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"Playing With Words": Effects of an Anagram Solving Game-Like Application for Primary Education Students

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Abstract

The present study reports the basic characteristics of a game-like application entitled "Playing with Words – PwW". PwW is a single-user application where a word must be guessed given an anagram of that word. Anagrams are presented from a predefined word list and users can repeatedly try to guess the word, from which the anagram is derived, by placing (drag & drop) successively the given letters into the correct orthotactic order. Each effort is assessed as either correct or incorrect, while reaction and total time consumed are also recorded. The purpose of this game is both to entertain the user and to provide teachers with a simple computerized assessment tool. Summative evaluation results, based on 76 primary schoolchildren sample, indicate that the performance of anagram solving tasks explain a significant proportion of variance in reading fluency.

Keywords: game-like application, anagram game, reading fluency, primary education

1. Introducation

Over the last few decades a growing bulk of research has addressed the issue of using recent technological advances and developments (Gee, 2003; Prensky, 2000) for educational purposes (Peterson, 2010). A major theme of both research and development work relates as to whether digital technology could be viewed as a potential for transforming teaching practices (Säljö, 2010). According to Ifenthaler (2010, p. 6) two are the main educational advantages of learning in the digital age: (a) "the independence of learning and teaching from the constraints of time and space", and (b) "the individuality of learning".

Whereas traditional teaching methods have been heavily criticised for failing in preparing students to meet the challenges of contemporary education (Hermans et al., 2008), the extensive proliferation of computers in schools is used to support the sift to implementing a more technocentric and innovating teaching approach (Drenoyianni, 1998). Current trends on digital learning research, such as **CAL** (computer assisted learning), **CBL** (computer based learning), **CSCL** (computer supported collaborative learning), **HCI** (human–computer interaction), put emphasis on scaffolding student's learning (see Säljö, 2010 for discussion). Within this framework, another form of computer-based learning approach is computer-assisted language learning (CALL), where language teaching and learning is supported by computer technology in terms of presentation, reinforcement and assessment of material to be learned, where computer applications usually include substantial interactive features. CALL incorporates two intriguing characteristics: bidirectional (interactive) learning and individualized learning (Ditcharoen et al., 2010).

Robertson and Howells (2008) however, argue that an appropriate teaching and learning approach presupposes the active engagement of the learner. Learning is not a straightforward process of retrieving stored information. It is rather a dynamic process of incorporating new information and skills into the learner's existing knowledge, not in an additive manner where new learning simply piles up (Piaget, 1971; Resnick, 2002). According to constructivism, learning is an internal process where knowledge is acquired when individuals assimilate and incorporate new experience into an existing framework (Jong et al., 2010). One way of providing children with interesting experiences is via games and simulations that constitute an important part of children's cognitive and social development (Provost, 1990).

The educational benefits of using computer games have been pointed out by many researchers. Robertson and Howells (2008) suggest that computer games provides learners a ''mental workout'', since children must develop various problem solving strategies, monitor complex tasks and engage in decision making processes (Johnson, 2005). The integration of computers and other automated technologies into mainstream teaching practice is considered to foster learning (Papastergiou, 2009; Farrell, 2003; McFarlane et al., 2002; Zea et al., 2010). The arguments for the implementation of computer game-like applications are framed in terms of motivational aspects, skill development and knowledge acquisition (Prensky, 2001; Sandford, et al., 2006). The positive effects of computer games on children's motivation towards learning are attributed to the fact that these technologies have specific features that enhance motivation to learn, such as curiosity and control over what is happening to the individual student (Jenkins, 2002). Other studies (Keller, 1992; McFarlane et al., 2002; Jenkins, 2002) offer some evidence that computer games may contribute to cognitive development of complex thinking skills related to problem solving or even facilitate language acquisition in students with learning difficulties.

Solid evidence that the integration of computers in classroom settings results to significant improvements in performance is a controversial issue (Säljö, 2010). Rather, it appears that the positive effects depend on several variables such as teacher's attitudes towards computers, which are widely acknowledged as an essential condition for the effective implementation of computer technology in schools (Woodrow, 1992). Thus, as several studies conclude, the most feasible way to ensure teachers engagement is to ensure that computer applications are relatively simple to use (Ertmer, 2001; Snoeyink & Ertmer, 2001–2002; Mahdizadeh et al., 2008).

Usability factors of educational games are not only linked to teacher's attitudes towards computers, but there are also close related to the learning process itself. Educational games urge users to follow a game scenario, observe various tasks, make real-time decisions and solve problems that arise during the game process. Thus, since usability bears upon the player's easiness of learning to play and understand a game, providing children with applications that are simple to use, we ensure that their cognitive resources are focused on the attainment of the learning objectives (Xenos et al., 2009). Frokjaer and his collaborators (2000, p. 345) describe three independent aspects that consist the definition of usability. These are **effectiveness** (e.g., *the accuracy and completeness with which users achieve certain goals*), **efficiency** (e.g., *the relation between (1) the accuracy and completeness with which users achieve certain goals and (2) the resources expended in achieving them*) and **satisfaction** (e.g., *the users' comfort with and positive attitudes towards the use of the system*). Although the notion of teaching through computer games has widely spread, since they meet the children's need to play, it is important to realize that elements related to the ease-of-use may affect this teaching practice (Hill et al., 2003). In that sense, developers should primarily focus on creating user-friendly graphical user interfaces in order to achieve the technology's optimal use, because the basic hurdle faced by young children is the process of developing the necessary skills to use any given application. According to Alessi and Trollip (2001), the successful implementation of educational software is based on design issues (e.g., learnability, appealing interface etc.) and the selection of worthwhile learning objectives that meet pedagogical needs.

