ESTUDIOS

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Phonological awareness digital program: a randomized controlled study

Marta Sá[1], Pedro Sa-Couto[2], Marisa Lousada[3]

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Abstract. The purpose of this study is to analyze the efficacy of the Phonological Awareness Digital Program (PADP) in typically developing preschool children aged 4 to 6 years. A randomized controlled trial was conducted with a total of 49 children assigned to two groups: the experimental group, EG (n=25) and the delayed control group, CG (n=24). Both groups were assessed before and after the implementation of the PADP. A follow-up study for the experimental group was also performed after two months. Outcome measures of phonological awareness skills (task 1: Syllable segmentation task; task 2: Syllable identification task; task3: Syllable omission task; task 4: Onset-rime units segmentation task; task 5: Phoneme segmentation task; task 6: Phoneme blending task) were evaluated at three separate moments. The results showed significant improvement in phonological awareness skills for the EG between the first and the second assessments for all the tasks considered. Between the second and third assessment, the results showed a significant improvement for the CG.
The follow-up study also demonstrated the PADP's efficacy. The PADP has shown to be an effective program in promoting the development of phonological awareness in children. These findings provide evidence for different professionals to use PADP with preschool children.
Keywords: phonological awareness, children, program.

[es] Programa digital para la conciencia fonológica: un estudio aleatorizado

Resumen. El propósito de este estudio es analizar la eficacia del Programa Digital de Conciencia Fonológica (PADP) en niños en edad preescolar con desarrollo típico de 4 a 6 años. Se realizó un ensayo controlado aleatorio con un total de 49 niños asignados a dos grupos: el grupo experimental, GE (n = 25) y el grupo de control retardado, GC (n = 24). Ambos grupos fueron evaluados antes y después de la implementación del PADP. También se realizó un estudio de seguimiento para el grupo experimental después de dos meses. Medidas de resultado de las habilidades de conciencia fonológica (tarea 1: tarea de segmentación de sílabas; tarea 2: tarea de identificación de sílabas; tarea 3: tarea de omisión de sílabas; tarea 4: tarea de segmentación de unidades de inicio-tiempo; tarea 5: tarea de segmentación de fonemas; tarea 6: tarea de combinación de fonemas) fueron evaluados en tres momentos separados. Los resultados mostraron una mejora significativa en las habilidades de conciencia fonológica para el GE entre la primera y la segunda evaluación para todas las tareas consideradas. Entre la segunda y la tercera evaluación, los resultados mostraron una mejora significativa para el GC. El estudio de seguimiento también demostró la eficacia del PADP. El PADP ha demostrado ser un programa eficaz para promover el desarrollo de la conciencia fonológica en los niños. Estos hallazgos proporcionan evidencia para que diferentes profesionales utilicen PADP con niños en edad preescolar.
Palabras clave: conciencia fonológica, niños, programa.

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Introduction

The development of phonological awareness (PA) in preschool children has received growing academic interest, as PA is one of the important predictors of literacy development (Bradley & Bryant, 1983; Carroll, Snowling, Hulme, & Stevenson, 2003; Ehri, 1989; Goswami & Bryant, 1990; Liberman, Shankweiler, & Liberman, 1990; Lukatela, Carello, Shankweiler, & Liberman, 1995; Mann & Liberman, 1984; Rack, Hulme, Snowling, & Wightman, 1994; Share, 2004; Wagner & Torgesen, 1987). It is crucial that prior to the introduction of the alphabetic principle, chil-

[1] School of Health Sciences (ESSUA), University of Aveiro, Aveiro, Portugal.
[2] Center for Research and Development in Mathematics and Applications (CIDMA), Department of Mathematics (DMAT), University of Aveiro, Portugal
[3] Center for Health Technology and Services Research (CINTESIS.UA), School of Health Sciences (ESSUA), University of Aveiro, Aveiro, Portugal. Email: marisalousada@ua.pt.

dren develop awareness that words are made up of smaller units, phonemes, and that they come together to form words, thus promoting the child's ability to read and form words (Fernandes, 2011). When PA is stimulated during preschool, it allows for later contact with letters to be simpler, as letter–phoneme correspondence will be more easily established. Thus, children who have the ability to manipulate and reflect on phonemes will find it easier to develop reading and writing (Correia, 2010; Fernandes, 2011).

It is therefore important to implement programs that promote PA together with other important pre-literacy skills (e.g., letter knowledge), in order to support later academic progress (Freitas, Alves, & Costa, 2007; Santos & Maluf, 2010; Silva, 2004; Melby-Lervåg, Lyster, & Hulme, 2012). Guidance documents for education professionals have been available in recent years (Direção-Geral da Educação, 2018). The Curriculum Guidelines for Pre-School Education emphasize the need for children to "gradually become aware of different phonemes that make up words," to identify "the number of syllables in a word," and to discover and refer to "words that end or begin in the same way" (Silva, Marques, Mata, & Rosa, 2016).

The development and implementation of PA stimulation programs allows children to reflect and analyze language sounds (Santos & Maluf, 2010). Previously several research papers demonstrated that this stimulation positively influences learning (Goswami & Bryant, 1990; Share, 2004).

Programs targeting PA have been used with children who have speech sound disorders (e.g., Gillon & McNeill, 2007; Gillon, 2000). However, the acquisition and advancement of PA is also an important basis for reading and writing in typically developing children, especially for preschoolers who are about to start primary school (Cardoso-Martins et al., 2011; Melby-Lervåg, Lyster, & Hulme, 2012).

There are a variety of PA stimulation programs for preschool children with typical development. The vast majority are available in paper version. Only one program developed in digital format was found specifically for PA focused on typically developing children (Segers & Verhoeven, 2005). There are many English PA apps available online, but they are generally not validated.

Although these programs differ in their tasks and in the levels of PA included, the studies performed to analyze their effectiveness show significant effects not only on the evolution of PA but also on the later learning of reading and writing (see Table 1) (Brady, Fowler, Stone, & Winbury, 1994; Brennan & Ireson, 1997; Byrne & Fielding-Barnsley, 1991; Carson, Gillon, & Boustead, 2013; Kelly et al., 2017; Olofsson & Lundberg, 1985; Segers & Verhoeven, 2005). In spite of the positive results, high-quality studies are needed to support the evidence of digital programs on PA in children.

