Phonological Awareness Software for Dyslexic Children

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Abstract. The improvement in the ability to process sounds in oral language (phonological awareness) through the contribution of Information and Communication Technologies (ICT) is reported by many researchers. However, deficits in phonological awareness may persist despite intervention. There is increasing research interest on how educational technology may assist the development of this critical ability. In this article we present the 'Phonological Awareness Educational Software' (PHAES) which is a hypermedia application for helping dyslexic readers, using phonological awareness training. The PHAES learning activities use the small units of language (phoneme/grapheme) presented alone, at the word and sentence level, both in spoken and written format. This work was based on the theoretical conceptualization of children's reading difficulties originating in the phonological domain and aimed to develop a useful tool to assist teaching efforts in helping dyslexic readers. The empirical results show that PHAES is a user friendly educational application and has the potential to set an example for future research in the area.

Keywords: Dyslexia, Phonological awareness, Educational software

Introduction

Helping children with learning disabilities has been a major concern of educational practice. Recent developments utilize ICT applications in order to support the learning needs of children with difficulties in reading and spelling. According to a recent definition "dyslexia is evident when accurate and fluent reading and/or spelling develops very incompletely or with great difficulty. This focuses on literacy learning at the 'word level' and implies that the problem is severe and persistent despite appropriate learning opportunities" (British Psychological Society, 1999). Children who encounter difficulties to acquire literacy skills are characterized by deficits in phonological awareness (see Vellutino, Fletcher, Snowling & Scanlon, 2004, for a review). Phonological awareness is the ability to manipulate sounds in oral language. Children who enter school with accurate phonological representations are more able to match the sounds with the corresponding letters and these will acquire the alphabetic principle easily and with little effort. Phonological deficits on the other hand will lead to reading difficulties. Children with phonological deficits have difficulties in grapheme-phoneme correspondence. Therefore, literacy develops slowly and with great effort. This leads to frustration, discouragement and accumulating difficulties throughout their school life (Stanovich, 1986).

Early intervention using phonological awareness training has been shown to help the development of literacy skills (e.g. Fielding-Barnsley, 2006; Lundberg, 2009). Intervention programs aiming to address the phonological difficulties of poor readers have successfully proved that it is an essential component of a successful reading intervention program (e.g.

Hatcher, Hulme & Ellis, 1994; Lovett, 2000; Reason & Morfidi, 2001). Along this line the present work is aiming to develop a computer-based approach to assist teaching efforts for the improvement of phonological and early literacy skills. Thus, it contributes to the research in this area and sets an example for future research. In the present work the aim is twofold. First, to describe the educational hypermedia application and second, to report how dyslexic readers interacted with it when running the program.

Helping dyslexic children using computer-based intervention programs

Although dyslexia has a genetic origin, the related deficits can be tackled through individualized intervention focusing on phonological skills training. However, the cost of such intervention is high. A computer-based intervention contributes to the development of phonological awareness and the improvement of reading and spelling minimizing teacher interference. This means that the implementation of Information and Communications Technology (ICT) will provide us with a powerful tool which will serve our purposes at a significantly lower cost. It has been suggested that computer–based phonological training has the same efficacy as traditional training. However, the latter approach requires much more training and consequently more time and money (Olson, 2005; Olson et al., 1997).

ICT may be used in conjunction with traditional teaching methods. It motivates students to engage in active learning and minimizes failure and disappointment. Some of the advantages in utilizing ICT for assisting children's reading are reported in the literature. ICT can be used as an intervention tool, as well as an assessment tool (Singleton, 1991), and enable teachers to form an individualized educational programs (Hauser & Malouf, 1996; Klems et al., 2006; Magnan & Ecalle, 2006). A longitudinal study using the computer-based cognitive assessment system *CoPS*, showed that it provides a highly satisfactory prediction of poor reading skills of children at risk of reading failure. Thus, computer-based cognitive profiling is able to facilitate differentiated teaching of early reading (Singleton, Thomas & Horne, 2000).

Interactive multimedia applications increase, motivate and encourage the active role of children by using multisensory channels. Multimedia applications not only allow, but also reinforce the bimodal presentation of information via visual and auditory channels. Thus, information processing is accelerated and mnemonic recall is facilitated. The deficits are confronted and children's self-esteem and motivation is getting increased because they do not get disappointed or quit their efforts (Lee & Vail, 2005). ICT applications using interactive tasks have been shown to have positive impact on the acquisition of oral and written language. Several studies provide converging evidence that computer-based reading intervention can enhance children's decoding and comprehension skills (Lynch, Fawcett & Nicolson, 2000; Olson & Wise, 2006; Singleton, 1991; Torgesen, 1986).

Several studies have shown that a computer-based literacy support system (the Reader's Interactive Teaching Assistant, RITA), which involves activities with sounds, words, onset and rime, reading, spelling and comprehension, has shown that it can support students with reading difficulties who experience failure even in secondary school. The program evaluation showed that apart from being economically effective, improvements were made in reading standard scores, reading speed, accuracy and comprehension (Lynch et al., 2000; Nicolson, Fawcett & Nicolson, 2000; Roderick, Fawcett & Nicolson, 2000).