Rosas and his collaborators (2003) argue that introducing computer games in education makes learning meaningful to students, because it creates a learning culture that is more in correspondence with students' interests. A game-like interface could be a useful alternative for routine tasks especially, when the external goal fails to provide the necessary motivation (Ebner & Holzinger, 2007), since it facilitates understanding of the tasks (Gee 2003; Squire 2003). In Washburn's study (2003) increased performance by participants was attributed to the fact that game-like computer tasks tended to elicit greater motivation. In fact, simple game-like goal oriented computer tasks that comprise individualized objectives, multi-sensory modalities and immediate feedback features may be particularly effective in various educational objectives, such as an instructing (DuPaul & Eckert, 1998) or an assessment tool (McDonald, 2001).

A popular category of language games are word games (Littman, 2001). A word game or word puzzle can be of several different types like solving nonsense anagrams. The goal in solving an anagram is to rearrange a set of given letters into an orthographically correct order (Novick & Sherman, 2008) that follows the orthotactic rules of the language. Solving anagrams tasks had been used to assess aspects of word recognition processes (Pammer et al., 2004). Word recognition involves the operation of a visual mechanism (Coltheart, 1981; Ellis, 2004) that extracts information about where letters are positioned within a word. Thereafter, in order for a person to perceive a word, letter strings should be mapped into acceptable word forms that can be compared to whole-word representations stored in memory (Pammer et al., 2004). Therefore, the use of anagrams allows the evaluation of visual word recognition process.

This study reports a computer game-like application, entitled "Playing with Words" (PwW), that uses words stored in a database to produce anagrams by rearranging the letters or letter strings to produce anagrams. The main objective was to develop a simple educational tool that incorporates a basic feature. That is the flexibility to be utilized both as a computer game appealing to young primary schoolchildren and a reading fluency evaluation tool. The PwW was developed in an effort to provide teachers with an alternative or supplemental assessment tool that evokes less anxiety to children, since, as it is well documented in the literature, traditional assessment settings are a major source of anxiety for children (McDonald, 2001). Three main research questions were addressed in this study:

(a) Do anagram solving tasks correlate to reading fluency measures?

(b) Can the PwW be used as a simple game-like educational tool to predict reading fluency in the Greek language?

(c) What do students think of PwW's ease-of-use?

2. Software Development and Description

The application was developed using the Microsoft Visual Basic programming language. The software was developed using the prototyping method (Alessi & Trollip, 2001; Panagiotakopoulos, Pierrakeas & Pintelas, 2005; Sommerville, 2007).

The development stages are depicted in Figure 1. In detail: Initially the content and user interface were developed after requirements analysis. All elements were integrated to a single environment through the Microsoft Visual Basic programming language and a software prototype was produced. Then, the prototype was formally evaluated by two students and one primary education teacher. The findings of the formal evaluation led the development team to review some elements in terms of ergonomics and interface settings. The cycle of prototype production and revision for the development of an improved model was performed for a total of three times. The above process's result was the final application, accompanied with all of its features, which was followingly subjected to the summative evaluation. The results of the summative evaluation are presented in this research.

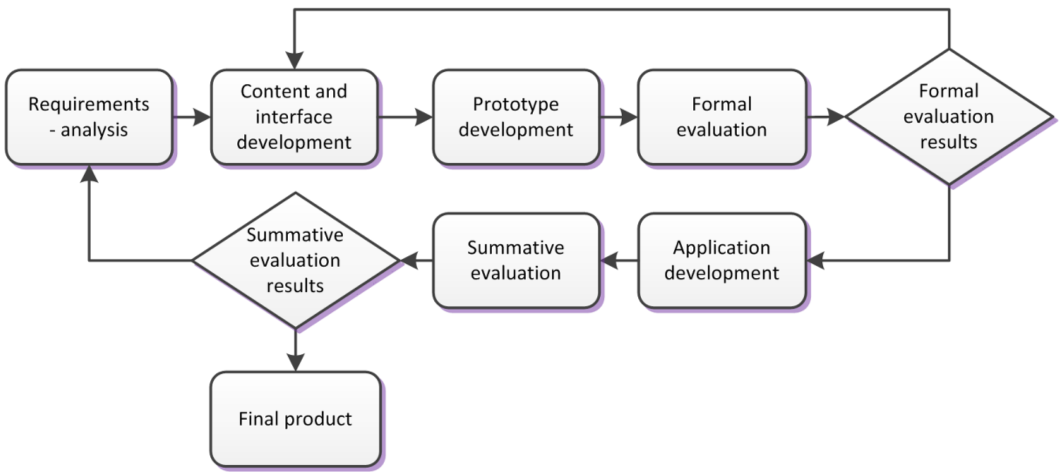


Figure 1. The software production process through the prototyping method adopted by the development team

The application consists of several modules. The first of them refers to the database operation for the preparation of the application's content.

The application uses two databases, the main and the custom database. The main database is a generic base, where the teacher can import a wide set of words. Also, the teacher is able to transfer a subset of the imported words to the custom database giving them individual display properties.

The next figure (Figure 2) illustrates the flow of the actions taken while importing words in the main database, while Picture 1 shows a screenshot of the application in this exact process.