Table 1 – International studies conducted on PA level.

Study	Sample Size	Type of scientific studies	Language	PA levels included	Intervention Characteristics	Follow-up
Brady et al. (1994)	n=61	Controlled Trial	English	Segment	18 weeks (3 20 minute sessions per week)	Non realized
Brennan & Ireson (1997)	n=38	Randomized Controlled trial	English	Syllable, syllabic constituents and segment	8 months (15-20 minute per day)	Non realized
Byrne & Fielding-Barnsley (1991)	n=126	Randomized Controlled trial	English	segment	12 weeks (25-30 minute per week)	Non realized
Carson et al. (2013)	n=129	Quasi-experimental	English	segment	10 weeks (4 30 minute sessions per week)	Non realized
Kelly, Leitão, Smith-Lock, & Heritage (2017)	n=120	Pre-test post-test group design	English	Syllabic Onset-rime segment	Two 40 minute sessions per week, 16 weeks	Non realized
Lundberg et al. (1988)	n=390	Quasi-experimental	Danish	Word, syllable, syllabic constituents and segment	8 months (15-20 minute per day)	Non realized
Olofsson & Lundberg (1985)	n=95	Quasi-experimental	Swedish	segment	8 weeks	After 1 year
Segers & Verhoeven (2005)	n=100	Quasi-experimental	Dutch	syllabic constituents and segment	40 weeks (15 minute per week)	After 6 months
Vanbecelaere et al. (2020)	n=191	Cluster randomized trial	Dutch	syllabic and segment	Five 30 min sessions, over 5 weeks	Non realized

For European Portuguese, there is also a variety of programs/activities that stimulate PA (Carvalho, 2012; Coutinho, Vale, & Bertelli, 2003; Ferraz, Pocinho, & Fernandes, 2018; Freitas et al., 2007; Rios, 2013). These consist of different tabletop games (e.g., board games, picture cards, or physical objects) and digital games. However, they present some limitations, such as the phonological levels included (some programs did not include the three levels of PA, syllabic, intrasyllabic, and segmental awareness), lack of controlled variables (the programs did not control the different linguistic variables such as *word length, syllable structure* and *segmental properties*), and the lack of scientific validation studies. Presently, the use of computers, smartphones, and tablets, among other devices, by preschool children is increasingly evident (Furió, González-Gancedo, Juan, Seguí, & Rando, 2013)we present an initial study to determine the subject preferences for educational computer games for children, in which 150 education professionals participated. From the results of this first study, we have developed an iPhone game for transmitting knowledge as part of multiculturalism, solidarity and tolerance following established learning theories, several design principles, and the objectives and competences of the Spanish law for primary education. We also report on a second study to determine whether the iPhone game has better learning outcomes than a traditional game by analyzing the participation of 84 children ranging in age from 8 to 10 years old. The frequency of playing with consoles or computer games was also taken into account in this second study, and the worldwide trend of previous studies has been corroborated. For learning outcomes, the results did not show significant differences between the two groups. However, 96% of the children indicated that they would like to play with the iPhone game again, and 90% indicated that they preferred the experience with the iPhone game over the traditional one. From these results, we can conclude that the children achieved similar knowledge improvements using both the autonomous game (iPhone game. Therefore, with the increase of these stimuli it becomes more difficult to gain children's interest and attention with other types of stimuli. In this sense, it is important that professionals who promote PA in children innovate their tools to make activities more dynamic and motivating (Martins, Madalena, Pinheiro, Blasi, & Central, 2008). The use of digital games is an effective option in learning experiences that meets children's interests, providing new challenges and fun learning moments (Papastergiou, 2009; Pereira, Brancalioni, & Keske-Soares, 2013)which was designed according to the curricular objectives and the subject matter of the Greek high school Computer Science (CS.

The COVID-19 pandemic presented a great challenge for kindergarten teachers to adapt all their classes to distance learning. A large majority had to adapt their teaching and learning methodologies in a very short time (Foti, 2020). Thus, digital programs are even more relevant in the current context.

In education, the use of information and communication technologies integrated with computers, shows a positive result in learning curves (Fessakis, Goulia, & Mavroudi, 2013). Therefore, these technologies can play an essential role in achieving the objectives of the early childhood education curriculum if supported by software-enabled applications (Fessakis, et al., 2013).

For European Portuguese, our research team (Sá et al., 2019; Lousada et al., 2021) has developed a PA program for children with typical development—the Phonological Awareness Digital Program (PADP).

The present study aims to analyze the efficacy (in syllabic, intrasyllabic and segmental awareness) of the PADP in a group of 49 preschool children (aged 4.0 to 6.2 years old) with typical language development, using a randomized controlled study design with two groups (control versus experimental) and a follow-up period.

Methods

Participants

Figure 1 presents the randomized controlled trial through the different phases considered (enrolment, intervention allocation, follow-up, and data analysis). Initially, a group of 50 typically developing preschool-aged children were recruited through two public kindergartens (convenient sample) in Barcelos, Portugal. The final study sample was constituted of 49 children, as one child was transferred to a different kindergarten dropping out of the study. All invited parents responded and agreed to participate in the study. The children were randomly assigned (using random.org) to one of two groups: an experimental group (EG) (n = 25; M±SD age = 59.3±8.3 months; 16-female; 9-male) and a control group (CG) (n = 24; M±SD age = 62.3±7.3 months; 7-female; 17-male).

Participants came from the same demographical region and shared similar socioeconomic backgrounds. Ethical approval for all study procedures was granted by the Ethics Committee, Research Unit in Health Sciences. Parents provided written consent for their children to take part in the study, prior to the data collection phase.

Subject inclusion criteria included: Children with European Portuguese as native language and age between 4 and 6 years old. Children with language impairment were not included in the study. Also, children with a history of referral to or enrollment in speech and language therapy were excluded. Children diagnosed with a biomedical condition (e.g., neurological impairment or intellectual disability) were also excluded. In order to control for these exclusion criteria, a sociocultural questionnaire characterizing the child's background was completed by their parents or guardians (e.g., birth date, first language, enrollment in speech-language therapy, presence of any biomedical condition).

