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Research paper

Efficacy of Berni: A software for preschoolers at risk of dyslexia☆

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ABSTRACT

The signs of dyslexia can appear as early as preschool. Teachers need effective and efficient programmes to overcome the difficulties these children face, making use of the available resources. The purpose of this study was to design an educational software that would enable effective intervention to improve the early difficulties of children at risk of dyslexia, and that a preschool teacher could apply in the classroom in an inclusive manner. Hence, the software named Berni was designed as an early intervention measure to overcome difficulties in phonological awareness, verbal memory, alphabetic awareness, receptive language and print awareness. The sample included 43 preschoolers aged 4 and 5 years old from 7 schools in the Basque Country (Spain), who showed warning signs of dyslexia. To evaluate the software, half of the participants used the Berni software in their regular classroom and a pre-test/intervention/post-test design was used with a control group. The results showed that multimedia training with the Berni programme helped to overcome difficulties in the variables that better predict dyslexia: phonological awareness, rapid automatised naming and verbal memory. Furthermore, teachers and children consider the Berni software to be perceptible, operable and adequately developed. Teachers consider it to be appropriate to the curriculum, effective and conducive to learning. However, autonomous use, feedback and adaptation possibilities could be improved.

1. Introduction

In the field of education, most curricular content is conveyed and internalised by means of reading and writing. Reading is a complex but fundamental skill to achieve academic success. However, depending on the language and culture in question, some 5%–15% of school-age children show difficulties in learning to read (Anon, 2014; Becker, et al., 2017). In the case of opaque languages such as English, almost 20% of the population show dyslexia-related traits, for example: problems with spelling, slow or poor reading skills (International Dyslexia Association, 2008). In the case of transparent languages such as Spanish or Basque, the prevalence of dyslexia is 3.2% (Jiménez, Guzmán, Rodríguez, & Artiles, 2009). Therefore, we can see that dyslexia is a common disorder that affects a significant number of children and adults around the world (700 million people, according to the Dyslexia and Literacy International organisation, D&LI).

Dyslexia is defined as a specific learning difficulty affecting the ability to read and write; it is hereditary and results from a basic phonological deficit (Snowling & Hulme, 2011). The most frequent way to detect a child with dyslexia is through poor performance at school (Carrillo, Alegría, Miranda, & Pérez, 2011), due to their reading abilities being below the levels expected for their current age (Becker, et al., 2017). This means that diagnosis and intervention protocols are not activated until a child fails, which affects the intervention's effectiveness and heightens poor academic performance and problems of an emotional nature (Nielsen, Andria-Habermann, Richards, Abbott, Mickail, & Berninger, 2018). Nevertheless, advances in recent years regarding the nature, etiology and assessment of dyslexia mean that it is now possible to recognise signs that a child is at risk of dyslexia as early as in Kindergarten stage (Caglar-Ryeng, Eklund, & Nergård-Nilssen,

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2019). This early identification should enable interventions to be implemented which would prevent pupils from falling into a downward spiral of underachievement, lowered self-esteem and poor motivation (Snowling, 2013). With this purpose in mind, an early intervention programme has been designed as part of this research project as a measure to identify the early possible signs of dyslexia and provide help with developing interventions to target skills needed to ameliorate or improve reading skills.

1.1. The impact of early identification and intervention

Research has shown that predictors of reading are indicators of reading success or failure in early years (Nohales & Giménez, 2008). So any apparent difficulties in these pre-reading skills during the Kindergarten stage enable the identification of pupils who are at risk of having reading problems (Lohvansuu, Hämäläinen, Ervast, Lyytinen, & Leppänen, 2018; Lonigan, 2006). One of the warning signs that has received most empirical backing is phonological awareness. It has been shown that the greater the phonological errors, the worse the reading outcomes (Bridges & Catts, 2011; Mayer & Motsch, 2015). However, there are other warning signs associated with the presence of difficulties in reading acquisition, such as difficulties in naming speed, alphabetic principle, verbal memory, receptive–expressive language or print awareness (Bowey, 2008; Catts, Fey, Zhang, & Tomblin, 2001). Nevertheless, the value for predicting future reading difficulties is different in each one, with difficulties in phonological awareness, letter knowledge and naming speed being the warning signs that best predict the presence of a level of dyslexia (Caravolas, et al., 2012; Ozernov-Palchik, et al., 2017; Snowling, 2013).

Early detection of these warning signs offers the chance to set preventive interventions in motion that are aimed at reducing the risk before the formal teaching–learning to read process begins. Early identification and intervention regarding the precursors of dyslexia have been proven to enable children to improve the necessary skills to deal with reading and reduce the difficulties they start off with Mayer and Motsch (2015) and Poulsen, Nielsen, Juul, and Elbro (2017). Early identification entails a proactive strategy in the identification of learning difficulties. It represents an alternative strategy to the reactive intervention model that just "waits for failure" (Luque, Giménez, Bordoy, & Sánchez, 2016). The proactive model also makes it possible to plan written language teaching, taking into account the detected difficulties and the needs of each child (Carrillo, 2012), which increases the prospects of adequate reading and writing development (Hulme & Snowling, 2009).