Van Daal and Reitsma (2000) conducted two pilot studies based on multimedia computer program in order to examine its efficacy on training phonological skills. The first study, which concerns the use of the program in kindergarten children, found that kindergarten readers learned in significantly less time as much as they would learn after formal reading instruction in the classroom. In the second study, students with reading difficulties practised spelling with computer. The most important finding in this study was that children with low motivation and feelings of uncertainty regarding their learning capabilities showed positive response during classroom instruction. They gained the expected six months progress according to the norms. The continuous feedback and the well structured computer program enhanced their motivation.

After a decade-long investigation of computer-based remediation of phonemic awareness two computer programs supplementing classroom instruction have been developed and tested. These are the Accurate Reading in Context (ARC) and Phonological Analysis (PA). In the first one, students spend 22 hours reading stories with speech recognition. The second one provides explicit instruction of speech articulation in addition to animated storybooks and word-level analysis. A trained teacher or instructional aide motivate and monitor young students while interacting with the program. A large study with elementary school students and matched control groups, found that students who participated in the programs demonstrated significant gains in phonemic awareness, decoding, and word reading which were maintained at a 1- and 2-year follow-up (Wise, Ring & Olson, 2000). Both programs produced similar results. The authors suggest that increased facilitated time spent reading–not the specific type of training–was the key to success and that additional time and transfer activities would increase performance and retention of gains (Olson & Wise, 2006).

The SeeWord software was designed in order to examine the extent to which the reading performance of dyslexics may be influenced by facilities that configure the writing environment: fonts, size and type of letters, spaces and the auditory feedback through software. Their research examined the contribution of ICT to help alleviating dyslexic children's difficulties. The students with dyslexia were assisted in reading and phonological awareness. The results showed that working with a computer not only facilitates the labour of practice, but it also tends to be their own spontaneous choice because it is less stressful and at the same time more efficient (Gregor et al., 2003; Pedler, 2001).

Similarly, the evaluation of LEXY revealed that the treatment which was computer-based and focused on learning to recognise and use the phonological and morphological structure of Dutch words found large, generalized treatment effects on reading accuracy, reading rate, and spelling skills. Following the treatment, participants attained an average level of reading accuracy and spelling (Tijms, 2004; Tijms & Hoeks, 2005).

In their study, Lewandowski, Begeny, and Rogers (2006) used a very simple (no graphics or animation) computer-based reading program along with a live tutor. They found that 66 third-grade students' word recognition, reading speed, and accuracy scores improved similarly, whereas students' scores in a no-help condition did not improve. This study strengthens the validity of an earlier one in which Montali and Lewandowski (1996) showed that audio plus visual input with computer-based practice helps elementary readers to perform as well as average achieving peers on word recognition and accuracy tests.

Magnan and Ecalle (2006) used an audiovisual program to evaluate the effects of training auditory discrimination and phonological skills of dyslexic children and suggested that such

programs enable a stable correspondence between phonemic and graphemic elements of language. Phonological representations could be specified by training both phonological and orthographic units. A computer-based remedial program facilitated the mappings between these two units.

The present research is aiming to develop a hypermedia application to aid children's literacy skills through phonological training. The theory suggests that phonological deficits constitute a core feature of dyslexia. Early identification of phonological deficits may prevent later difficulties in reading and writing and a phonological approach to teaching can be beneficial (e.g. Lundberg, 1995, 2009; Snowling, 2000, 2001). The present research builds on the body of research highlighting the demand for phonological training, and incorporates the elements of a successful phonological training program into a software application.

PHAES, Phonological Awareness Educational Software

Phonological Awareness Educational Software (PHAES) has been designed following Mayer's perspective towards the design of multimedia and hypermedia educational software. He postulates that approaches to develop education hypermedia applications serve a double goal, "a theoretical goal of contributing to a cognitive theory of how students learn from multiple representations and a practical goal of contributing to the design of effective multimedia instruction have to be set in order to reach positive learning outcomes" (Mayer, 2002, p. 69). Learning is achieved when learners engage in active processing within the visual-pictorial channel and the auditory-verbal channel. In contrast to the traditional attitude of education according to which verbal modes of instruction have a significant role, Mayer examines how adding visual modes of instruction to verbal ones can result in learners' deeper understanding.

The software environment was designed considering early literacy development and the intention to be attractive to children at this young age. All graphics were simple and amusing. Every screen included only the appropriate data for the particular learning activity, avoiding cognitive overload. Navigation was simple and user friendly. The child was free to navigate and choose any activity at will. The activities were presented in groups depending on their level of difficulty. The proposed hypermedia application has been developed using Macromedia Flash MX Professional 2004, and can be run on any computer with no particular specifications.

PHAES consists of four stages. The theme of the four seasons was used to set the context of the application because young children are very familiar with it. Figure 1 shows the structure of PHAES.

PHAES demands only basic computer skills. The way it could be used depends on the particular teaching goals that the teacher aims to achieve and the child's literacy level. In practice, it can be used either with the presence of an instructor, or by the student (alternatively group of students) alone. The software can be used by the educator in conjunction with traditional teaching methods. In this case, the student is mainly responsible for the operation of the computer and the educator acts as a moderator. Practice at home with the parent operating as a moderator is also feasible. The software can be used straight away, without the presence of an adult, as it contains clear and easy instructions for inexperienced users. It can be used in the class or out of it. Presence of the teacher is

optional. The age group the application is addressed cannot be strictly defined. It may be used to enhance learning at the early stages of literacy acquisition or support students who have been taught reading without success. This means that PHAES can be used by different age groups, depending on the child's learning experiences or difficulties. Moreover, it can be used to support early reading skills in the class, as a supportive tool for teaching.