Both CG and EG groups were assessed at the same time for the first and second assessments (five weeks apart). The third assessment occurred at a different time for both groups. Children from the CG were assessed five weeks after the second assessment (treatment in the CG) while children from the EG were assessed two months (follow-up) after the intervention was concluded (Figure 1). All children were available on the proposed evaluation dates.

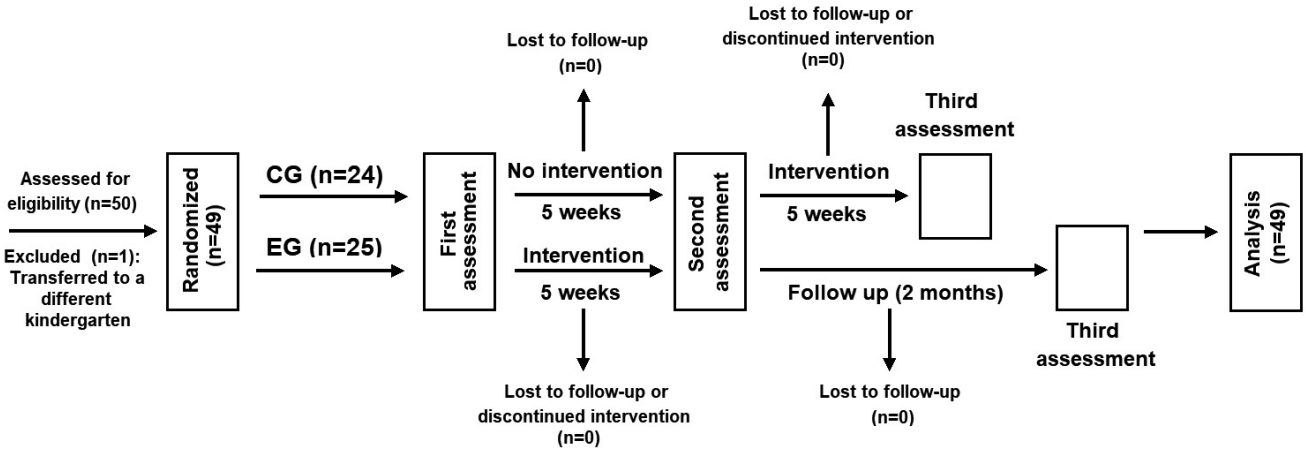

Figure 1. Flow diagram of the controlled randomised trial progress.

The sample size calculation was based on the work presented by Cardoso-Martins et al., (2011). In that study, two groups were considered (CG and EG) and the difference in means (standard deviation) for the alliteration detection, similar to our task 2 (with a maximum classification of 12 points) between the pretest and posttest was: CG= 0.6 (4.0) and EG= 3.0 (1.2). Using a two-sided significance level of 0.05 and 80% power, the total sample size was 50 subjects (25 in each group).

First assessment (baseline)

Children's PA abilities were assessed by a speech-language pathologist—SLP1 (blind to the aims of the study) using subtests of two instruments validated on Portuguese children: the Phonological Awareness Tasks (Afonso, 2015a) and the Oral Language Assessment test (Sim-Sim, 2001).

The Phonological Awareness Tasks have been validated for the Portuguese population and allow the evaluation, through a set of seven tests, of different levels of PA: syllabic awareness, intrasyllabic awareness and segmental awareness.

The evaluation performed with this test was complemented with the phoneme blending task of the Oral Language Assessment test (Sim-Sim, 2001) since this task was not included in the previous test.

The following paragraph contains a brief description of the six tasks used in the current study.

Task 1: Syllable segmentation task (Afonso, 2015a). This task consisted of 54 binary items (correct or incorrect answer, total score of 54 points) with an internal consistency of 0.98, measured by Kuder-Richardson formula 20 (KR-20). The test/retest reliability was measure by the intraclass correlation coefficient (ICC, two-way mixed effects, absolute agreement). The ICC value was 0.83 with the correspondent 95%CI of [0.62;0.93]

Task 2: Syllable identification task (Afonso, 2015a). This task consisted of 35 binary items (correct or incorrect answer, total score of 35 points) with an internal consistency of 0.97. The ICC value was 0.88 with the correspondent 95%CI of [0.73;0.95]

Task 3: Syllable omission task (Afonso, 2015a). This task consisted of 35 binary items (correct or incorrect answer, total score of 35 points) with an internal consistency of 0.99. The ICC value was 0.90 with the correspondent 95%CI of [0.78;0.96].

Task 4: Onset-rime units segmentation task (Afonso, 2015a). This task consisted of 5 binary items (correct or incorrect answer, total score of 5 points) with an internal consistency of 0.78. The ICC value was 0.89 with the correspondent 95%CI of [0.76;0.95].

Task 5: Phoneme segmentation task (Afonso, 2015a). This task consisted of 35 binary items (correct or incorrect answer, total score of 35 points) with an internal consistency of 0.69. The ICC value was 0.88 with the correspondent 95%CI of [0.73;0.95].

Task 6: Phoneme blending task (Sim-Sim, 2001). This task consisted of 10 binary items (correct or incorrect answer, total score of 10 points) with an internal consistency of 0.79 The ICC value was 0.66 with the correspondent 95%CI of [0.22;0.85].

Intervention

Twenty-five children received the PADP in small groups (containing a maximum of five children each). A speech-language pathologist (SLP2 – the first author) delivered the program at the kindergarten in rooms equipped with headphones and computers for each child.

The PADP is a tool that can be used by different professionals working with children (e.g., speech therapists, kindergarten teachers, teachers, and psychologists). Parents can also use PADP with their children, under the guidance of professionals. Its purpose is to promote the development of PA in preschool or early school-age children. The examiner's manual includes all instructions to implement the program.

This program consists of 11 activities that are organized into three levels of PA: three for syllabic awareness, two for syllabic constituents' awareness, and six for phonemic awareness.