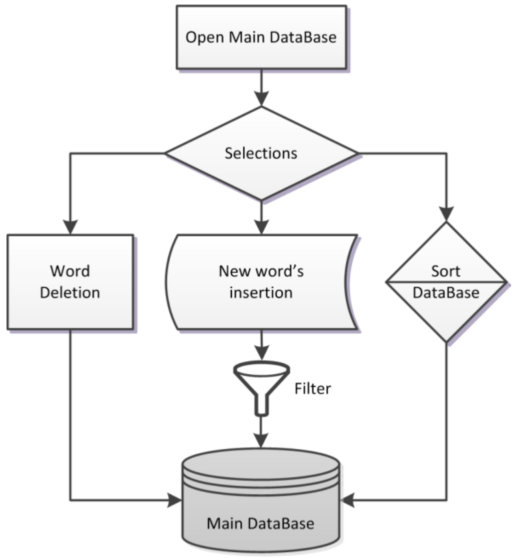
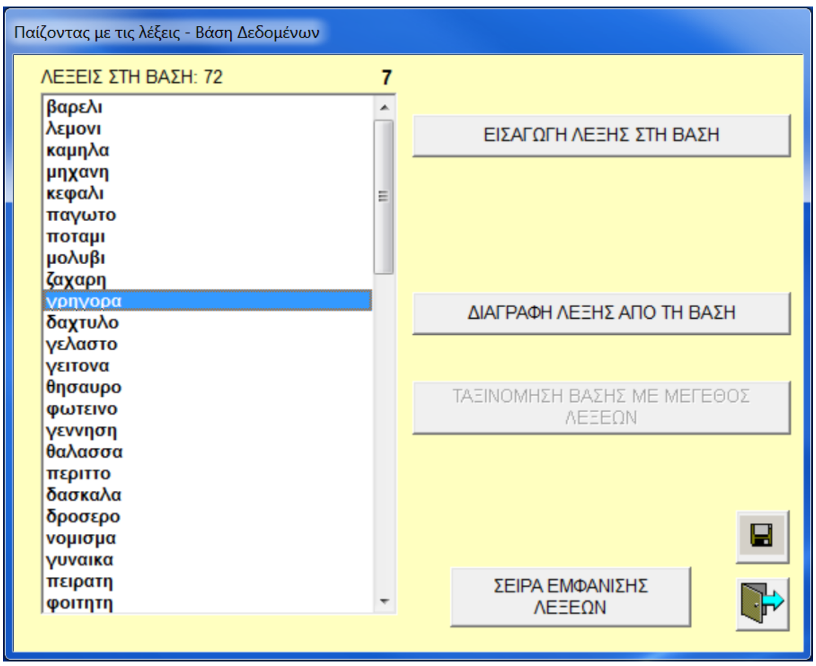


Figure 2. The flowchart in the main database module

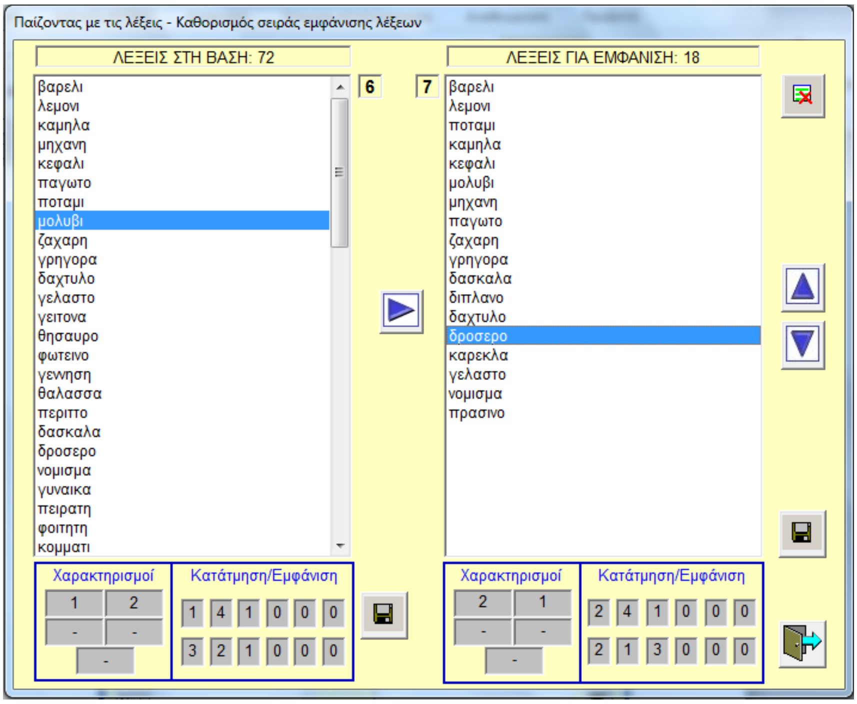


Picture 1. Actual screenshot from the words import process in the main database

The screenshot of Picture 1 shows the list of the words contained in the main database. The buttons located at the bottom right of the picture stand for three distinct functions, which are: import, deletion and classification of words according to their length.

The teacher-administrator is able to enhance the custom database by selecting and transferring words from the main database's content. Furthermore, he can characterize every word, determine the way of segmentation and define the word segments display order of the custom database (Picture 2). In general, the amount and which words of the main database will be displayed to the student through the custom database, are determined by the main database module.

Picture 2 shows on the left side the list of words contained in the main database (list 1) and on the right side the list of words contained in the custom database (list 2). By selecting one word of list 1 and pressing the arrow located at the middle of Picture 2 (between the two lists), the selected word is transferred to list 2, i.e., the custom database. Using the up and down arrows (found at the right of list 2), any word of list 2 can be moved upwards or downwards respectively, determining this way the word display sequence in runtime.



Picture 2. Actual screenshot of copying words from the main to the custom database, while defining word properties

Under list 1, there exist fields where information regarding the type of word (left frame), way of segmentation and word segments display order (right frame) can be recorded and stored. For example, the word «μολύβι» (i.e., “pencil”) that has been selected, has been defined to be segmented in three segments with amount of characters equal to 1 for the first segment («μ»), 4 for the second («ολύβ») and 1 one for the third («ι»). The display order is defined by the numbers 3, 2, 1, which means that the application is set to display first the segment «ι», second the segment «ολύβ» and third the segment «μ».