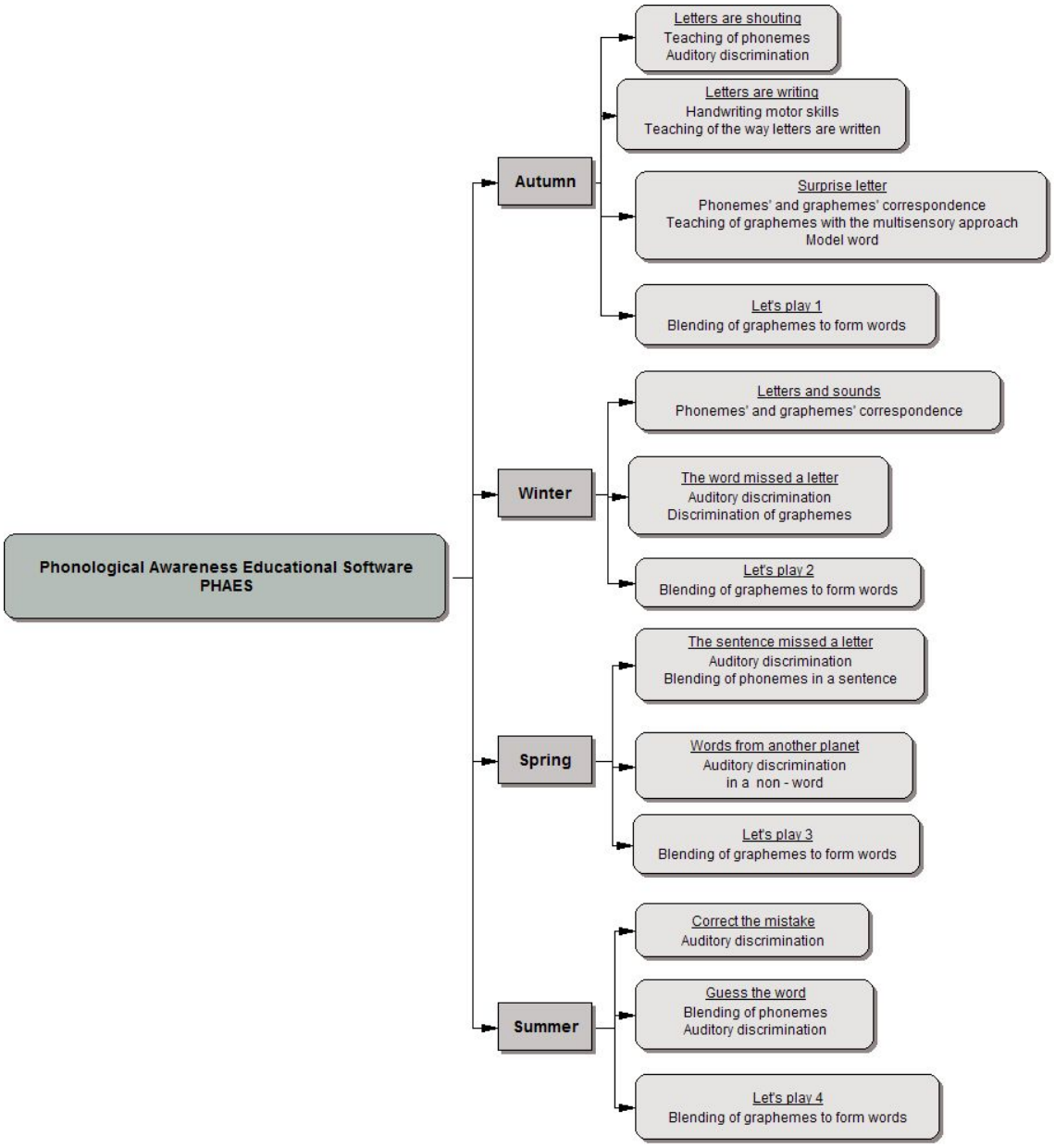

Figure 1. The structure of PHAES

Stage 1: Autumn

The aim of stage 1 activities is practice with letter-sound correspondences. It presents the letter sounds and their written forms so that the child has a reference point to turn to every time s/he comes up with a difficulty or whenever s/he forgets a grapheme or a phoneme. This stage is particularly useful for a child who confuses graphemes and phonemes and has difficulty in corresponding graphemes with phonemes and vice versa. It gives the opportunity not only to go back and check this knowledge, but also to choose the exact

grapheme or phoneme that causes them extra difficulty. The alphabet is being presented in a way that forms cognitive schemata which are easy to learn and memorize. This is achieved by adopting a multisensory approach (Mayer, 2002). 'Autumn' includes three separate activities.

Activity 1.1: 'Letters are shouting': teaching phonemes – auditory discrimination of phonemes

In this activity the letters of the alphabet are presented on a simulated keyboard and the child can, on a key press, hear the phoneme and see the way it is articulated through a video in which a real human mouth is presented pronouncing each phoneme separately (Figure 2).

