Evaluating New Approaches of Intervention in Reading Difficulties in Students with Dyslexia: The ilearnRW Software Application

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Abstract
The aim of this paper is to increase knowledge and understanding on how the implementation of language content through specialized software, such as the "Integrated Intelligent Learning Environment for Reading and Writing-iLearnRW", can enhance learning during intervention procedures to enhance reading skills for children with dyslexia.The iLearnRW software is a newly designed tool that makes use of innovative technology and provides individualized intervention through games that incorporate learning activities, addressing those language areas that are most challenging for children with dyslexia in a highly entertaining and motivating way. Individualized intervention is provided through an underlying user profile, which incorporates these language features and is constantly updated as the child uses the software playing games, presenting language material selected based on his difficulties and recording his progress. A group of 78 students (52 male, 26 female) diagnosed with dyslexia, aged between 9 and 11 years old, was assessed for phonological, morphological and vocabulary skills. The students logged in the iLearnRW software on a mean of 14.18 days over a six-month intervention. After the 6-month intervention, the students were assessed once again on the same skills so as to establish the tool's effectiveness.The results' analysis revealed the following: (i) there was a strong constructional linkage between the profile entries of the sample, the language content of the tasks of the screening test as well of the games and its effectiveness in the students' performance; (ii) the students who received specific guidance by their teachers, obtained higher success rates in most of the games than the students without any guidance, and (iii) the quantity of the language content and the time playing were not correlated with the students' performance in the software's games.
Keywords: Digital technology, assistive computer software, dyslexia, learning environment

1. Introduction

Reading is one of the basic linguistic skills, along with production and comprehension of oral speech. However, it is different from speaking and listening in that it is not acquired but learnt and taught and often even found difficult by children who have no other apparent language difficulties whatsoever (Peterson & Pennington, 2012). The process of reading mainly involves (even at very early stage) the skills of decoding and comprehension, in order visual symbols to be translated into mental representations used to extract meaning (with or without turning these visual units into sound in loud reading) (Coltheart et al. 2001; Florit & Cain, 2011; Kendeou et al., 2009b; Kendeou et al, 2013).

The most widely investigated developmental written language disorder which is characterized by a significant deficit in printed word recognition in the face of adequate instruction and general cognitive abilities, is dyslexia (Grigorenko & Elliott, 2014).

Several theories have been developed aiming to reveal the complexity of the problem and the wide range of its symptoms and extensions.

The phonological processing deficit theory underlies word-reading difficulties in many children with dyslexia. Subsequent experimental studies support the hypothesis that poor phonological awareness in dyslexia reflects the phonological deficit might lie in some cognitive skills applied to phonological representations in certain tasks, such as: (i) slow development and production of phonological codes, (ii) phoneme-grapheme correspondence, and (iii) semantic appreciation of words (Berent et al., 2012; Castles & Coltheart, 1993; Inoue et al., 2011; Marshall et al., 2009; Mundy & Carroll, 2012; Ramus & Ahissar, 2012; Soroli et al., 2010).

Current studies (Cuetos & Centeno, 2009; Zoccolotti & Friedmann, 2010), comparing the performance of children with dyslexia with that of children with no learning difficulties and, examining the effects of intervention, are focused on the psycho-cognitive correlates of dyslexia as well as the neural correlates of word recognition (e.g., N170 ERP component).

Regardless the theoretical different approaches in investigating the causes of dyslexia, the complexity and the continuity of a variety of difficulties necessitate the development of the most appropriate as well as the most well applied form of interventions. Interestingly, it has been supported that if these difficulties are left untreated, the frustration and difficulties caused by the learning problems both at home and school, creates stress and hardship. As a result children feel bad about themselves (Zakopoulou et al., 2014). Additionally, children with reading problems were found to be significantly more likely to display poor task engagement, poor self-control, externalizing and internalizing behavior problems (Riddick, 2009). Anxiety, depression, stressful events, emotional trauma and other conditions affecting concentration make learning more of a challenge (Morgan et al., 2008; Zakopoulou et al., 2013).

1.1 Intervention approaches in dyslexia

Over the past two decades, a series of well organized, systematic, and strictly structured intervention studies (Denton et al., 2010; Denton et al, 2013; Torgesen, 2004; Vellutino et al., 2008), demonstrated cumulative effects in learning disabilities, from early stages of development.

However, it is widely argued that effective learning for children with dyslexia presupposes processes of providing them with key elements of literacy instruction (Angeleli et al., 2010; Clark et al., 2014). Such elements are phonemic awareness, decoding, spelling, word reading accuracy and fluency, and comprehension, as well as encouraging the multisensory learning, supporting the development of metacognitive and self-regulatory strategies, enhancing motivation to read, and providing with appropriate resources to support individual learning styles adequately addressed (de Jong et al., 2009; Papadopoulos and Kendeou, 2012; Verhoeven. Reitsma and Siegel, 2011).

Particularly, teaching methods themselves need to match the individual's learning style (Camahalan, 2006; Reid, 2002), as well as to follow fundamental principles, such as: (i) making teaching interesting and fun; (ii) breaking information down into small, easily recalled sections; (iii) working at a gradual pace which ensures continued enthusiasm and confidence through successful learning; (iv) giving acknowledgement and praise for good content and meaning (Mather & Goldstein, 2001; Westman, 1990).

To sum up, children with dyslexia seem to fall behind compared to their peers in two main areas: (i) phonological awareness, as it is encapsulated by grapheme-phoneme correspondence knowledge, and (ii) metacognitive control of their learning process.

Therefore, the teaching strategies that have proven (Hatcher et al., 1994; Townend, 2000; Walker, 2000) to be most effective in facilitating the process of learning to read by students with dyslexia, involve multisensory, direct teaching of phonological routines and enhancing metacognitive skills, by training students to detect similarities, relationships, and systematic patterns in language.