If one word is transferred from the main to the custom database, its properties-features are transferred as well. If a word of list 2 is selected, the same properties described above are shown under list 2 in the respective frames. The difference is that the frames under list 2 are in read only status, meaning that the properties of the words contained in the custom database are not editable. Figure 3 shows the flowchart of the module responsible for word transfer from the main to the custom database.

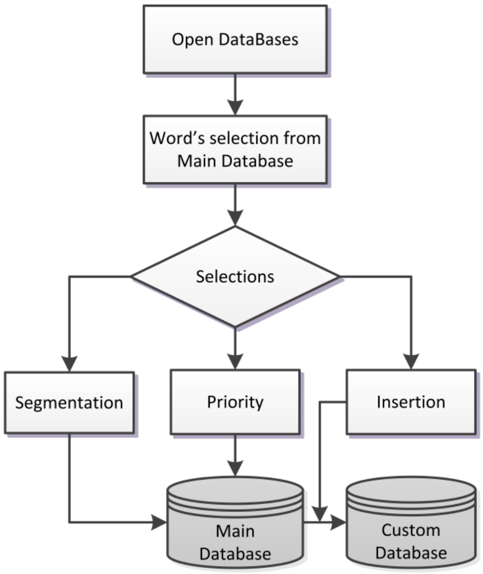
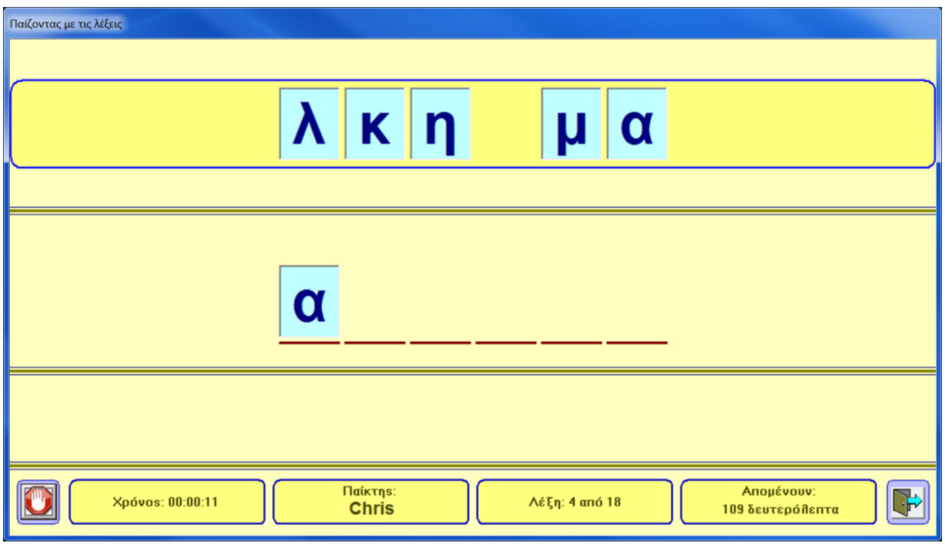


Figure 3. The flowchart of the control module of the custom database

As mentioned before, the application can be executed in two modes. In the first mode words are segmented into letters, while in the second mode words are segmented into letter groups. The teacher can define at start the appropriate mode.

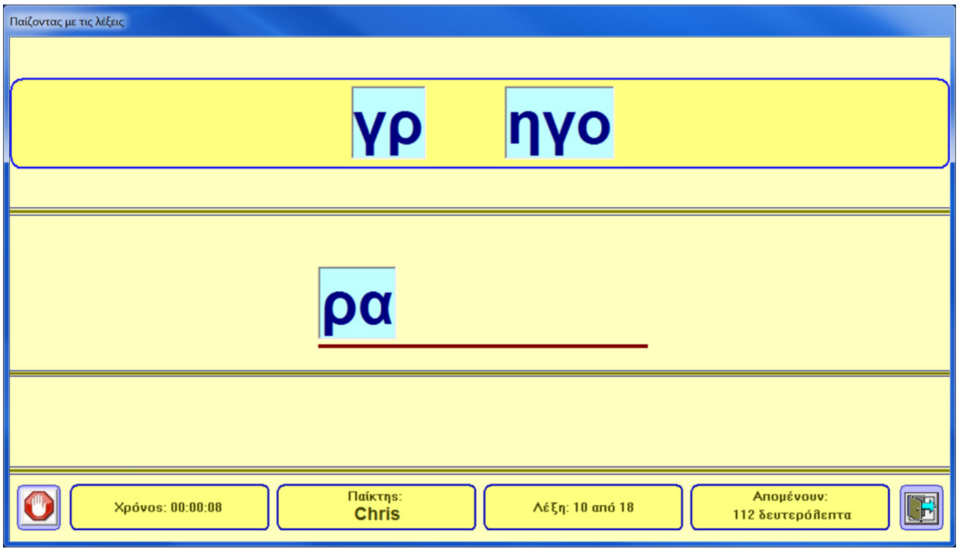
The user can control the application after logging in and the segmented words are presented according to the predefined order in the custom database.

While operating the application in the first mode (i.e., word segmentation into letters), a number of fixed lines, equal to the available letters, appear under each anagram. The user through drag & drop may drag any letter and place it on any fixed line, in order to form the word he believes it emerges by anagramming the given letters. If one letter is placed near a fixed line, the application automatically relocate it to a certain position on the fixed line. Picture 3 shows a screenshot of the application running in this mode, illustrating both the available letters as those were suggested by the application and the letter 'α' that the user has already placed on the first of the given fixed lines.