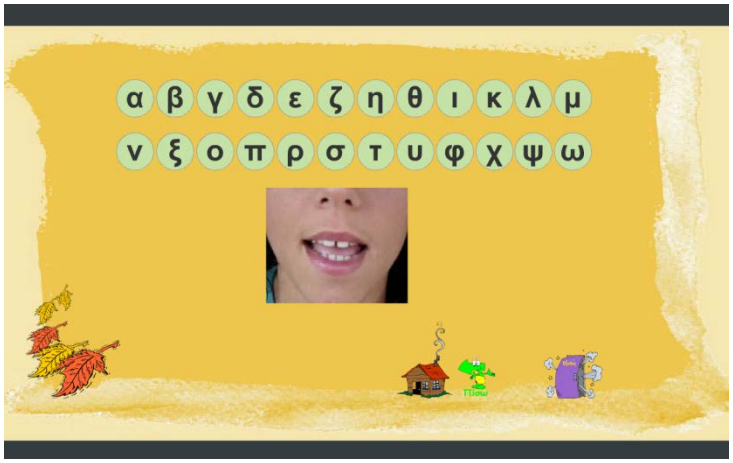

Figure 2. 'Letters are shouting'

Activity 1.2: Letters are writing: Handwriting motor skills - teaching of the way letters are written

In this activity, letters are divided into minuscule and capitals. The child can choose to practice the one that is troubling him/her each time. By choosing a letter from the simulated keyboard they can see the grapheme in a relatively big size on the screen. At the same time, they can see a dot moving along the letter, following the route they must take in order to draw the letter on their paper with a pencil. This dot is aiming to motivate the child to 'follow the same route' which stands for the correct orientation of the letter (Figure 3). This activity is suggested for improving spelling as well.

Figure 3. The simulated keyboard and the grapheme

Activity 1.3: 'Surprise letter': involves the teaching of grapheme – phoneme correspondences with the multisensory approach and contact with the word

In this activity the letters of the alphabet are presented followed by the sounds, their written forms, guidelines for writing, and letter presentation within words. All the necessary information about the minuscule and capital letters is presented. The child can choose any letter and see how the grapheme is written as well as its correspondence with the correct phoneme. They can also hear a word, or read a word starting with this letter and associate the grapheme with a relevant image (e.g. /x/ /ˋxaϱakas/ (ruler) (Figure 4), /ɣraˋvata/ (tie), /**i**ˋpokabos/ (hippocampus), /ˋ**ð**romos/ (road)) (Figure 5).

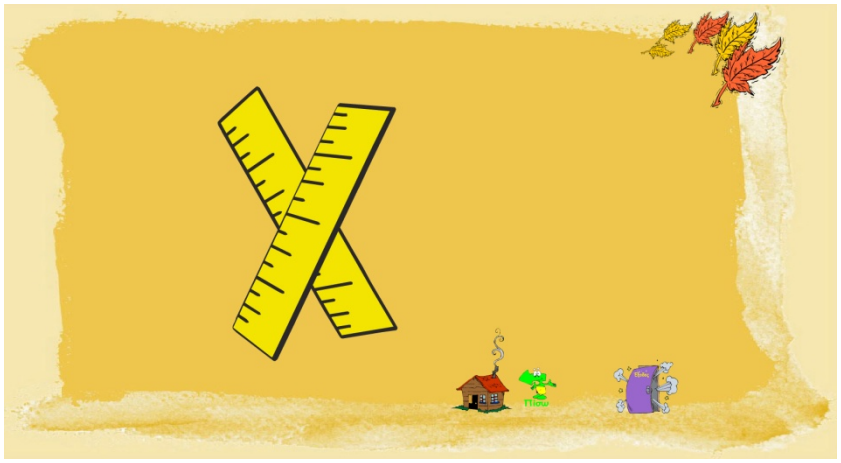

Figure 4. Representation of grapheme /x/ (/ˋxarakas/, (ruler))

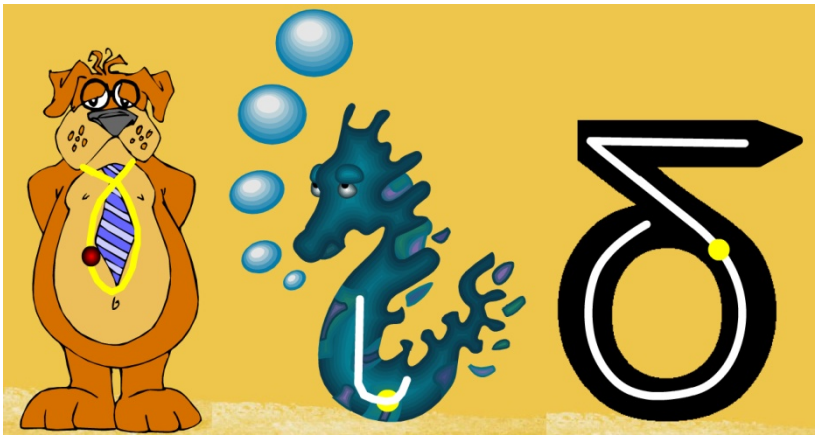

Figure 5. The activity 'surprise letter' (/ɣraˋvata/ (tie), /iˋpokabos/ (hippocampus), /ˋðromos/ (road))

Activity 1.4: 'Let's play 1': Forming words

The game is given as a reward at the end of each 'season' differentiating the level of difficulty (*let's play 1, 2, 3, 4*, see below). At the first stage of the game, the words come from the vocabulary of the first grade of the Greek primary school books and the vocabulary children of this age tend to use in their everyday life. The child is asked to play with the letters and form common words. The words consist of two syllables with a CVCV syllabic structure (C: consonant, V: vowel) e.g. /maˋma/ (mother), /ˋɣala/ (milk), /ˋɣata/ (cat) (Figure 6).