The selection of the words used took into account the variables *word length (number of syllables)*, *syllable structure (CV – consonant, vowel; CCV – consonant, consonant, vowel; CVC - Consonant, vowel, consonant), word stress*, and *segmental properties (articulatory properties – stop, fricative, lateral, etc.)*. Thus, it was possible to establish levels of complexity in each activity, which are increasingly organized and can be used depending on the age and/or level of PA of each child (Afonso, 2015b; Alves, 2012; Rios, 2009; Veloso, 2003). For example, within syllabic segmentation, the first level includes dissyllabic words with simple syllabic structure (CV) and other advanced levels include polysyllabic words with complex syllabic structures. The words used in each activity were illustrated by a professional designer with experience in illustration for children.

The PADP was built around the circus theme. It includes 225 pictures of the words used, 11 characters related to each activity (e.g., magician Rony, the trapeze artist Jade), and five scenarios. The PADP also has a booklet of stickers for each activity, so that stickers of the respective character and the associated accessory can be used as rewards (see Figure 2).

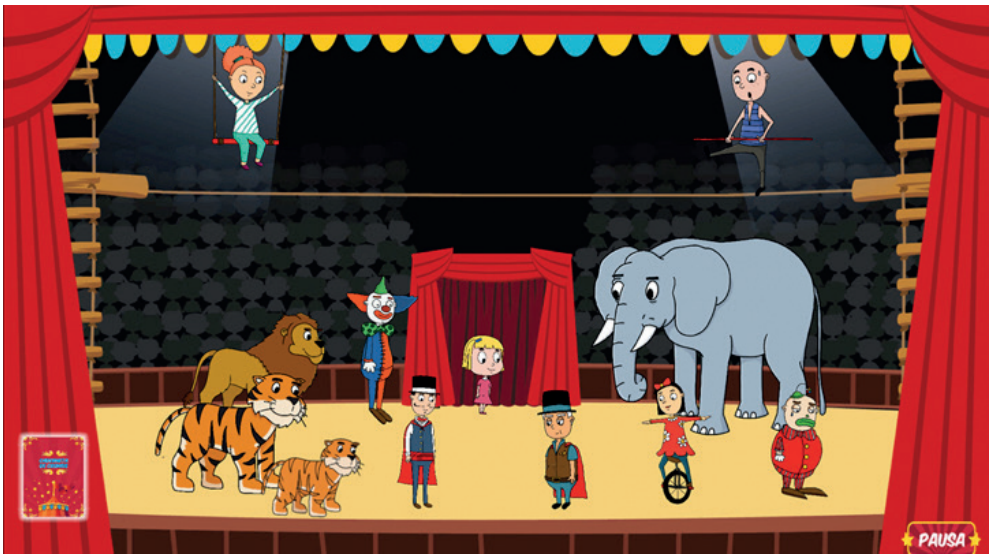

Figure 2. PADP

The content validity of the PADP was previously tested by a panel of five experts in the field (linguists and speech and language therapists). Each expert received a questionnaire with specific questions related to the PADP (e.g., clarity and adequacy of the instructions used) (Reference removed to preserve anonymity). Data were analyzed using the content validity index. The average global index was 0.95, indicating excellent content validity (Polit & Beck, 2006).

The program consisted of five sessions (one hour a week). In the first session, syllable segmentation activities, identification of the initial syllable and omission of the final syllable were performed. In the second session, the onset-rime segmentation and blending were performed. In the third session, the activities of segmental synthesis and identification of the initial phoneme were implemented. In the fourth session, the initial phoneme omission and final phoneme addition activities were performed. Finally, in the fifth session, the initial phoneme replacement and phoneme segmentation activities were performed. Table 2 describes in detail all PADP activities, considering the controlled variables - word length, syllable structure and segmental properties. All children received the same exact activities during all sessions. As children play, the database collects the information about their percentages of success in each activity, allowing the professional, over time, to analyze the performance of each child and compare the results before and after the implementation of the program and, consequently, analyze the gains obtained.

Each PADP activity - digital version presents the game instructions. In addition, as children play, positive or negative feedback is given, depending on their answers.

Table 2 – PADP activities.

PA Levels	Activities	Levels
Syllabic awareness	Syllable segmentation	**Level 1:** disyllabic and trisyllabic words with non-branching onset rhyme. **Level 2:** polysyllabic words with non-branching onset rhyme. **Level 3:** disyllabic words with non-branching onset rhyme. **Level 4:** monosyllabic words with non-branching onset and branching and non-branching rhyme (branching nucleus).
	Identification of the initial syllable	**Level 1:** words with non-branching onset rhyme. **Level 2:** words with onset branching and non-branching rhyme. **Level 3:** words with non-branching onset and branching rhyme [ɾ] and [l].
	Omission of the final syllable	**Level 1:** disyllabic and trisyllabic words with non-branching onset rhyme in the initial syllable. **Level 2:** disyllabic and trisyllabic words with non-branching onset and branching rhyme on the initial syllable.
Syllabic constituents' awareness	Intrasyllabic synthesis	**Level 1:** words with non-branching rhyme (branching nucleus) **Level 2:** words with branching onset and branching rhyme and words with branching rhyme.
	Intrasyllabic segmentation	**Level 1:** words with non-branching rhyme (and branching nucleus) **Level 2:** words with branching rhyme
Phonemic awareness	Segmental synthesis	**Level 1:** disyllabic words with fricative as the initial segment. **Level 2:** disyllabic words with lateral approximant as the initial segment. **Level 3:** disyllabic words with nasal as the initial segment. **Level 4:** disyllabic words with plosive as the initial segment.
	Identification of the initial segment	**Level 1:** words with non-branching onset rhyme with fricative as the initial segment. The intruder word differs in the initial segment in manner and at the place of articulation level. **Level 2:** words with non-branching onset rhyme with lateral approximant as the initial segment. The intruder word differs in the initial segment in manner and at the place of articulation level. **Level 3:** words with non-branching onset rhyme with nasal as the initial segment. The intruder word differs in the initial segment in manner and at the place of articulation level. **Level 4:** words with non-branching onset rhyme with plosive as the initial segment. The intruder word differs in the initial segment in manner and at the place of articulation level. **Level 5:** words with non-branching onset rhyme with fricative as the initial segment. The intruder word differs in the initial segment at the place of articulation level. **Level 6:** words with non-branching onset rhyme with plosive as the initial segment. The intruder word differs in the initial segment at the place of articulation level, and, for some words, in the voicing.
	Initial segment omission	**Level 1**: disyllabic words with non-branching onset rhyme **Level 2:** disyllabic words with non-branching onset and branching rhyme.
	Final segment addition	**Level 1**: monosyllabic words with non-branching onset rhyme.
	Initial segment replacement	**Level 1:** words with non-branching onset rhyme, on which the replaced segment is fricative. **Level 2:** words with non-branching onset rhyme, on which the replaced segment is a lateral approximant. **Level 3:** words with non-branching onset rhyme, on which the replaced segment is nasal. **Level 4:** words with non-branching onset rhyme, on which the replaced segment is plosive.
	Segmental segmentation	**Level 1:** disyllabic words with non-branching onset rhyme. **Level 2:** disyllabic words with branching onset. **Level 3:** disyllabic words with branching.