1.2 Multimedia learning environments

The broad use of digital technology during the last decades has changed the ways of learning offering (i) environments that get the today's active and communicational learner more involved in the learning process, and (ii) new tools that rewire the brain and redefine and shape thinking (Abdullah & Gazelle, 2014; Siemens, 2014). The potential benefits of digital technology in the educational settings are well documented at all educational levels from preschool to higher education (Pange, Lekka, & Toki, 2010). Technology offers new learning environments that can be used fruitfully by everyone, from young children to adults, simply by plugging into sources and work with new tools in order to learn what is needed for tomorrow (Pange et al., 2010; Siemens, 2014).

The significance of the benefits of multimedia learning environments is well established in the educational and clinical setting from learning, teaching and evaluation to assessment (Toki, Pange, & Mikropoulos, 2012) and intervention procedures (Drigas & Petrova, 2014; Hirano et al., 2010; Pelayo, 2013). Multimedia material can inspire students, promote learning and creativity and serve as pleasure at the same time (Robin, 2008; Toki, 2013).

Furthermore, in a multimedia environment digital games are commonly one of the most favourable leisure-time activities especially for children (Mayer, 2006). Game based learning and serious games offer effective, interactive experiences that motivate and actively engage children in the learning process (Berninger et al., 2015).

Scientific reports highlight on digital game-based learning (DGBL) potential benefits, as educational and motivational tools due to the fact that: (i) digital games can maximize children's attention, (ii) children prefer game based learning tasks more than traditional ones (Ronimus et al., 2014). Erhel and Jamet (2013) state that in DGBL and if regular feedback is provided on learners' performance, the entertainment instruction results in deep learning. Thus, a serious game environment that provides learners with active educational content feedback, can enhance both learning and motivation.

Although the value of serious games is undeniable, still game features supporting learning effectiveness and the types of learning outcomes that can be achieved through game play, need further study (Guillén-Nieto & Aleson-Carbonell, 2012).

Recent literature points out that digital technology can provide young children with disabilities with an enriched environment that can promote participation, social and cognitive growth (Asuncion et al., 2012; Coleman et al., 2006; Drigas et al., 2015; Sansosti & Powell-Smith, 2008; Saridaki et al., 2009; Toki & Pange, 2010).

1.3 The use of assistive learning digital tools in dyslexia

The use of assistive computer software in dyslexia composes an effective perspective; it provides multi-sensory feedback to the reader in order to reinforce his reading skills, contributing also to the comprehension process.
However, the issue that demands more research into the contribution of computer technology in dyslexia is its effectiveness in the learning process itself. Digital technology must offer children with disabilities more autonomy and independence with attention to their special educational needs and their hidden potential (Giliberti et al., 2011; Toki et al., 2012).

Software systems and digital strategies have been developed to accommodate learning processes in the effort to guarantee same rights to every student in a digital environment (Abbott et al., 2011; Asuncion et al., 2012; Avellis et al., 2014; Bastanfard et al., 2011; Drigas & Kokkalia, 2014; Drigas et al., 2015; Pelayo, 2013). Specific technologies such as personal computers, tablets, smartphones, smartTVs, white boards, game consoles, video games, audio-video recording systems and all the other toys and tools of the digital age, may be used to target the difficulties encountered by a child with disabilities.

Specifically, Van den Audenaeren et al. (2013) report on the design guidelines for development of an assessment tool for their DYSL-X project, which is a tablet game that incorporates tests to take specific performance measures that allow early prediction of dyslexia for 38re-schoolers. This prediction comes as an accurate measurement due to the result of the optimal game experience that ensures the pre-schoolers' higher motivation and attention.

Based on the phonological deficit hypothesis, the GraphoGame computer assisted intervention aims to improve the phonemic awareness and letter-knowledge processes of children with learning disabilities at early stage (Lyytinen et al., 2009).

The GraphoGame reward system provides the user with immediate feedback, encourages him/her to play similar activities multiple times, and facilitates the processes of building the connections between spoken and written language, maintaining the effectiveness of learner's engagement till the completion of tasks (Lyytinen & Richardson, 2013; Papadopoulos et al., 2010).

Rello and Baeza-Yates (2014) report on DysWebxia, a reading app for people with dyslexia running on iOS devices. The app first prototype is for Spanish presenting text with the ability to show synonyms on demand for complex words. For the evaluation of DysWebxia, thirty two dyslexics and thirty eight strong readers without dyslexia were compared to evaluate the quality of the synonyms on demand. In addition, twelve participants evaluated the usability of the app. The results indicated the potential impact of the app for people with dyslexia as that the algorithm used generated quality synonyms and participants found the app very usable.

All in all, in seeking to define the effectiveness of the use of assistive learning digital tools in dyslexia, the balance must be clear between specific learning requirements and successful learning outputs related to motivation, cognitive, perceptual as well as linguistic abilities aiming to improve phonological, reading, and writing skills.

1.4 Objectives-Research questions

The aim of this paper is to increase knowledge and understanding on how the implementation of language content through digital technology can enhance learning during intervention procedures on linguistic skills for children with dyslexia.

Precisely, a new approach to intervention in dyslexia, a specialized software, the "Integrated Intelligent Learning Environment for Reading and Writing- (iLearnRW)", is used. Aiming to explore the above the main objective of this study was to examine the following hypothesis: "whether the language content of the iLearnRW software was well adapted to learning profile of dyslexia in order the usability of the software to enhance the learning experience concerning reading skills of students with dyslexia". The specific research questions were formulated:
Questions related to the linguistic/learning profile of dyslexia:

- Which of the profile entries (language categories in the profile) represent the greatest difficulties encountered in dyslexia?
- Which of the tasks in the screening test are more demanding for students with dyslexia?

Questions related to the usability and operation of the iLearnRW software:

- Does the linguistic content of the activities indicate any preference of the children to specific activities?
- Does the software success in drawing and keeping students' interest?