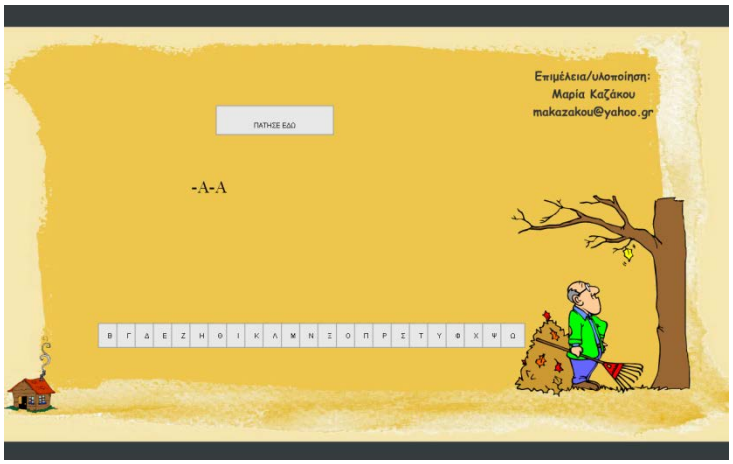

Figure 6. 'Let's play 1'

Stage 2: Winter

In 'winter', the child can practice letter – sound correspondences alone or embedded in words. This stage includes three activities.

Activity 2.1: 'Letters and sounds': phonemes and graphemes correspondence

The purpose of this activity is to find which grapheme represents each phoneme in a playful way. There is a bar on the screen with the 24 letters of the Greek alphabet. There are 24 buttons, followed by a megaphone, each one corresponding to a phoneme. The child must click on the megaphone-button in order to listen to the phoneme and then choose the correct grapheme that corresponds to this sound (Figure 7). The activity is completed when all 24 megaphone-buttons have been matched to the corresponding letter. The child may repeat the same process both for minuscule and capital letters and then choose which one of the two letter categories may wish to work with.

Figure 7. A screen from the 'letters and sounds' activity

Activity 2.2: 'The word missed a letter': auditory discrimination

In this activity the child is asked to choose the correct sound, in order to complete a word, among three alternatives. Both the word and the phonemes are presented visually and auditory (Figure 8).

Figure 8. The activity of phonemic blending

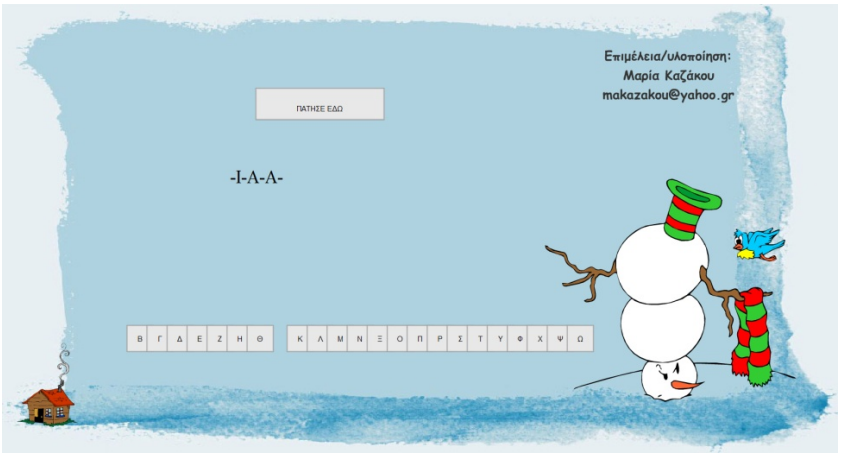

Figure 9. Blending of graphemes to form words

Activity 2.3: 'Let's play 2': Forming words

The child is asked to play with the letters and form common words. All the words of the game come from the basic vocabulary of the second grade of the Greek primary school books and consist of three syllables with a CVCVCV syllabic structure e.g. /pa`tata/ (potato), /ka`ravi/ (ship), /le`moni/ (lemon), /`maθima/ (lesson), /ka`pelo/ (hat) (Figure 9).

Stage 3: Spring

Till the previous stage, the student came up with separate phonemes, graphemes and words. In this activity s/he deals with sentences. Gradually, the level of difficulty is being increased. 'Spring' contains three activities.

Activity 3.1: 'The sentence missed a letter': auditory discrimination – blending of phonemes within a sentence

The aim of this activity is training with graphemes and phonemes that are particularly confusing e.g. /f/-/v/, /θ/-/ð/. A sentence is presented both visually and orally. The child is able to choose either the visual or the oral representation, or both. Sometimes the sentence is correct, while other times it is wrong. Initially, they must choose whether it is wrong or right (Figure 10). Then, if the sentence is wrong, there is a choice to amend the sentence by choosing the appropriate phoneme among three alternatives (Figure 11).