Picture 3. Actual screenshot from the stage of moving letters for the creation of the anagrammed word, while operating in the 1st mode

Picture 4 depicts the operation of the application in the 2nd mode (i.e., words are segmented into groups of letters instead of single letters).



Picture 4. Actual screenshot from the stage of moving a segment for the creation of the anagrammed word, while operating in the 2nd mode

As shown in Picture 4, the line where the anagrammed word is placed is continuous and the user chose to move the first segment 'ρα'. Every time a new segment is moved near the line, the mounting position determines the application's reaction regarding segment alignment. Thus, if the second consecutive segment is placed close to the first but with a gap between them, then it is micrometrically aligned in the line and the gap remains. On the contrary, if the second consecutive segment is placed close to the first without a gap between them, then the application will align one segment beside the other, as a single set of discrete segments. When the user moves the last segment on the mounting line he can place it either at the end of the previous segments or at an empty space. Then, irrespective of the produced word being correct or not, all of the segments are aligned in the middle of the line as a set of discrete segments. The user even at this stage may revise his decision and move the segments again reforming the word according to his wish. Figure 4 shows the software's flow during the application's operation by the user in both running modes.

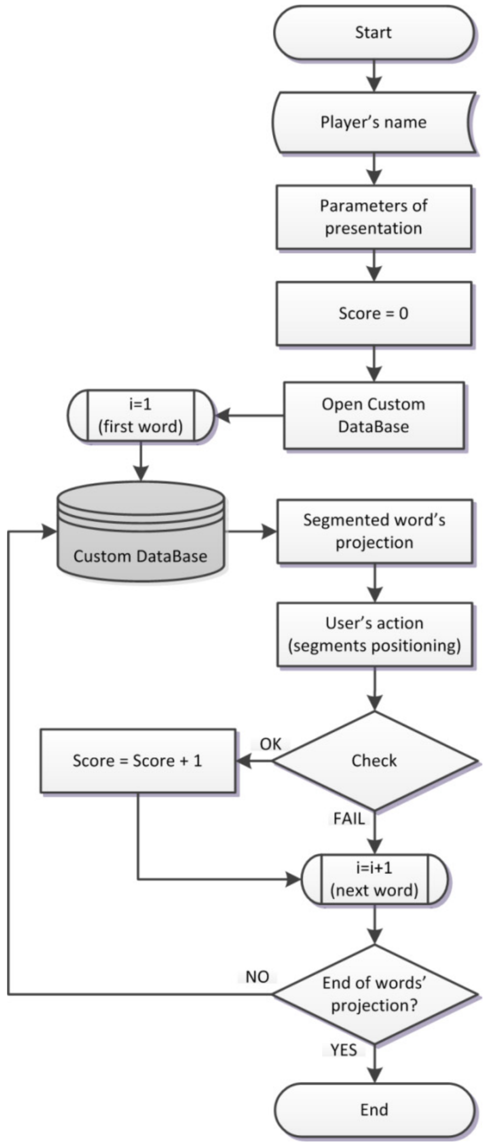


Figure 4. The general flowchart of the application

After moving all letters or segments from their initial position, below the anagrammed word in the middle of the screen, a label with the indication 'ok' appears. If the user clicks on this indication, then the screen presents segmented the next word in order.

Appropriate setting allows to provide or not feedback to each user's action, both through sound indications and proper messages. The application can also show (if it is set) the correct arrangement and formation of the required word through animated graphics, after the completion of an unsuccessful attempt.

Finally, there is the ability to show the correct position of the first and/or the last letter or a word segment in the fixed line, in order to provide help to find the requested word.

The application can record all user's actions and reaction times, to allow the study of his strategy of acting and choices during the application's usage. The teacher can followingly export the respective file and import it in a word processor or a spreadsheet program, in order to thoroughly analyze all events and times required for the user's actions.

3. Methodology

3.1 Participants

A total of 76 Greek-speaking children were randomly selected from three primary schools within the area of Patras. 44 were boys and 32 girls. They were all native Greek speakers and attending the sixth grade of elementary school. Their mean age, during testing, was 11.61 years. None of them had visual or hearing difficulties.

3.2 Experimental Procedure

Data collection lasted for two months and was coordinated by a single person in order to avoid any possible experimenter effects during data collection. The main experimental procedure was preceded by a pilot test. Four children were selected from one school for the pilot test and they all were excluded from the main experimental procedure. Results led to minor revisions of the software calibration settings, ergonomics and the presentation format of the anagrams.

One typical desktop personal computer with Microsoft Windows 7 and a LCD/TFT display 17" was used for collecting the data. The participants were tested individually in the computer laboratory of each school. During data collection the computer laboratory was accessible only to the participants and the experimenter. The laboratory setting was quiet and without any visual distractions.

A reading speed test was administrated individually to the participants as an oral reading fluency measure. Participants had to read aloud a two passage grade-appropriate narrative text (of 206 words) selected from the students' curricular basal reading series. The reading time of each participant was recorded and the reading fluency was calculated (words per minute - wpm). After the main experimental procedure, the participants were also asked to rate attributes, such as ease-of-use, aesthetics and motivational features, based on a simple questionnaire (see Appendix 1).

The 72 words selected for the experimental procedure had the most common syllabic structures in the Greek language (i.e., CV, CCV, CVV and CVC). All words were of middle frequency ($\approx$ .323) and were selected from a database that consisted of all words that are included in the students' curricular reading textbooks of the 6th grade (see Appendix 2).