Questions related to the effect and effectiveness of the iLearnRW software on enhancing learning experience:

- Does the quantity of the linguistic content (words), played in the activities, correlate with the students' success rate in the games?
- Is the students' success rate affected by the frequency and duration of software use?
- Does teacher guidance affect students' success rate in the activities?
- Does teacher guidance affect the improvement of the student's achievement between initial and final screening tests?

2. Materials and Method

2.1 Participants

Seventy-eight (78) students (52 male, 26 female) aged between 9 and 11 years, formally diagnosed with dyslexia and/or reading/writing difficulties, participated in the software evaluation. They were all monolingual students with formally diagnosed specific learning difficulties (mainly dyslexia) and attended special education classes in ten state primary schools in Ioannina, Greece. The students were divided into two groups: (i) a teacher-guided (TG) group (60 students), which would use the software under the guidance and supervision of thirty-five trained teachers, and (ii) a non-guided control (NGC) group (18 students), which would use the software at homes without any supervision.

2.2 Procedure

The evaluation procedure began with training the teachers who would supervise the software use by the TG group. Teachers were offered two-hour training sessions in order to be familiarized with the software and the evaluation process. Specifically, they were familiarized with the game world, the user profile and the activities, while they were also trained on the screening/re-evaluation administration process.

Members of the research team informed the students participating in the evaluation along with their parents about the general concept of the research. They were presented with the nature of the games and the duration required to complete the sessions of the games. The children of the NGC group were instructed to use the system at their homes as often as they pleased, while their parents were instructed to refrain from guiding their children while using the software. Consent forms were signed by the parents of the children of both groups, handing permission to the research team to collect data from their children's use of the software during the evaluation.

The whole evaluation process comprised three phases: (a) the screening – initial evaluation phase, (b) the intervention phase, and (c) the re-evaluation phase. The screening – initial evaluation phase commenced in January 2015, during which the children of both groups were administered a language-screening test, assessing their skills or difficulties in the areas included in the profile. The intervention phase differed for the two groups: for the TG group, intervention included use of the software once or twice on a weekly basis within the prearranged setting (school or clinical centre) for each child.

During each session, the children were asked to log in the system in order to start and complete an activity. Upon completing a session, the game would proceed to the next level of difficulty until achieving the final goal of the game. For the NGC group, system use was left uncontrolled, so as to explore the system performance with respect to motivation and engagement.

The intervention phase lasted for a period of 4 months, with the length of played time in each session averaging between 5-20 minutes for the TG group. Finally, the re-evaluation phase took place in June 2015, whereby all children were assessed on the same areas as tested in the initial evaluation phase using the same screening tool, so as to explore the effects of the system use on the students' skills.

2.3 Materials

2.3.1 The iLearnRW system

The iLearnRW system aims to: (i) target the children's particular difficulties, (ii) facilitate the interaction of the system with the user following particular teaching strategies, including text and content classification with respect to the user's profile through visual techniques that combine highlighting, text-reformatting and word segmentation, (iii) apply innovative delivery methods, suitable for children, and (iv) construct engaging environments such as mini games, reading activities and tests, integrating all the above in a serious game.

The software was developed in Greek and English under the European-funded research project FP7 "Integrated Intelligent Learning Environment for Reading and Writing-iLearnRW", while the two versions were evaluated by members of the research team in Greek and English populations respectively. The present paper presents the evaluation results on the Greek version of iLearnRW.

Particularly, through the implementation of the iLearnRW, we tested the capability of the system to: (i) meet the child's needs in acquiring and developing the specific skills that contribute to reading and writing, including phonology, memory, grammar, syntax, vocabulary and comprehension, adapted to the child's age and developmental stage, (ii) be applied in individual and group work, respectively, and (iii) combine appropriate theoretical learning and teaching strategies, integrated in a multidisciplinary supportive learning environment.

2.3.1.1 User Profile

The basic information that the iLearnRW system stores in order to work properly is a profile for each child/user. It was quite important to have access to data that describe a single user and all information contained in his/her dyslexia related profile. By that possibility, the iLearnRW system provides specialized and personalized learning sessions to each of its users.

The profile for individuals with dyslexia that was incorporated into the system was based on a model that included a general classification of the types of errors usually made and the difficulties encountered by these populations, as defined by the type of dyslexia exhibited (i.e. phonological, surface or deep dyslexia; similarly, the types of spelling errors were based on phonological and morphological rules and characteristics). Therefore, the two columns in Table 1 present the information stored in the profile: eight language areas were included, that is, eight categories (C) of linguistic difficulty often exhibited in dyslexia (left column), and a number of typical tokens of each category, ordered with respect of increasing difficulty-complexity (right column).

Table 1. User's Profile

Difficulty in specific language areas	Types of errors (linguistic material)
Letter (visual) similarity	α/ο, ψ/ω, 3/ε/ξ, η/μ, φ/β/θ, κ/χ/γ/λ, π/τ, δ/ρ/σ/6
Phonemes (sound similarity): a) consonants b) vowels	/t/-/d/, /p/-/b/, /k/-/p/, /k/-/t/, /m/-/n/, /θ/-/ð/, /f/-/v/, /χ/-/γ/, /k/-/γ/, /k/-/χ/, /s/-/z/, /l/-/r/, /ð/-/v/, /f/-/θ/, /f/-/v/, /θ/-/ð/, /kt/-/pt/ /ks/-/ps/, /ks/-/sk/, /ps/-/sp/ /ðr/-/θr/, /fr/- /χr/ /χθ/-/fθ/, εϋ: /eɪ/ οϋ: /οɪ/ αϊ: /aɪ/ αη: /aɪ/ οΰ: /oi/ αΐ: /ai/
Grapheme-phoneme correspondance	Consonant clusters in various positions: 2-syll. initial, 2-syll. internal, 3-syll. initial, 3-syll. internal; idiosyncratic vowel combinations.
Word recognition: sight/irregular words	NOUNS: State/property/quality/ Colours/ Plants/ Activity/activity outcome
Syllable division	cv-cv, cv-v, v-cv, cv-vc, vc-cv(c), cvc-cv(c), cv-ccv(c), ccv-cv(c), ccvc-cv(c), cv-cccv(c) v-cccv(c) ιά/ειά, ιά/ία αί/αΐ, εί/εΐ, οί/οΐ αί/άι, οί/όι άι, όι (diphthongs) αι/αϊ, οι/οϊ, ει/εϊ ου/οϋ, ού/οΰ αυ/αϋ, αύ/αΰ εύω
Grammar: function words	Indefinite articles, definite articles, prepositions
Prefixing	ADJS: Privative/Opposite/ Difficulty; ADJS&NOUNS: Quantity (over/under); VERBS: Quantity(over/under); VERBS Lexical prefixes
Suffixing: a) Derivational b) Inflectional	a) NOUNS & ADJs: Diminutives-Enlargement, profession, place, instrument/means/container, state/property/quality, activity/outcome; ADJs, VERBS. b) freq. noun classes (case and number of increasing complexity), less freq.noun classes, frequent and less frequent adjective and verb classes