Figure 10. 'The sentence missed a letter'

Figure 11. The three alternatives graphemes

Activity 3.2: Words from a strange planet: auditory discrimination within a word using nonwords

In order to prevent the possibility of guessing the right word because of its meaning (semantic identity) nonwords have been chosen. The nonwords follow the morphological and phonological rules of a language but lack meaning. A couple of either similar or identical nonwords are presented auditorily. The child must find whether there is any phonological difference between them (Figure 12). In a second level, the activity proceeds beyond the decision task. The child is asked to identify the graphical representation of a nonword set that matches the auditory (Figure 13).

Figure 12. Words of a strange planet

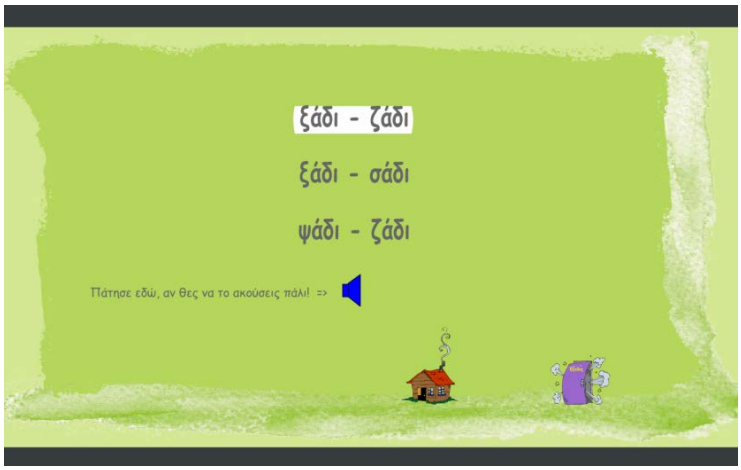

Figure 13. Identification of the graphical representation of a nonword set

Figure 14. 'Let's play 3'

Activity 3.3: 'Let's play 3': Forming words

The child is asked to play with the letters and form common words. All the words of this game came from the basic vocabulary of the second and third grade of the Greek primary school books as well as from the vocabulary of their everyday communication. It consists of words with a CVCV syllabic structure, which also include double consonants (ξ /ks/, ψ /ps/) and diphthongs (αυ /av/ and αι /e/) e.g. /`avrio/ (tomorrow), /`ksero/ (know) (Figure 14).

Stage 4: Summer

In order to deal with the activities of 'summer' the young students must be able to manipulate graphemes and phonemes. The level of difficulty here is higher than before. 'Summer' has three different activities.

Activity 4.1: 'Correct the mistake': auditory discrimination

A sentence, which might have a phonological mistake in one of its words, is presented auditorily. The child has to decide if this presented sentence is wrong or right (Figure 15). If it is wrong, then there is a choice to amend the sentence by choosing the appropriate word among three alternatives (Figure 16). In the end, the correct sentence is presented with emphasis on the selected word (Figure 17).

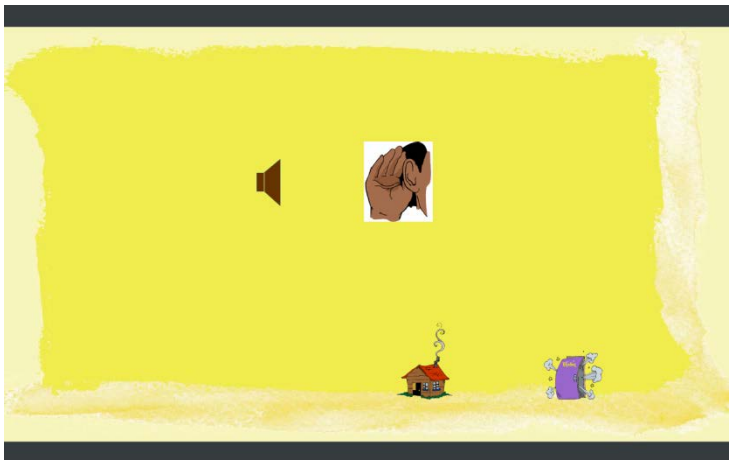

Figure 15. 'Correct the mistake'

Figure 16. The three alternatives words

Figure 17: The mistake was found

Activity 4.2: 'Guess the word': phonemic blending – auditory discrimination

Reading demands translation of graphemes into phonemes whereas writing involves presenting phonemes into their corresponding graphemes. This activity provides the opportunity to practice both. First, the child is watching a video with a real human mouth

pronouncing the separate phonemes of a word (e.g. /**n**/-/i/-/s/-/i/) (Figure 18). Then, three words are presented on the screen (Figure 19). All three words have phonological similarities that confuse individuals with phonological deficits (e.g. /**m**/-/i/-/s/-/i/, /**n**/-/i/-/s/-/i/, /**l**/-/i/-/s/-/i/). The child is asked to choose the word that matches the one presented broken down into phonemes. After providing the correct answer, the construction of the right word appears on the screen (Figure 20).