The main procedure involved two experimental sessions. The first test comprised of 36 anagrams. All anagrams derived from 2-syllable words (5-6 letters) after repositioning the letters. In the second test 36 anagrams were used that derived for 3-syllable words (6-7 letters) after repositioning letter strings that did not match the syllable boundaries. Participants had to complete six successive testing sessions for each experiment. Each session was set to last up to 15 minutes and children had to solve the anagrams within this time limit. Anagrams were allocated into three presentation categories:

- 1st part of the word to be presented first - First,
- 2nd part of the word to be presented first - Middle, and
- 3rd part of the word to be presented first - Last.

Reaction time, total time and accuracy scores were calculated for each participant.

During testing, no visual or audible indicators pointed out the user's success or failure, in order to avoid any encouraging or discouraging effects.

4. Results

Reading fluency scores were calculated by taking the total number of words read in one minute and subtracting the number of errors (Table 1). In order to divide the set of participants into two groups a median split was employed. Participants were allocated into two categories of reading fluency (i.e., 38 normal and 38 moderate readers).

Table 1. Frequencies for reading fluency measure

Median	139 wpm
Range	66 wpm
Minimum	116 wpm
Maximum	182 wpm

A Pearson correlation coefficient was computed to assess the nature of the relationship between reading fluency and anagram solving performance. Results revealed a negative correlation between the variables, $r = -0.55$, $n = 76$, $p < 0.001$. Thus, as expected, as values on reading fluency increase values on the total time consumed for solving anagrams decrease. The students with high reading fluency scores tend to solve anagrams quicker.

Table 2 presents the mean performance scores (reaction and total time) for each experimental task.

Table 2. Mean performance scores in ms (SD's shown in brackets)

	Reaction time		Total time	
	Letter anagrams	Letter strings anagrams	Letter anagrams	Letter strings anagrams
Normal readers	.80 (.51)	.71 (.38)	15.02 (13.05)	8.87 (5.85)
Moderate readers	1.09 (.72)	.81 (.51)	20.61 (17.99)	11.19 (8.98)

Mean differences for normal and moderate readers were calculated using separate independent-samples t-tests. As Figure 5 depicts, normal readers solved the anagrams in both tests quicker that the moderate readers. In the letter anagrams condition, normal achieved lower time scores for both reaction time [$t(2012) = -10.32$; $p < .001$] and total time [$t(2012) = -7.8$; $p < .001$].

The same pattern of results was observed in the letter strings anagrams condition. Statistically significant were revealed for reaction time [$t(2606) = -5.79$; $p < .001$] and total time scores [$t(2582) = -7.76$; $p < .001$] respectively.

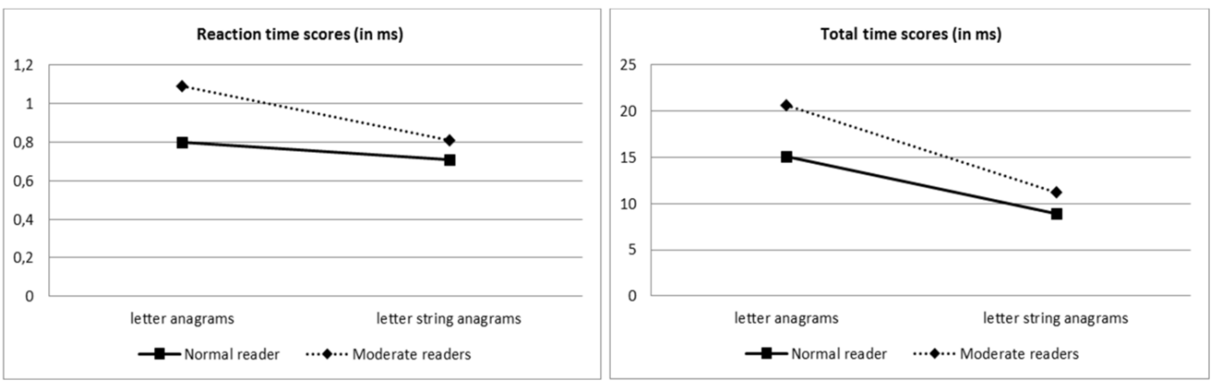


Figure 5. Mean performance time scores for normal and moderate readers

Table 3 illustrates the mean accuracy scores in the letter and letter strings anagram conditions. In both experimental procedures the normal group outperformed the moderate readers group. It is important to note that the letter string anagram condition was proved to be easier for both groups, despite the fact that the letter strings did not match the syllable boundaries of the Greek language.

Table 3. Mean performance scores in % (SD's shown in brackets)

	Letter anagrams	Letter strings anagrams
Normal readers	77.78 (41.61)	97.22 (16.45)
Moderate readers	68.98 (42.29)	93.61 (24.47)

Results were analyzed using an independent-samples t-test. This analysis revealed significant differences between the two groups for both experimental condition, letter anagrams [$t(2734) = -5.24$; $p < .001$] and letter string anagrams [$t(2734) = -4.48$; $p < .001$]. The sample means are displayed in Figure 6, which shows that participants in the normal reading group scored significantly higher on accuracy than did children in the moderate reading group.

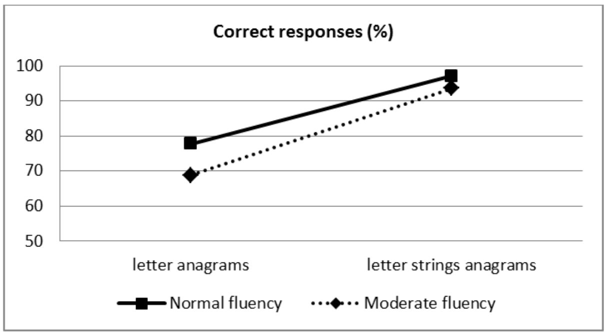


Figure 6. Mean accuracy scores for normal and moderate readers

A final analysis using a simple regression analysis was conducted to investigate the ability of the PwW application to predict reading fluency (Table 4).