The specific language tokens related to each category were assigned index numbers, beginning from 1 and rising as the complexity of the tokens increased. Table 2 presents the first six indexed tokens of a sample language areas.

Table 2. Sample Indexed Tokens of a Language Areas: Syllable Division

Index		1	2	3	4	5	6
Category N	1						
Specific case	Syllable Division	cv-cv	cv-v	v-cv	cv-vc	vc-cv(c)	cvc-cv(c)
Example word		*κα-λά /ka'la/ (=well)*	*χα-ο-τικός /χaoti'kos/ (=chaotic)*	*α-πό /a'po/ (=from)*	*χά-ος /'χaos/ (=chaos)*	*ασ-βοί /az'vi/ (=badgers), ασ-βός /az'vos/ (=badger)*	*καρ-ποί /kar'pi/ (=seeds), καρ-πός /kar'pos/ (=seed)*

The index numbers related to each language area/difficulty are used to provide an estimation of the severity of each user's difficulty, drawing information every time he/she uses the system to play a game or complete an activity. The user is placed on a specific point in the index scale, based on the number and types of errors made. By placing a user on a certain point in the index scale, the system 'knows' the kind of language instances that the specific user has greater difficulty and presents him/her with more examples of that type in the games, so as to facilitate learning. At the same time, these index numbers are used to indicate progress, as user profiles are updated every time the system is used. To facilitate the operation of the system in achieving this purpose, the indexed tokens of each language category were grouped into clusters, as many of these tokens differed minimally and represented the same level of complexity. For example, the language area of syllable division presented in Table 2 comprises 20 indexed tokens, grouped into five clusters (indexes 1-6 presented in Table 2 all belong to Cluster 1). Therefore, a student was placed on a specific cluster for each language area after screening, so that the system would aim to teach him examples of that particular cluster before moving to the next.

The user profile set a baseline that enabled the evaluation of the appropriateness of the linguistic content for each individual child, the content classification, and the content integration into coherent learning programmes.

2.3.1.2 Game activities: a promising delivery mechanism

The serious games component comprises a unique and innovative part of the iLearnRW software environment. It contains a set of motivating, flexible and entertaining learning games (activities) that have been created to encourage children to engage in learning activities. The games were designed to address the language difficulties included in the profile, drawing linguistic material that corresponds to each language token of every difficulty having as a result the achievement of particular learning outcomes (see Table A for the mapping of the games onto language difficulties of the user profile and relative learning outcomes). The child's progression in the games feeds back his/her profile, updating it and changing his/her position in it. The serious games were seen as the answer to the engagement problem: as children prefer to play games instead of doing reading exercises in front of a computer, the system was expected to successfully draw its users' interest.

The learning games are all integrated into a 2D virtual world, the World of the Dead, which was based on the Mexican Día de los Muertos theme. Within the game world, the player can walk around and interact with non-player characters. Each character is associated with a set of difficulties/indexes within the student profile. Upon interaction with these characters, activities to address those difficulties are launched, while the child's performance in each game feeds and updates the user profile.

The learning activities were designed firstly to incorporate the following teaching strategies: (i) use of a multi-sensory (visual, auditory, tactile) approach, (ii) use of images, variable font colour and size; visual–sound discrimination of shapes, (iii) bottom-up or top-down teaching approaches, (iv) enhance metacognitive and metalinguistic awareness through continuous feedback to the child and, secondly to contribute to: (i) strengthen and improve the cognitive mechanisms of short-term memory, visual and auditory perception and attention, (ii) facilitate the acquisition of the skills of phomeme-grapheme correspondence, meta-phonological awareness, reading, writing and spelling and, (iii) simplify complex linguistic functions, such as: identification of letter shapes and word patterns, composition, segmentation and blending of words, identification of different morphemes, recognition of sight/irregular words (see Appendix for a list of the learning outcomes of each activity).

2.3.2 Screening test

All the students were administered a specialised screening tool so as to assess their skills prior to the beginning of the intervention phase as well as at the end of it, in order to check whether any progress had been made. The screening test consisted of 4 types of tasks assessing reading accuracy, identification of syllables and affixes and sentence completion: "Read" (read the words), "Split" (split the words into syllables by drawing lines), "Circle 1" (circle word prefixes), "Circle 2" (circle word suffixes), and "Fill" (choose the word to fill the gap). The words and phrases/sentences used corresponded to the categories included in the user profile, representing the whole scale of index numbers in each difficulty. To that end, the user profile categories were processed so that the specific instances of each difficulty were grouped into broader clusters.

Scoring was performed on a binary scale (Correct/Incorrect), while a required field with the option of Confident/Hesitant and a No Response option was also provided. The results of the screening test were entered into the iLearnRW system so as to inform the user profile and enable the system to present each student with a personalised intervention scheme for the 4-month period.