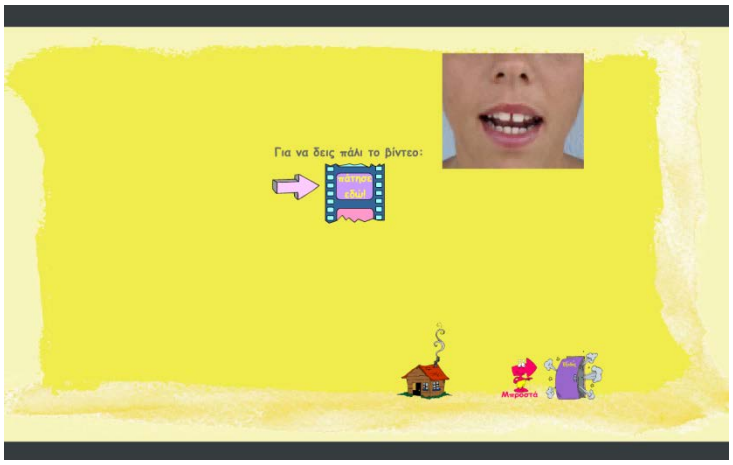

Figure 18. The activity 'guess the word'

Figure 19. The three words presented on the screen (/ni`si/ island)

Figure 20. The construction of the right word on the screen

Activity 4.3: 'Let's play 4': Forming words

The words of this game came from the vocabulary of the second and third grade of the Greek primary school books as well as from a commonly used vocabulary. In particular, it consists of multisyllabic words, consonant clusters e.g. /`stroma/ (mattress), /polikati`cia/ (block of flats) (Figure 21). The child is asked to play with the letters and form common words.

Figure 21. 'Let's play 4'

Empirical study

The second aim of the current work has been to report how dyslexic readers may interact with the educational hypermedia application. Aiming to achieve this goal we asked

1. whether the program is user friendly and could be used without the instructions of an adult
2. the level of success in completing the program
3. the level of satisfaction from the use of the particular software, that is to identify those activities that children may find challenging or enjoyable.

Participants

Five primary school students participated in the present research. They were attending school as follows: a girl and a boy in the second grade (7 year olds), two girls in the third grade (8 year olds) and a boy in the fourth grade (9 year old). Three of them were receiving remedial teaching at school. One of them had a diagnosis from an authorized diagnostic unit. The rest had clear symptoms of dyslexia according to their teachers. All the participants agreed to take part in the study with enthusiasm, especially when they were informed that they had to use computers.

Procedure

In order to examine whether PHAES was user friendly, the instructions clear and easy to follow, and the activities at an appropriate difficulty level, each stage was initially trialed on two children. Through this process problems or omissions were determined. Thus, two different types of instructions were included. The first type should address to parents and

educators, giving general information about the application. The second should address to students, explaining how to navigate in the application. After ensuring that the goals had been achieved, the design of the each stage was completed. Then the five students run PHAES. The students' attitude towards the application was positive and enthusiastic. During initial assessment those letters that the five children encountered difficulty with had been identified. Therefore, they practiced only the letters they had not been able to recognize in the initial assessment. Thus, each student practiced 5 to 10 letters. PHAES was administered in a quiet place either at home or at school. For two of them the procedure took place in their school classroom, while for the rest it took place at home. During the PHAES sessions the researcher observed each student and took notes of the information she intended to collect: time needed to run the program, level of completion, whether students were able to run the software alone, whether they needed more information, and which activities they found more interesting.

In order to be able to know whether the computer use offered an extra benefit to dyslexics, the researcher presented a sample of the activities used in PHAES by conventional teaching methods. For example, the letters were presented on cards, the words or sentences were presented on sheets followed by oral presentation. Our intention was not to compare the two different methods and find the most efficient (this would demand a different study), but to allow some exposure to both means in order to let them develop their preference.

Each student worked with the application for approximately two hours, completing all the thirteen activities successfully for the letters they had difficulty with. Since the application offers an extended data base covering all graphemes and phonemes, the students had the opportunity to navigate in the application, choosing the activities they preferred to deal with according to their difficulties. The letters they did not encounter difficulties had been excluded. During these two hours, the students managed to run all of the thirteen activities.

Results

All the students succeeded in running the program independently and with enthusiasm. They were able to run the program easily and effortlessly from the first session, while the researcher intervened only on technical issues, such as the increase of sound volume. Usually, they seemed very impatient about whether there would be another meeting so that they could 'play' on the computer. Table 1 shows the activities the students completed or quitted, the ones they found challenging and their preference for some of them.

The activities were successfully completed by all students. When asked whether they found any activity significantly difficult, two of them reported the activity 'guess the word' from the summer part, which demands blending separate phonemes in order to form a word, perhaps explained by the nature of their difficulties (see Figures 18, 19, 20). All students responded with great enthusiasm to the activity 'surprise letter' from the autumn part, perhaps because of the alternative method used to supply the graphemes (see Figures 4, 5). Every time they dealt with this activity they were very excited and impatient to find out where the next letter was hidden. Similarly, they were very enthusiastic about the activity 'letters are writing' in which they were impatient to follow the same route that the dot indicated in order to design the letter in their notebooks (see Figure 3). Finally, they expressed their preference for the activity 'letters and sounds' concerning the

correspondence of letters and sounds (see Figure 7), as well as the game, which they asked to play intensively 'Let's play 1, 2, 3, 4' (see Figures 6, 9, 14). It should be mentioned that in some cases when it was difficult for the students to find the target word they did not quit the game and even if they had failed, they looked forward to proceeding to the next target word.