Second assessment

Five weeks after the baseline assessment was carried out, all children were assessed (post-implementation of the PADP to the EG) by the SLP1, with the same assessment instruments used during the baseline assessment.

Third assessment

After five weeks of intervention, the children from the CG were assessed by the SLP1, with the same PA instruments used during previous assessments. Two months after the PADP implementation in the EG, the children were assessed in order to determine the maintenance of the results.

Outcome measures

To compare the results obtained in the two groups at the pre- and post-intervention points, the total scores of the six tasks from the two assessment instruments were analyzed for all children. The description of each task will be presented below:

Task 1: Syllable segmentation task

Instruction: "I'm going to say a word and I want you to clap one time for each syllable I say. *'Bolo'* (cake) Now, clap it with me. Bo-lo. Now, you try it by yourself." There were 5 demos for this task.

Task 2: Syllable identification task

Instruction: "I'm going to say a word and I want you to tell me the first syllable in the word. *'Carta'* (letter). The first syllable is *'car'*". There were 4 demos.

Task 3: Syllable omission task

Instruction: "I'm going to say a word and then I'm going to ask you to say it without the first syllable. For example, 'Preto' (black), without the first syllable is *'to'*". There were 4 demos.

Task 4: Onset-rime units segmentation task

Instruction: "I'm going to say a word and then I want you to tell me the parts. For example, we can divide the word *'pão'* (bread) into p…ão.". Three demos were used in this task.

Task 5: Phoneme segmentation task

Instruction: "I'm going to say a word and then I will say each phoneme in the word.

'Alho' (garlic) a-lh-o. Now, you try it by yourself." There were 4 demos for this task.

Task 6: Phoneme blending task

Instruction: "I'll say the sound of a word. You guess what the word is. What word is this? j-á the word is *'já'* (now). There were 2 demos. What word is this? _____"

Qualitative assessment

Three questionnaires were developed to explore the effectiveness of the intervention, one to collect parents' views of the program, another to analyse children's experiences with the program, the third one to gather kindergarten teachers' perceptions, in order to enhance the ecological validity of the results.

The questionnaire for children allowed us to analyze whether they liked to "play" the PADP and whether they would like to do it again.

The questionnaires for the participant's parents (n=49) and the kindergarten teachers (n=3) focused on the following areas: enjoyment of program and syllabic, intrasyllabic, and phonemic awareness improvement, using a 5-point Likert scale, where 1 represented "the child didn't like" or "the child didn't improve" and 5 meant "the child likes a lot" or "the child improved a lot." A questionnaire was conducted with the children, using a 3-point Likert scale (with emojis and other characters), and focused on their enjoyment of the activities and their willingness to continue to do them.

Data analysis

All statistical analyses were performed using SPSS Software, version 24.0 (SPSS Inc., Chicago, IL), and p-values under 0.05 were considered significant.

The outcome measures analyzed in the present study are described above. In order to characterize the sample, a chi-square test for contingency tables was conducted to explore gender differences. An independent samples t-test was performed to evaluate possible effects of age, and a non-parametric Mann Whitney U test was used to analyze the results of the tasks performed in the first (initial) assessment (data did not follow a normal distribution) between groups. Finally, a repeated one-way ANOVA was used to evaluate the mean differences of the tasks performed between the assessments for each group, followed by multiple comparisons for the significant results. A Bonferroni correction was applied for the post-hoc analysis. In some cases, when Mauchly test failed to present

sphericity, the epsilon of Huynh-Feldt was used. All the presented results were confirmed with the non-parametric Friedman test.

To analyze the effectiveness of PADP implementation, a 2x3 two-factor mixed ANOVA was performed. The two factors were group (CG versus EG) and moment of assessment (first second, and third). The assumptions for its application (sphericity criterion by Mauchly test and homogeneity criterion by Levene test) were met. Again, in some cases, when Mauchly test failed to present sphericity, the epsilon of Huynh-Feldt was used (epsilon≥0.75). Post-hoc analysis was performed for the EG and CG, respectively, using the Bonferroni multiple comparisons approach.

The assumption of normality of residuals (assessed by the Kolmogorov–Smirnov test) was not verified for all statistical tests performed with the ANOVA. However, because the sample size of the groups is nearly identical and close to the empirical value of 30 subjects for each group, the ANOVA is robust despite violating this assumption. Finally, the QQ plots analysis shows that the sample values are close to normal distribution values.

Results

Sample characterization

Table 3 presents the sample and tasks' characterization in the first assessment. Regarding age, the results of the independent samples t-test showed that there were no significant differences between the mean ages of the EG and the CG ($p = 0.177$). A difference between the number of female and male children in both groups was found. The chi-square test for contingency tables revealed that these differences were significant ($p = 0.022$).

For the first assessment, task 1 (syllable segmentation task) presented mean values somewhat higher than the middle point of this task (higher than 27), while the other tasks showed very low mean values. No significant results between groups were found for the proposed six tasks, with the exception of task 1 ($U = 200.5$; $p = 0.046$).

Table 3 – Sample and tasks characterization in first assessment (baseline).