2.4 Statistical analysis

To begin with, the specific components of the user profile are specified as follows: i) Category (C): the included linguistic material (vowels, consonants, syllables, words), ii) Difficulty (D): individual token or item in each category, and iii) Cluster (Cl): collection of indexes/difficulties within one category used for screening and profile initialisation as well as progress.

Secondly, as independent variables were measured the quantity of the linguistic content played which was calculated using the Total Number of Words Played and Number of Unique Words Played (words presented only once), the profile entries addressed, and the teachers' guidance; as dependent variables were examined the mean success rate in the games, and the success scores in the screening test.

Additionally, the following relationships amongst variables were tested:

- Correlation between language content (N of words played, N of unique words played) and success rate
- relationship between individual activities and success rate
- relationship between the type of task with success rate and language type (stratification)

- comparison between the initial evaluation (screening before system use) and re-evaluation (after system use)
- comparison between the two user groups on each of the above measures.

Finally, an analysis of the students' scores on each task of the screening test, as well as on material corresponding to each language category included in the profile was performed, so as to determine which of these categories represent the most severe difficulties in dyslexia.

All scale variables were described with the use of means and standard deviations while categorical variables with the use of counts and percentages. The Shapiro Wilk test was implemented were required to assess normality. The Pearson correlation coefficient was used to evaluate correlations between scale variables. The paired samples t-test was used to assess differences in the screenings at the two time points of interest. Statistical significance was set at p=0, 05 in all cases and the analysis was carried out with the use of SPSS v.21.0.

3. Results

The students logged in the software on a mean of 51.048 min over the six-month period of the evaluation.

The profile entries are regarded one of the main components of the language content of the software, as they include the most type of learning difficulties that the participated students face. The following table (Tab.3) shows that the largest and the most common categories of difficulties were the Syllable Division (28.1%), the Sound Similarity between vowels (16.3%) - consonants (10.9%) and the Suffixing (15%).

Table 3. Profile Language Entries Addressed

		Frequency	Percent
Valid	Syllable Division	1489	28.1
	Sounds Similarity (consonants)	577	10.9
	Letter (visual) Similarity	445	8.4
	Sounds Similarity (vowels)	863	16.3
	Suffixing	793	15.0
	Word Recognition: sight/irregular words	281	5.3
	Grammar: function words	259	4.9
	Prefixing	383	7.2
	Grapheme-phoneme Correspondence	205	3.9
	Total	5295	100.0

The above profile language entries were well built in the main construction of the game's activities, targeted to become core indicators of revelation of the real difficulties of the children and of the user's preference and/or capability of playing particular activities.

The user's preference is represented by the frequencies that show the times each game was played. Accordingly, these frequencies indicate the most frequent elaborated language entries and the relative learning outcomes that were to be achieved through the games, as the following table (Tab. 4) shows:

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Table 4. Most Frequent Games, Language Areas, and Learning Outcomes

Games	Frequency	Language Areas	Learning Outcomes
Moving Pathways	38, 5%	-Phonemes: vowels - consonants -Letter (visual) similarity -Grapheme-phoneme correspondence -Word recognition: sight/irregular words	-Identify similar letter shapes -Identify grapheme-phoneme correspondences on a (multisyllable) word -Identify word patterns (sight words, irregular words) -Acquire regularity in phonemes/letters alternation (word level)
Mail sorter	16, 2%	-Derivational suffixing -Inflectional suffixing -Prefixing	-Perform word decomposition and identify morphemes (suffixes, prefixes)
Whack a mole	12, 7%	-Letter (visual) similarity -Derivational suffixing -Inflectional suffixing	-Discriminate letters that look similar -Perform word decomposition and identify morphemes (suffixes, prefixes)
Serenade Hero	9,6%	-Grammar: function words -Derivational suffixing -Inflectional suffixing -Prefixing	-Build words from stems and affixes -Build phrases and sentences -Process function words and their role in a sentence
Harvest	7,5%	-Phonemes: vowels -Grapheme-phoneme correspondence -Syllable division -Grammar: function words -Derivational suffixing -Inflectional suffixing -Prefixing	-Identify phonetic similarities (long vowels, consonant clusters) -Syllabify -Identify common phonetic patterns in written words -Identify common morphemes (prefixes and suffixes) in different words -Classify words grammatically
Mail Delivery	7,3%	-Syllable division -Derivational suffixing -Inflectional suffixing -Prefixing	-Compose words from letters or syllables -Identify common suffixes / prefixes automatically and use them to create words

In regard to the linguistic material of the activities, a quantitative description shows that a mean of 1615. 5 words and a mean of 895. 8 unique words presented in the games have been played by the students.

Table 5 presents the correlations between the mean success rate as aggregated per student and the total number of words played, the total number of unique words played and the total number of applications used in the whole sample. In all cases the estimated p-values are rather high, above 0.4, showing that success rates are not correlated to any of the indices measured.

Table 5. Correlations between Success Rate and Number of Words Played in the Whole Sample

		Mean Success Rate	Total Duration	Total Number of Words Played	Number of Unique Words Played	Total number of applications
Mean Success Rate	Pearson Correlation	1	.010	.092	.037	.067
	Sig.(2-tailed)		.930	.422	.744	.556
	N	78	78	78	78	78

The following tables (Tab.6 & Tab.7) show that even though there was no significant divergence between the recorded mean success rates in the two groups, the students under their teachers' guidance, recorded higher success rate in the total of the games than the students without guidance.