In sum, the students had difficulty with seven of the thirteen activities, as follows: three of them found 'Let's play 1' difficult, while two of them found 'Let's play 2', 'Let's play 3' 'Let's play 4' difficult. Concerning the rest of the activities, 'letters and sounds' presented some difficulty to three of them, while the summer activities 'Correct the mistake' and 'Guess the word' challenged one and two children, respectively. All of them showed their preference for the same eight activities: 'Letters are writing', 'Surprise letter', 'Letters and sounds', 'The word missed a letter' 'Let's play 1', 'Let's play 2', 'Let's play 3' and 'Let's play 4'. They all answered that they liked these 'games', despite the fact that some of these activities made it hard for them to complete.

Table 1. Students' responses to the different activities

	Activity	Complete	Quit	Difficult	Preference
Autumn	1.1 Letters are shouting	5/5	0/5	0/5	-
	1.2 Letters are writing	5/5	0/5	0/5	5/5
	1.3 Surprise letter	5/5	0/5	0/5	5/5
	1.4 Let's play 1	5/5	0/5	3/5	5/5
Winter	2.1 Letters and sounds	5/5	0/5	3/5	5/5
	2.2 The word missed a letter	5/5	0/5	0/5	5/5
	2.3 Let's play 2	5/5	0/5	2/5	5/5
Spring	3.1 The sentence missed a letter	5/5	0/5	0/5	-
	3.2 Words from another planet	5/5	0/5	0/5	-
	3.3 Let's play 3	5/5	0/5	2/5	5/5
Summer	4.1 Correct the mistake	5/5	0/5	1/5	-
	4.2 Guess the word	5/5	0/5	2/5	-
	4.3 Let's play 4	5/5	0/5	2/5	5/5

Number of children in each category/Number of children participating, -: no specific preference was expressed

Discussion

The aims of this study had been to develop an educational hypermedia application able to meet dyslexic children's difficulties using phonological training and explore children's interaction with it. The present work cannot be used to formulate conclusions as to whether dyslexics benefit from ICT. This would demand a long scale empirical study and report students' profile before and after experiencing PHAES. However, our approach presents some common features with findings reported in other studies. As mentioned above, PHAES deals with units of language (phoneme/grapheme, word, sentence), presented using the auditory and visual channels which is a strength when addressing the needs of young readers or readers with difficulties.

As far as the efficacy of the software is concerned, the present study showed that PHAES can be used without any difficulty or technical problems. With regard to the level of success in completing the program, it was shown that, it takes about two hours to run the activities (given that the students had difficulty with only some of the letters) and children have been able to work on them with enthusiasm. PHAES is a software application that tries not to transfer pencil and paper activities onto the computer. According to the results of the present study, PHAES seems to be a highly motivating tool for young learners with dyslexia. Moreover, it uses multisensory channels for the involved activities, exploiting dynamic multimedia elements that traditional techniques cannot incorporate, under the control of students. When they were asked about the preferred method (i.e. PHAES or the pencil and paper) they all chose the former. Children's preference for computerized approaches is described in other studies as well (Gregor et al., 2003; Lynch et al., 2000; Nicolson et al., 2000; Pedler, 2001).

With regard to the level of satisfaction, there is some variability among the activities children encountered greater difficulty. Apart from the 'let's play' activity which requires guessing, two other activities the 'correct the mistake' and 'guess the word' have been reported to present some level of difficulty. The former requires subtle sound discrimination at the sentence level, while the latter requires sound blending of easily confusable sounds. Both tasks however involve phonological processes.

ICT seem to provide an important opportunity. They relieve parents of a great emotional and financial burden considering that parents of dyslexics feel stress when they realize that they are unable to help their children on their own and it is difficult for them to afford the financial burden of continuous private education (Olson, 2005). Besides the educational effectiveness, the economical and emotional effectiveness have been shown by different studies. It has been reported that RITA offered relief to dyslexics, their homes and schools (Lynch et al., 2000; Nicolson et al., 2000). Because of the difficulty of their profession, teachers of special education usually face dead ends, as there is no specialized material to use. PHAES provides a tool not only useful for the special educator, but also for the mainstream teacher. So, even though this software has been primarily designed as an intervention tool for students with dyslexia, it can also be used as a tool for assessing and retracing children's successful mapping of letters and their corresponding sounds.

Finally, we should mention the importance of early intervention. According to Nicolson, Fawcett and Nicolson (2000) and their evaluation of early intervention using RITA, it is probably the most cost-effective method of avoiding reading failure. Despite early intervention some children will need continuous support. PHAES is designed on that basis, aiming to support children's early literacy skills at a critical age.

It is for future research to investigate how a tailor made intervention using PHAES activities can help to address the particular needs of children with phonological deficits. An experimental study employing phonological and reading measures before and after the application of intervention using PHAES is necessary. Furthermore, it is a subject of future research to investigate how the rationale underpinning the construction of PHAES can be extended to address the phonological and literacy needs of readers beyond the early stages of literacy acquisition.

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