		EG (n=25)	CG (n=24)	Statistical result
Gender	Female	16 (64.0%)	7 (29.2%)	$x^2(1)= 6.0$ p= 0.022
	Male	9 (36.0%)	17 (70.8%)	
Age (months)		59.3 ± 8.3	62.3 ±7.3	t(47)= -1.4 p= 0.177
Tasks	Task 1	29.9 ± 18.3	39.1 ± 15.7	U= 200.5 p= 0.046
	Task 2	15.1 ± 10.9	15.1 ± 11.7	U= 288.5 p= 0.817
	Task 3	5.3 ± 11.4	9.4 ± 14.1	U= 270.5 p= 0.501
	Task 4	0.4 ± 1.0	0.4 ± 0.6	U= 279.0 p= 0.577
	Task 5	0.1 ± 0.4	0.4 ± 1.0	U= 261.0 p= 0.200
	Task 6	1.1 ± 2.2	1.1 ± 1.3	U= 253.0 p= 0.283

Legend: n (%); Mean ± Standard deviation; Task 1: Syllable segmentation task; task 2: Syllable identification task; task3: Syllable omission task; task 4: Onset-rime units segmentation task; task 5: Sound segmentation task; task 6: Sound blending task

PADP efficacy analysis

The effectiveness of the implementation of the PADP was analyzed by comparing the results obtained in the first and second assessments, in the case of the EG it referred to the period after the implementation of the PADP, while for the CG it referred to the period between the second and third assessment.

Table 4 presents PADP efficacy analysis for the first, second, and third assessments in the experimental group (EG) and control group (CG). These results are illustrated in figure 3. The inclusion of the factor gender as a covariate in the model did not produce significant changes in the results presented in table 4, only very slight changes in the values presented.

Table 4 – Mean (raw) scores (and standard deviation) for the efficacy analysis of PADP: first, second, and third assessments results for the experimental group (EG) and control group (CG).

Tasks	Assessment	EG (n=25)	CG (n=24)	Statistical result
Task 1	First	29.9 18.3	39.1 15.7	FA: F(1.4;68.0)=34.2; p<0.001 FB: F(1;47)= 0.3; p=0.589 FA x FB: F(1.4;68.0)=6.7; p=0.005
	Second	48.7 5.7	42.6 12.2	
	Third	51.3 3.2	51.8 2.5	
Task 2	First	15.1 10.9	15.1 11.7	FA: F(2;94)= 77.7; p<0.001 FB: F(1;47)= 2.7; p=0.108 FA x FB: F(2;94)=11.4; p<0.001
	Second	28.2 9.3	17.0 11.4	
	Third	32.1 5.9	32.7 4.9	
Task 3	First	5.3 11.4	9.4 14.1	FA: F(1.9;87.3)=96.5; p<0.001 FB: F(1;47)= 3.4; p= 0.071 FA x FB: F(1.9;87.3)=23.4; p<0.001
	Second	27.7 10.5	10.3 13.3	
	Third	30.7 9.4	29.3 8.4	
Task 4	First	0.4 1.0	0.4 0.6	FA: F(1.8;85.4)=205.3; p<0.001 FB: F(1;47)=30.8; p<0.001 FA x FB: F(1.8;85.4)=57.2; p<0.001
	Second	3.3 1.5	0.2 0.7	
	Third	3.8 1.3	3.1 0.6	
Task 5	First	0.1 0.4	0.4 1.0	FA: F(2;94)=56.0; p<0.001 FB: F(1;47)= 4.7; p=0.034 FA x FB: F(2;94)= 13.3; p<0.001
	Second	7.9 6.7	1.0 3.8	
	Third	8.7 5,6	8.3 7.2	
Task 6	First	1.1 2.2	1.1 1.3	FA: F(2;94)= 155.7; p<0.001 FB: F(1;47)=16.9; p<0.001 FA x FB: F(2;94)=28.1; p<0.001
	Second	6.4 2.9	1.5 2.1	
	Third	7.6 1.7	7.2 1.8	

Legend: FA= assessment moment; FB= group; FAxFB= FA and FB interactions. Mean ± Standard deviation. Task 1: Syllable segmentation task; task 2: Syllable identification task; task3: Syllable omission task; task 4: Onset-rime units segmentation task; task 5: Sound segmentation task; task 6: Sound blending task

The results showed significant improvement in the EG for all the tasks (task 1: F(1.1;25.6)=33.5, p<0.001; post-hoc analysis: Assessment 1 < Assessment 2 < Assessment 3, p<0.005; task 2: F(2;48)=53.7, p<0.001; post-hoc analysis: Assessment 1 < Assessment 2 < Assessment 3, p<0.005; task 3: F(1.4;32.9)=78.0, p<0.001; post-hoc analysis: Assessment 1 < Assessment 2 = Assessment 3, p=0.055; task 4: F(2;48)=105.0; p<0.001, post-hoc analysis: Assessment 1 < Assessment 2 < Assessment 3, p<0.05; task 5: F(2;48)=39.6; p<0.001, post-hoc analysis: Assessment 1 < Assessment 2 = Assessment 3, p=0.99; task 6: F(2;48)=87.5, p<0.001; post-hoc analysis: Assessment 1 < Assessment 2 = Assessment 3, p=0.06).

For the CG, the results were also significant but with a different response pattern (task 1: F(2;46)=9.1, p<0.001; post-hoc analysis: Assessment 1 = Assessment 2 < Assessment 3, p<0.005; task 2: F(2;46)=53.7, p<0.001; post-hoc analysis: Assessment 1 = Assessment 2 < Assessment 3, p<0.001; task 3: F(2;46)=44.1, p<0.001; post-hoc analysis: Assessment 1 = Assessment 2 < Assessment 3, p<0.001; task 4: F(2;46)=203.5, p<0.001; post-hoc analysis: Assessment 1 = Assessment 2 < Assessment 3, p<0.001; task 5: F(1.3;30.9)=30.2, p<0.001; post-hoc analysis: Assessment 1 = Assessment 2 < Assessment 3, p<0.001; task 6: F(1.6;36.0)=97.6, p<0.001; post-hoc analysis: Assessment 1 = Assessment 2 < Assessment 3, p<0.001).

Figure 3 demonstrates the improvement in the CG (between second and third assessment) as being similar to the slope displayed in the EG (between first and second assessment), for all tasks, with the exception of task 1. In this case, the EG presented a more abrupt slope. It is worth notice that the mean values presented in the third assessment were identical for both EG and CG, suggesting that PADP efficacy was identical and beneficial for both groups.