Table 6. The Mean Success Rate Difference per Game for Students without Guidance

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Junkyard	45	.79	.07	.01	.77	.81
Mail Delivery	188	.89	.07	.00	.88	.89
Endless Runner	77	.84	.05	.00	.81	.85
Harvest	174	.87	.08	.00	.86	.89
Mail Sorter	169	.83	.07	.00	.82	.84
Moving Pathways	429	.83	.07	.00	.83	.84
Serenade Hero	246	.82	.06	.00	.81	.82
Typing Train Dispatcher	34	.82	.07	.01	.79	.84
Whack a Mole	156	.77	.07	.01	.76	.78
Total	1518	.83	.08	.00	.83	.84

Table 7. The Mean Success Rate Difference per Game for Students without Guidance

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Junkyard		98	.77	.07	.01	.76	.78
Mail Delivery		232	.83	.07	.00	.82	.84
Endless Runner		142	.82	.07	.05	.80	.82
Harvest		256	.83	.07	.00	.82	.84
Mail Sorter		761	.85	.07	.00	.84	.85
Moving Pathways		1784	.88	.06	.00	.87	.88
Serenade Hero		305	.82	.08	.00	.81	.82
Typing Train Dispatcher		76	.79	.08	.01	.77	.81
Whack a Mole		574	.83	.07	.00	.83	.84
Total		4228	.85	.07	.00	.85	.85

Following, grapheme (Figure 1) shows the mean success rate on each of the five areas of the screening for each student. A and B stand for Pre and Post of the intervention respectively. As Figure 1 illustrates, the students without guidance were better than guided ones in almost all tasks but their improvement from testing A to testing B seems smaller. Additionally, although syllabification (Split) and identification of suffixes (Circle 2) were the hardest tasks, both of them were significantly improved in testing B.

Interestingly, comparing prefixation (i.e. Circle1) to suffixation (i.e. Circle2), it becomes obvious that the identification of suffixes was much harder than identifying prefixes for both groups, which can be explained either by word-position (word-initial segments are easier to process than word-final ones), or by function (Circle2 included both derivational and inflectional suffixes).

Furthermore, the Paired samples t-test (Tab. 8) shows that the students who received no guidance from their teachers achieved a statistically significant rise in the success rate judging by the means Pre (A) and Post (B) the intervention but only in “Read” (p=0.018), “Split” (p=0.009), and “Circle 2” (p=0.05) screening categories.

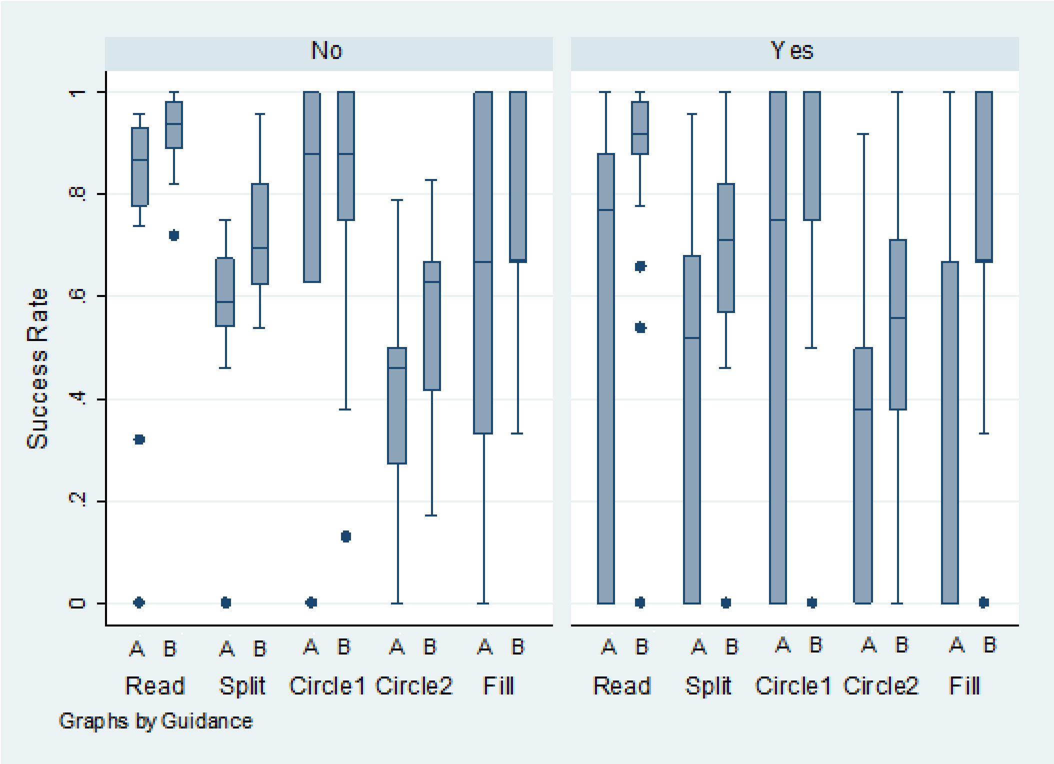

Figure 1. Mean Success Rate on Screening A and B of Students with and without Guidance

Table 8. The Mean Success Rate Difference on Each of the Five Areas of the (A) and (B) Screening for Students without Guidance

Paired Samples Test		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Read A-B	-.144	.215	.054	-.258	-.029	-2.67	15	.018
Pair 2	Split A-B	-.167	.222	.055	-.285	-.048	-2.99	15	.009
Pair 3	Circle1 A-B	.000	.328	.082	-.174	.175	.000	15	1.00
Pair 4	Circle2 A-B	-.145	.273	.068	-.292	.000	-2.13	15	.050
Pair 5	Fill A-B	-.064	.251	.063	-.197	.070	-1.02	15	.325

Testing the improvement of the achievement in the two screening tests of the students that were supported by their teachers, the paired sample test shows that there is a statistically significant improvement in all screening sectors, with significance levels of $p<.01$ in all cases, between screening A and B (Tab.9).