Table 4. Summary of the regression statistics

Predictor variable	*B*	*SE B*	*β*	*t*	*p*
Total time score	-4.19	.75	-.546	-5.6	.000

B = unstandardized beta coefficient, *SE B* = standard error, *β* = standardized beta coefficient, *t* = t-test statistic, *p* = significance value.

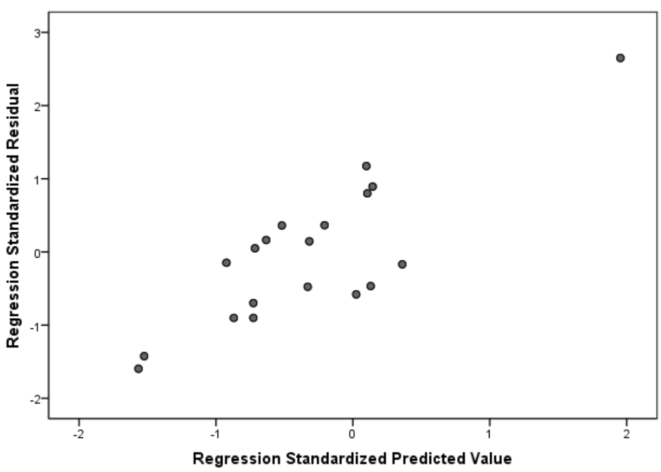


Figure 7. Edited scatterplot of residuals against predicted scores

The results were statistically significant $F_{(1, 75)} = 31.38$, $p < .001$. Total time scores significantly predicted reading fluency scores, $\beta = -.55$, t(75) = -5.6, $p < .001$ (see Figure 7). Total time scores also explained a significant proportion of variance in reading fluency scores, $R^2 = .30$. The equation accounted for 30% of the variance in reading fluency.

In the case of the PwW a key issue was to assess the application's features in regard to the ease-of-use. Participants were asked to evaluate the PwW's usability through a five-grade Likert scale question (Table 5). The Chi-Square Goodness-of-Fit test was found to be statistically significant for participants [$x^2 = 41.05$; $df = 3$; $p < .001$].

Table 5. Frequencies and percentages of ease-of-use

	Participants	
Answer	Frequency	Percent
Very easy	38	50.0
Easy	26	34.2
Neutral	10	13.2
Difficult	2	2.6
Very difficult	0	0.0
Total	76	100

A Mann-Whitney U test was also conducted in order to check for presumable differences among gender. Results fail to reach statistical significance ($z = -1.39$; $p > .05$). Boys had an average rank of 17.21, while girls had an average rank of 21.09 in the ease-of-use variable.

Participants were also asked to choose the most attractive factor of the PwW application among ease-of-use, animation and aesthetics-colors. The Friedman's test analysis revealed statistically significant differences ($x^2 = 46.92$; $df = 2$; $p < .001$). Table 6 shows the mean rank for each factor.

Table 6. Mean ranks for ease-of-use, animation and aesthetics

Factor	Mean Rank
Ease-of-use	1.58
Animation	2.45
Aesthetics - colors	2.76

A final analysis was conducted aiming at exploring PwW's motivational features. Mean ranks for each factor are presented in Table 7. A Friedman's test analysis revealed statistically significant differences among factors ($x^2 = 34.61$; $df = 2$; $p < .001$).

Table 7. Mean ranks for motivational factors

Factor	Mean Rank
Countdown timer	1.08
Difficulty levels	1.59
Other	2.62

5. Discussion

This paper discusses development and evaluation issues concerning a simple game-like application entitled "Playing with Words – PwW." The PwW application was developed primarily as an alternative educational tool intended to assess reading fluency. Like most educational game-like computer applications, PwW's objective is to exploit children's natural tendency to play in order to get them engaged in anagram solving tasks.

During the development of the PwW application emphasis was put on taking into account several operational features. Our main objective was to produce an appealing game-like application that exploits an interactive interface and gives emphasis on educational objectives. Thus, the ease-of -use along with aesthetic issues and motivational features were also under investigation.

Several educational characteristics were also included during the development. After the presentation of the stimulus, the student could act on one's own without having the PwW imposing any limitations that constrain the player's scheme to solve the anagram. Participants could also try to solve the problem by selecting different strategies being able to review their actions. The exploratory learning environment of PwW and its game-like characteristics were found to have positive effects on children's attitudes towards the application. As reported by the participants, features like the countdown timer, that was signaling the player's available time, positively motivated them to solve the anagram tasks. Moreover, PwW's capability to trace the user-application interaction in detail could give the experimenter clear insights of the solving strategies utilized by each participant. It should be mentioned at this point that the application can be used in a personalized manner, selecting each time a different group of words form the main database depending on the performance level and the age of the student.

Current research, on the field of visual word recognition and reading, focus on the issue of the initial processing stages involved in transforming the visual stimulus into a linguistic code (Ziegler et al., 2010). A major question concerns the manner that letter position in words is processed by good and poor readers, since access to stored word forms is mediated by the recognition of component orthographic units such as letters (Courrieu & Lequeux, 2004).

However, in the literature, to the authors' knowledge, there have been no field investigations that focus on anagram computer games as an alternative reading fluency measure, even though numerous studies link anagram solving to word recognition and hence to reading fluency. This study attempted to bridge that gap developing a game-like application which could employ the use of a digital anagram game as an alternative method of reading fluency assessment.

Returning to the results of the study, we measured oral reading fluency adopting the classical words read correctly per minute paradigm (Williams et al., 2011). The fluency scores (Md = 139 words per minute), which were well within the normal average rates (Carver, 1990), were used to allocate participants into two reading fluency groups (i.e., normal and moderate readers).