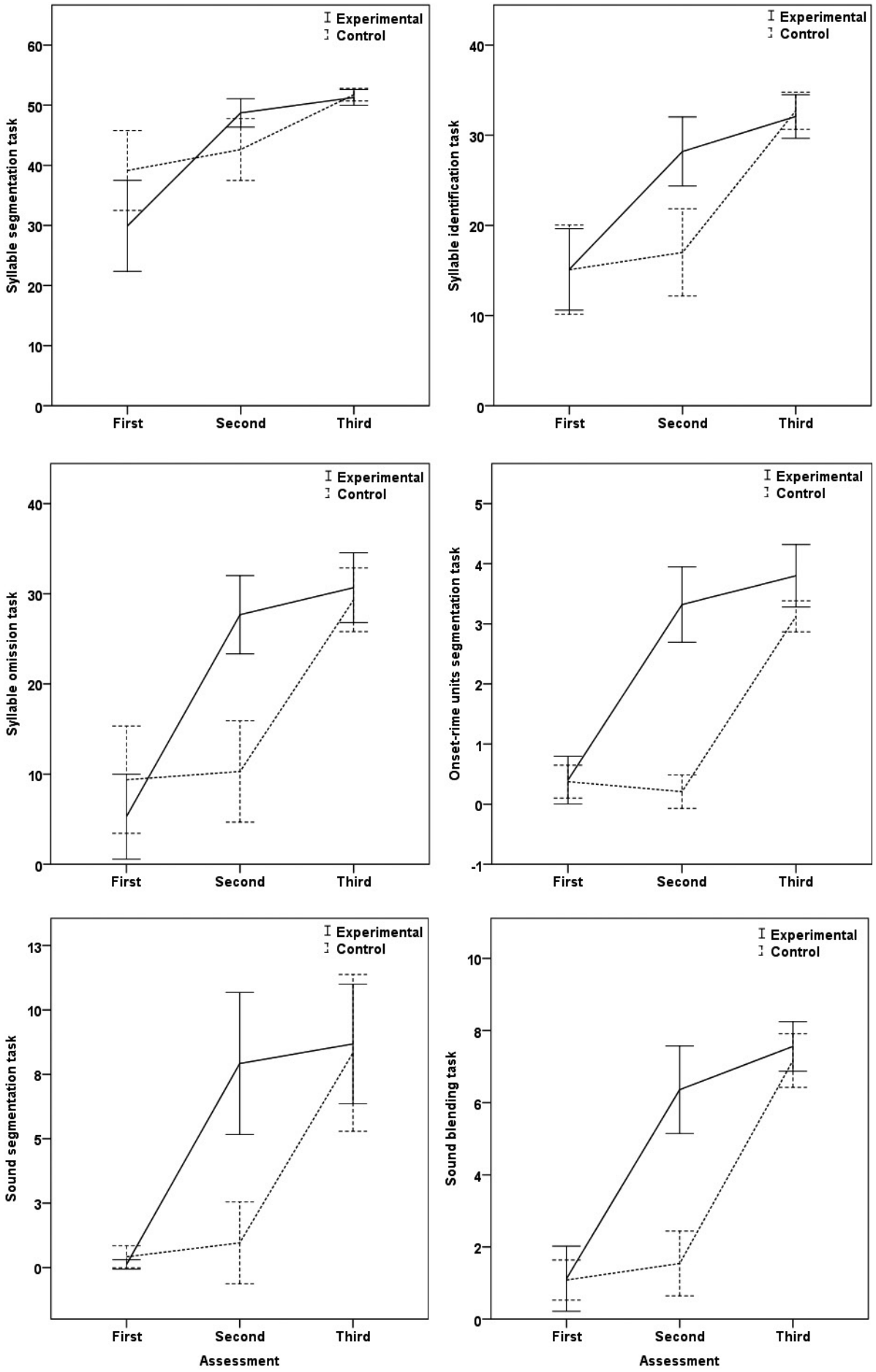

Figure 3. The mean (raw) scores (and its 95% confidence intervals represented by the vertical lines) for efficacy analysis of PADP for the experimental group (continuous line) and control group (dashed lines).

Finally, the interaction between the group and moment of assessment was significant ($p < 0.05$) for all tasks (see table 4 for statistical details). Figure 3 illustrates the interaction by showing a significant improvement effect when the PADP program was implemented, for the EG group between first and second assessment and for the CG between the second and third assessment.

The post-hoc analysis for the EG (see table 4 for mean scores and standard deviations), showed three different significant effects in the assessments (First<Second<Third) for the tasks 1, 2, 3, 4, and 6, respectively. Two different statistical effects were observed only for task 5 (First<Second=Third). The effect of the PADP program was significant between the first two assessments and promoted a positive effect for the follow-up. In addition, the variability decreased during and after the program implementation.

The post-hoc analysis regarding the CG showed two different statistical effects (First=Second<Third) for all the six tasks (see table 4 for mean scores and standard deviations). Between the first two assessments, no significant changes were found, but between the second and third assessments, significant improvements occurred due to the PADP program in a similar fashion as it happened for the EC (see figure 3).

Qualitative assessment

When asked about syllabic awareness, the three kindergarten teachers involved in the qualitative assessment of the program reported that it had contributed to the improvement of the children's PA. Concerning the evaluation of intrasyllabic awareness, two of the teachers thought that the children improved greatly, and one teacher believed that there was some improvement. Finally, two teachers reported that the children showed a large improvement in segmental awareness, and one teacher reported that there was good improvement.

Similarly, 71.4% of the participants' parents thought that their children's phonemic awareness skills improved greatly, 26.5% reported that there was good improvement, and 2.0% thought that there was some improvement. Regarding syllabic awareness, 69.4% of parents believed that the children showed great improvement, 20.4% believed that there was good improvement, and 10.2% believed that there was some improvement. The majority of children (95.9%) reported that they enjoyed playing the PADP, and 87.8% said they would like to play it again.

Discussion

The aim of the present study was to analyze the effectiveness of the PADP in preschool children with typical language development. The sample size characterization, showed a difference between the number of female and male children in the experimental and control groups. This difference was due to the random distribution generator used to establish the EG and CG. However, this gender imbalance was not significant in our results. Also, the studies presented by Balestrin, Cielo, & Lazzarotto (2008) Lonigan, Burgess, Anthony, & Barker (1998) Santos & Maluf (2010) Yes-Yes (1998) and Veloso (2003), show that the gender does not influence the results in FC. A similar mean age in both groups was observed in the first assessment, indicating that age did not significantly influence the results.