Table 9. The Mean Success Rate Difference on Each of the Five Areas of the (A) and (B) Screening for Students with Guidance

Paired Samples Test		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Read A-B	-.227	.496	.063	-.353	-.101	-3.60	61	.001
Pair 2	Split A-B	-.219	.369	.046	-.313	-.125	-4.68	61	.000
Pair 3	Circle1 A-B	-.240	.507	.064	-.368	-.111	-3.73	61	.000
Pair 4	Circle2 A-B	-.180	.357	.045	-.271	-.089	-3.98	61	.000
Pair 5	Fill A-B	-.209	.499	.063	-.336	-.083	-3.31	61	.002

4. Discussion

One of the main issues, that still remains unresolved in the research of accessibility and effectiveness of digital devices relative to the difficulties of reading and writing, is the role of the language content of these apps in agreement with Comer, (2012) and Rello & Baeza-Yates (2014). Aiming to contribute to the study of this issue, the findings of this study signalize the strong significance of the language content within the context of iLearnRW software that was applied.

In line with the studies of Grajo & Candler (2014) and Yussof, Abas & Paris (2014), this study also elucidate that the components of the language content should be considered as prerequisites which an intervention software should meet. Hence, the software can contribute to the users' need in overcoming their difficulties in reading and writing as well as to be engaged and participate in the learning process.

Specifically, the findings reveal that:

(i) The strong constructional link between the profile entries of the sample, the language content of the tasks of the screening test as well of the games and its effectiveness in the students' performance were premised on the first fundamental finding.

(ii) The non-significant correlation of the quantity of the language content and the time playing with the students' performance in the software's activities was an essential finding.

(i) The evidence of the teacher's guidance and educational instructions' value to the students' improvement was recorded as a core finding.

Seeking the best understanding of the significance of those findings, a detailed analysis of the research questions posed, would contribute to the discussion, as following:

- In regard to the questions related to the linguistic/learning profile of dyslexia:

The most common difficulties recorded in the user profiles were related to the categories of syllable division, sound similarity between vowels and consonants, and inflectional suffixes and prefixes (Torgesen, 2005; Vellutino et al., 2004). Importantly, these skills were improved at the final testing in both groups of students, but mostly in those guided by their teachers.

Investigating the pedagogical effects of the above connection it becomes necessary to identify the underling construction of linkage between all the screening tasks and the profile's language categories: the task of "Read" (read the words) included the profile's categories of discrimination of letter (visual) and phonemes (sound) similarities, and grapheme-phoneme correspondence in word level; the task of "Split" (split the words into syllables) was referred in the identification and division of syllables; the tasks of "Circle 1" (circle word prefixes) and "Circle 2" (circle word suffixes) involved the categories of prefixing and suffixing; the task of "Fill" (choose the best fitting word in the phrase, applying the knowledge according to the context) depended on the category of utilizing the function words of grammar.

Regarding the underling cognitive mechanisms, (i) the task "Read", was seeking to address the skills of phonemic awareness, knowledge of letters sounds and names, and reading fluency similarly to the notifications of Compton et al. (2010) and Zumeta et al., (2012), (ii) the tasks "Split" and "Circle 1 & 2" addressed the skills of applying grammatical rules, specifically with concern to the syllabification and prefixing and suffixing as confirmed by van den Broek et al (2005) and finally, (iii) the task "Fill the gap" addressed the skill of reading comprehension likewise Papadopoulos et al (2014).

The description of the above correspondences draws the role of the iLearnRW, as an effective intervention chain-link. That is, specific language areas of the user's profile are tested through the screening test revealing respective difficulties. Correspondingly, these difficulties define the treatment through the software learning activities that are customized and personalized to each user's profile.

In accordance with the Nilsson's documentation (2008), we expected the strong connection between well implemented language components and particular activities to have an effectiveness to the users' performance; that was confirmed by the higher success rate which was recorded in the above games for both groups of users with and without guidance.

- In regard to the questions related to the usability and operation of the iLearnRW software:

The results suggest that the degree in which the sample showed preference to particular activities ("Moving Pathways"), was mostly dependent on their difficulties.

In that respect, the finding indicates that the students enjoyed more playing activities with simpler linguistic content, such as letters instead of words. But, for those students, the interesting mechanics and attractive audiovisual content of the games were the fundamental key for engagement, interest, and motivation in running the games.

Interestingly, these findings are consistent to the results of the study of the National Reading Panel & National Institute of Child Health and Human Development (NRP-NICHD, 2000, (p.2-6), indicating that a complete reading program should involve not only a language-based training but aspects such as motivation, engagement, interest and attention to reading.

A core hypothesis was that it would be an association between the means of the total number of word played, the total number of applications used in the whole sample, and the mean success rate of each student.

Under the above condition, the students should be improved as they kept on playing, or vice versa, in sense that with high success rates they would feel rewarded and therefore motivated to continue playing.

However, these assumptions are not met after the analysis: no statistical significance was recorded, indicating that the success rate was not affected by the time of playing nor the amount of used words nor the total number of applied activities.

The ineffective contribution of words is similarly observed by De Santana et al. (2012), Houts et al. (2006), and Berget et al. (2016), according to which people with dyslexia tend to pay more attention to images than words.

In general, we could assume that the motivation for learning was independent of the quantity of the linguistic material and/or games used and/or time playing.

- In regard to the questions related to the effect and effectiveness of the iLearnRW software on enhancing learning experience:

It is well documented (Lovett et al., 2014; Guskey & Yoon, 2009; Yoon et al., 2007) that interactive work between student and teacher, sufficient involvement of a well-trained teacher or expert, and individualized in-school instructional guidance establish an effective intervention program for students with dyslexia. Complementing this aspect, the present findings reveal that the students who received specific guidance by their teachers obtained higher success rates in most of the games compared to the students without any guidance. The students' high performances in iLearnRW reveal that well-adjusted learning and teaching components are the key for students to overcome their difficulties through the implementation of the games.

Respectively, the key factor with significant influence in estimating the success rate in particular learning skills, both in the games and the screening test, was the guidance students received or not by their teachers (special educators).

