Mobile game-based learning to enhance the reading performance of dyslexic children. International Journal of Advanced Trends in Computer Science and Engineering, 2020, 9(1.3):332–337. https://doi.org/10.30534/ijatcse/2020/5191.32020

[61] R. Görgen, S. Huemer, G. Schulte-Körne and L. Moll, Evaluation of a digital game-based reading training for German children with reading disorder. Computers and Education, 2020, 150. https://doi.org/10.1016/j.compedu.2020.103834

[62] R.T. Bigueras, M.C.A. Arispe, J.O. Torio, D.E. Maligat and T.D. Palaoag, Design of mobile game-based learning application for children with dyslexia. International Journal of Advanced Trends in Computer Science and Engineering, 2020, 9:322–326. https://doi.org/10.30534/ijatcse/2020/4991.32020

[63] M. Rauschenberger, R. Baeza-Yates and L. Rello, Screening risk of Dyslexia through a web-game using language-independent content and machine learning, W4A '20: Proceedings of the 17th International Web for All Conference, 2020, 13, 1–12. https://doi.org/10.1145/3371300.3383342

[64] V. Vanden Abeele, J. Wouters, P. Ghesquière, A. Goeleven and L. Geurts, Game-based assessment of psychoacoustic thresholds: Not all games are equal!. CHI PLAY '15: Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play, 2015:331–341. https://doi.org/10.1145/2793107.2793132