In the first assessment, the syllabic segmentation task and the syllable identification task presented higher scores for both groups. The syllable omission, onset-rime units' segmentation, phoneme segmentation, and phoneme blending tasks presented low scores. As the children in this study are on average 5 years old, these results were expected for the level of syllabic awareness, since at this age children are more sensitive to this level of PA (Freitas et al., 2007; Maluf & Barrera, 1997). Because intrasyllabic and segmental awareness levels are more complex for this age (Afonso, 2015b; Rios, 2009; Sim-Sim, 2001; Veloso, 2003), lower results were expected for these PA levels.

When comparing the results obtained on first assessment in each of the tasks, among the two groups, we found that the groups did not differ. Only the syllabic segmentation task revealed statistically significant differences between the groups, with a p-value very close to the significance level ($p=0.046$). Therefore, the EG and the CG were in similar circumstances prior to the implementation of the PADP.

In the implementation of the program in the EG, the statistical results showed significant differences in the average scores of all tasks among the different assessment moments. The interaction between the group and assessment moment was also significant for all tasks. These results show the effectiveness of the PADP in promoting improvements in PA. Although we used different methodologies (e.g., sample sizes, PA levels included in the programs), the results obtained are consistent with the results of international studies by Brady et al. (1994), Brennan and Ireson (1997), Byrne and Fielding-Barnsley (1991), Carson et al. (2013), Olofsson and Lundberg (1985), and Segers and Verhoeven (2005), which also showed positive effects of stimulation programs in the development of PA in typically developing preschool children.

The analysis of the results also demonstrated positive improvement in the EG, from the first assessment to the second assessment, in the different levels of evaluated PA. In the CG, the results were similar in both assessment moments, except for the segmentation test in syllable constituents, where there was a slight regression. These were the expected results because only the PADP has been implemented in the EG.

At a later stage, the PADP was also applied to the CG. Then both groups were reevaluated. A positive development can be found in both groups, once again reinforcing the effectiveness of the program in promoting improvements at the PA level, and suggesting that a higher improvement occurs only when the program is implemented.

There were also no significant differences between groups after the implementation of the PADP for all tasks. This analysis showed that the program was successfully applied in both groups, and once again displaying its positive effect on the development of PA.

Finally, the follow-up to the EG was performed by analyzing the results obtained in the first, second, and third assessment moments, which showed the presence of statistically significant differences between the assessment moments for all tasks. In addition, the multiple comparison results concluded that these three assessment moments presented significantly different results in tasks 1, 2, 3, 4 and 6. Task 5 showed results without significant differences between the second and third assessments. Thus, the results showed the maintenance of the positive effects of PADP two months after the implementation of the program. Moreover, the findings showed that the implementation of this program enhances the independent development of this competence. These results are in line with the results obtained in studies by Olofsson and Lundberg (1985) and Segers and Verhoeven (2005), which show that PA gains are maintained after a period of time. Generally, the kindergarten teachers and the parents reported that the program contributed to the child's PA development in both phonemic and syllabic levels and that the children enjoyed the program. These views support the findings of the study, a significant improvement of children's abilities after the implementation of the program.

The qualitative analysis of the children's questionnaire revealed that a high percentage of children enjoyed "playing" PADP and would like to play it again, which reinforces the ludic and dynamic nature of the program. The results obtained from the questionnaire for teachers reveal that all of them considered PADP effective in stimulating PA. Therefore, this program can be a useful tool for kindergarten teachers to use in their educational context. Lastly, the questionnaire for parents showed their perspectives and the impact of the program in the natural context of the children. Some simple examples were used throughout the questionnaire in order to enable the comprehension of the questions and consequently obtain their perception about the implementation of the program. The results showed the positive effects that the program presents outside of the context where it was applied. Professionals that work with children often feel the need to innovate and expand the strategies and activities used. One solution to this issue is the use of software to better suit the actual interests of today's children (Pereira, Brancalioni, & Keske-Soares, 2013)which was designed according to the curricular objectives and the subject matter of the Greek high school Computer Science (CS. The use of a computer game-based approach to teaching and learning is considered an effective tool that can promote and enhance learning experiences and children's motivation (Papastergiou, 2009)which was designed according to the curricular objectives and the subject matter of the Greek high school Computer Science (CS. This study showed that our digital program was effective in stimulating PA skills. The program can make the work more fun, dynamic and motivating for children attending preschool and aged 4 to 6 years old.

Thus, this program distinguishes itself from the rest (already validated) by being available for iOS and Android (e.g., for a tablet), which can currently be an advantage. However, considering the potential risks of too much screen time, the program only includes 11 activities. Other advantages are the inclusion of the the three levels of PA (syllabic, intrasyllabic, and segmental awareness), and the control of linguistic variables (*word length, syllable structure, word stress* and *segmental properties)* in the selection of stimuli.

The first author conducted the intervention being aware of the aim of the study and this might be considered a limitation. Future research should examine the effects on early literacy skills of children, beyond PA and adaptation of the program to other languages (e.g., English). Additionally, the same subtests were used at the second and third assessment moments, and this could have influenced the results. Although this procedure is line with other recent similar study (e.g., Vanbecelaere et al., 2020).

Conclusions

The present study was undertaken to analyze the effectiveness of the Phonological Awareness Digital Program, and it was seen as a useful tool for different professionals working on PA in preschool children. In addition, the PADP promoted the development of PA (at different levels), with statistically significant results. These results are supported by the experimental group, after the PADP implementation, showing a significant improvement over a control group, which was not a target of this program's implementation. When the PADP was implemented in the CG, the results were identical to the ones obtained by the EG. Moreover, the follow-up study conducted in the EG showed that the improvement in PA was maintained over time.

Thus, the PADP is an effective program that promotes the development of PA, giving children the ability to manipulate and reflect on phonological units, and it may facilitate later learning of reading and writing. This program becomes particularly relevant at the present time considering the pandemic 19 and the consequent need to use validated digital materials in kindergarten context.

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