The support and guidance given by the teachers was targeted to enhance the best learning experience of the students. Based on the aspect that the students with dyslexia meet multifaceted difficulties, the teachers' assistance was tailored to individual learning needs. This assistance, integrating the learning content, presented in more sensible and comprehensible order the decision of playing particular activities in sequence and the combination of selected activities that could keep students in working.

This finding could lead to the argument that when students with dyslexia do not receive any support while (i) encountering a difficulty, (ii) not understanding a part of the content of the game, and (iii) getting bored with it, are more prone to easily interrupt or replace or abandon any game. Similarly, without any support, the students are possibly unable to transfer or generalize any acquired knowledge from one game to another.

The outcomes of the final implementation of the screening test are coming to confirm the finding that those students who worked under the guidance of their teachers improved their achievement in all screening tasks ("Read", "Split", "Circle 1&2", and "Fill", $p<0,005$), while these who worked without any guidance achieved a statistically significant rise only in three screening tasks: "Read", "Split", and "Circle 1", $p=0,05$).

To sum up, the above findings emphasize the value of the language content integrated in the profile. They also highlight the specific domains of the difficulties that students with dyslexia usually meet. Moreover they provide an assessment as accurate as indicative for an effective, tailored and personalized intervention given by the learning games.

Furthermore, they suggest that the best elaboration of that language content in the context of an in-guided implementation of the games has a great effectiveness in the students' performance and increase their engagement in playing serious learning games.

4.1 Limitations and Future Directions

Particular limitations could be stated in regard to the likelihood that confounding factors could affect the results, such as (i) the teachers' assistance, and (ii) the different space (school/home). Thus, the impact of the software on students may vary as students with severe learning difficulties need longitudinal interventions to explore and conceive a great amount of the language material and particular games.

However, a useful recommendation could be considered the iLearnRW or similar software to be integrated in the educational system following modifications to adjust to the curriculum of the school.

Furthermore, another option to be explored, is the use of distance learning techniques, such Interactive Videoconferencing (Anastasiades et al., 2010), where experts can support and provide guidance to teachers, students and families on using such a software system.

5. Conclusions

In a broader context of the analysis of the current research data, the findings initially highlighted the language content and pedagogical principles as a fundamental component of learning technologies. Essentially, the findings showed that students with specific difficulties in reading and writing are well motivated working within an intelligent learning software environment.

Furthermore, the current study based on the Greek language content and aiming students with learning

disabilities is one of a few studies (Papadopoulos et al., 2014; Toki et al, 2012), contributed towards the demand for a better understanding of the pedagogical outcomes using technology from different regions at primary school as it has being well documented (Perez-Sanagustin, 2016).
Overall, what is important to be kept in mind is:
The main purpose of an intelligent learning environment intended for students with learning disabilities must be to encourage pleasant and effective learning. Some students may never master the necessary mechanisms for effective reading, but they should have access to literacy and communication that does not necessarily rely on these mechanisms.

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Conflict of interest
Neither of the authors had no conflicts of interest during the development and publication of this paper.

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Appendix

Table A

Games and Language Difficulties and Learning Outcomes

A/A	Games	Language areas	Learning outcomes
1	Moving Pathways	-Phonemes: vowels - consonants -Letter (visual) similarity -Grapheme-phoneme correspondence -Word recognition: sight/irregular words	-Identify similar letter shapes -Identify grapheme-phoneme correspondences on a (multisyllable) word -Identify word patterns (sight words, irregular words) -Acquire regularity in phonemes/letters alternation (word level)
2	Whack a mole	-Letter (visual) similarity -Grapheme-phoneme correspondence -Word recognition: sight/irregular words -Derivational suffixing -Inflectional suffixing	-Identify similar letter shapes -Discriminate letters that look similar -Identify grapheme-to-phoneme correspondences on a grapheme-phoneme and word level -Identify word patterns -Perform word decomposition and identify morphemes (suffixes, prefixes)
3	Mail sorter	-Letter (visual) similarity -Grapheme-phoneme correspondence -Word recognition: sight/irregular words -Derivational suffixing -Inflectional suffixing -Prefixing	-Identify similar letter shapes -Identify grapheme-to-phoneme correspondences on a grapheme-phoneme and word level -Identify word patterns -Perform word decomposition and identify morphemes (suffixes, prefixes)
4	Endless Runner	-Phonemes: vowels -Phonemes: consonants -Word recognition: sight/irregular words	-Automate phoneme-grapheme correspondence -Automate letter shapes -Automate common morphemes (suffixes and prefixes) in different words
5	Harvest	-Phonemes: vowels -Grapheme-phoneme correspondence -Syllable division -Grammar: function words -Derivational suffixing -Inflectional suffixing -Prefixing	-Identify phonetic similarities (long vowels, consonant clusters) -Syllabify -Identify common phonetic patterns in written words -Identify common morphemes (prefixes and suffixes) in different words -Classify words grammatically
6	Train Dispatcher	-Word recognition: sight/irregular words -Syllable division -Grammar: function words -Derivational suffixing -Inflectional suffixing -Prefixing	-Identify word pattern -Identify word decomposition and identify morphemes (suffixes and prefixes) -Identify and decode sight and irregular words -Segment and blend words -Automate grammar rules
7	Mail Delivery	-Syllable division -Derivational suffixing -Inflectional suffixing -Prefixing -Grammar: function words	-Compose words from letters or syllables -Identify common suffixes / prefixes automatically and use them to create words -Build words from stems and affixes -Build phrases and sentences -Process function words and their role in a sentence
8	Junkyard	-Syllable division -Derivational suffixing -Prefixing	-Syllabify -Perform word decomposition and process inflectional and derivational suffixes -Identify different morphemes (suffixes and prefixes) in sight and irregular words -Build words from affixes and suffixes
9	Serenade Hero	-Grammar: function words -Derivational suffixing -Inflectional suffixing -Prefixing	-Build words from stems and affixes -Build phrases and sentences -Process function words and their role in a sentence