Data analysis revealed that reading fluency was highly correlated to anagram solving performance and competent anagram solvers tended to achieve higher reading fluency scores. Reading rates demonstrated a negative correlation with the total time spend to solve the anagrams. Students with higher reading fluency scores tended to solve anagrams quicker. There was also a clear advantage of normal over moderate readers on both letter anagram and letter strings anagrams conditions. Normal readers not only solved anagrams quicker but tended to achieve higher accuracy scores on both conditions, with the letter string condition to be easier than the letter anagrams. These results are consistent to recent findings where skilled anagram solution is acknowledged as an extension of word-reading ability (Henin et al., 2009).

The PwW was also tested for its ability to predict reading fluency. The time spent for anagram solving was linearly regressed on reading fluency rate values. Results revealed that children's performance on anagram solution tasks explained 30% of the variance in reading fluency. The regression analysis suggests that performance on anagram solving tasks may be considered as a significant predictor of reading fluency rate.

Finally, the summative evaluation focused on determining the participants' attitudes related to the PwW application's operational characteristics and gather feedback information concerning its usability features. The questionnaire results were in general very encouraging. Participants, despite being novice computer users, evaluated the PwW application as rather easy to use. Positive comments were reported for the pale colors and the simplicity of the Graphical User Interface (GUI), which were proven to be especially appealing. Moreover, participants commented on the specific application that they did not experience any stress effects during playing the PwW.

6. Conclusions

To conclude, this paper reports a game-like anagram solving application entitle "Playing with Words". Anagram solving tasks have a rather multifaceted nature and various studies directly link performance in such tasks to word recognition skills. We have attempted to explore this connection using the specific computer application that enables detailed recording of user-application interactions.

Although our investigation is in its initial stages, results seem to be promising indicating a respectable predictive ability of anagram solving skills to identify students with low reading fluency performance. Further research should be done on this field since the need for computerized educational assessment is growing. Another key issue, which needs to be thoroughly examined, are the strategies that students apply during anagram solving tasks. What seems to be of great importance is the selection of the first letter or letter string, that provide important information on visual word recognition processes.

The present findings though need to be replicated in a larger sample in all grades across elementary school.

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Appendix 1

Questionnaire

Subject code (filled by the experimenter) ____

1. Gender ☐ Male ☐ Female

2. Date of birth __ / __ / ____

3. Select one answer from the following, regarding the ease-of-use of the application.

☐ Very easy

☐ Easy

☐ Neutral

☐ Difficult

☐ Very difficult

4. Select the most attractive factor of the application (rank: 1= most, 3= least).

☐ Ease-of-use

☐ Animation

☐ Aesthetics-colors

5. What was the most motivating factor of the game? (rank: 1= most, 3= least)

☐ Countdown timer

☐ Difficulty levels

☐ Other, please state: ________________________________

Appendix 2

Word list

2syllable words			**3syllable words**		
βάρκα	/varka/	boat	βαρέλι	/vareli/	barrel
βόλτα	/volta/	ride	γείτονα	/gitona/	neighbour
βροχή	/vrochi/	rain	γελαστό	/gelasto/	smiling
γέρος	/geros/	old-man	γέννηση	/genisi/	birth
δάσος	/dasos/	forest	γρήγορα	/grigora/	quickly
καιρό	/kero/	time	γυναίκα	/gineka/	woman
καλός	/kalos/	good	δασκάλα	/daskala/	teacher
κάρτα	/karta/	card	δάχτυλο	/dachtilo/	finger
κλαδί	/kladi/	branch	διπλανό	/diplano/	next
κλάμα	/klama/	cry	δροσερό	/drosero/	cool
κοινό	/kino/	common	ζάχαρη	/zachari/	sugar
κόλλα	/kola/	glue	θάλασσα	/thalassa/	sea
λαιμό	/lemo/	throat	θησαυρό	/thisavro/	treasure
λάκκο	/lakko/	pit	κάλυμμα	/kalima/	cover
λευκό	/lefko/	white	καμήλα	/kamila/	camel
λόγος	/logos/	reason	καρέκλα	/karekla/	chair
λύκος	/likos/	wolf	κάτοικο	/katiko/	resident
μαλλί	/mali/	wool	κεφάλι	/kefali/	head
μαύρο	/mavro/	black	κόκκινο	/kokino/	red
νάνος	/nanos/	dwarf	κομμάτι	/komati/	piece
νύχτα	/nichta/	night	κύτταρο	/kitaro/	cell
παιδί	/pedi/	child	λεμόνι	/lemoni/	lemon
πείνα	/pina/	hunger	μέταλλο	/metalo/	metal
πεύκο	/pefko/	pine	μηχανή	/michani/	machine
πόρτα	/porta/	door	μολύβι	/molivi/	pencil
σειρά	/sira/	series	ναυτικό	/naftiko/	navy
σκάλα	/skala/	stair	νόμισμα	/nomisma/	currency
σπαθί	/spathi/	sword	παγωτό	/pagoto/	ice cream
τόπος	/topos/	place	παιδικό	/pediko/	childish
τρένο	/treno/	train	πειρατή	/pirati/	pirate
τροφή	/trofi/	food	περιττό	/perito/	unnecessary
φίλος	/filos/	friend	ποτάμι	/potami/	river
φτερό	/ftero/	wing	πράσινο	/prasino/	green
φύλλο	/filo/	leaf	συλλαβή	/silavi/	syllable
χαρτί	/charti/	paper	φοιτητή	/fititi/	student
χυμός	/chimos/	juice	φωτεινό	/fotino/	bright