1.2. Computer game-based practice and early intervention for dyslexia

Children at risk of dyslexia require an intervention programme with a more individualised approach (Torgesen, 2002). Computer-assisted teaching of reading has been studied as an intensive and feasible method of teaching that is aimed at the individual (Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011). The intervention of computer-assisted reading has been shown to be effective in teaching children in a situation of risk (Regtvoort & van der Leij, 2007; Saine et al., 2011).

At present, and with access to digital educational content, there is an abundance of online games and mobile apps aimed both at training pre-reading skills and at their difficulties. Thus, Table 1 describes the objectives and age of the children targeted by technology-mediated interventions, which have proved their effectiveness.

Recently there has been significant growth in computer-based interventions for children with special educational needs. In the case of dyslexia, the aim of most of these computer games is to intervene in the difficulties of children diagnosed with dyslexia (Dickinson, McCabe, & Sprague, 2003; Lonigan & Purpura, 2009; Saine et al., 2011; Ven, Leeuw, Weerdenburg, & Steenbeek-Planting, 2017). Other studies aim to improve the early difficulties in children at risk of dyslexia, but target

Table 1
Evidence-based games for dyslexia intervention.

Computer game	Author	Objective	Age
GraphoGame	Lyytinen et al. Lyytinen, Ronimus, Alanko, Poikkeus, and Taanila (2007)	To improve the phonemic awareness and letter-knowledge processes of children with learning disabilities at an early stage.	6–8
EasyLexia	Skiada et al. Skiada, Soroniati, Gardeli, and Zissis (2014)	Mobile application to improve reading comprehension, orthographic coding, short-term memory and mathematical problem solving.	7–12
DysWebxia	Rello and Baeza-Yates Rello, Bayarri, Otal, and Pielot (2014)	To facilitate the spelling acquisition of reading in children with dyslexia.	6–11
ilearnRW	Zakopouluo et al. Zakopoulou, et al. (2017)	To enhance learning during intervention procedures to improve reading skills for children with dyslexia.	9–11
Lexia	McMurray McMurray (2013)	Web-based reading intervention designed to enhance reading through a phonics-based approach.	6–7
Tradislexia	Jiménez et.al. Jiménez and Rojas (2008)	To train the impaired cognitive processes of children with dyslexia.	9–14

children over the age of 6 (Lyytinen et al., 2007; McMurray, 2013; Rello et al., 2014; Skiada et al., 2014).

However, according to the education systems of some countries, the age at which children begin learning to read corresponds to Grade 1. Nevertheless, it is at the preschool stage when students begin to work on the alphabetic principle and phonological awareness. Thus, given the fact that scientific literature has proven that warning signs associated with the presence of difficulties in reading acquisition are phonological errors (Bridges & Catts, 2011; Mayer & Motsch, 2015), naming speed, alphabetic principle, verbal memory, receptive–expressive language and print awareness (Catts et al., 2001), it is more than likely that difficulties could be detected before learning to read. Consequently, interventions can be made to improve them and enable students to deal with such a complex process as learning to read.

On the other hand, many of the studies reviewed do not determine whether the tool has been used in a regular classroom or in a differentiated one; whether it was led by the teacher, the school specialist or by the researchers; whether the children used it in small groups or individually, neither are the resources of the classroom or the teacher described. However, this information is important in order to be able to assess whether the tools we create and empirically evaluate will have a real application in classrooms, given the conditions and resources available. Furthermore, in relation to design, the evaluation of interactive applications for children has to be studied from the field of Child–Computer Interaction (CCI) (Hourcade, 2015). Child–Computer Interaction is an emerging field that has recently focused on participatory design, tangibles, design and education, as Giannakos, Papamitsiou, Markopoulos, Read, and Hourcade (2020) conclude in their mapping of the intellectual progress of CCI research. In the field of design for children, human–computer interaction guidelines have been developed that are useful for guiding perceptibility, operability and developmental fit (Hourcade, 2015). Similarly, design evaluation has also been explored further as a central aspect of product development, either to assess the suitability or success of a product, or to identify features that need to be improved or redesigned (McKnight & Read, 2011).

In the context in which this research takes place, the resources required to carry out an intervention from an inclusive point of view are lacking. Early, preventive and inclusive intervention is supposed to be implemented in a regular classroom, but with a ratio of 25 children per classroom at the preschool level and with just one computer, this type of intervention is not feasible for one single teacher. So, as long as the difficulties are very evident, the specific programmes are not implemented.

So, the main objective of this research study was to design and assess an educational software programme, which was called Berni, as an intervention tool in addressing dyslexia, that can be implemented in a regular classroom, using the computer corner and with only one teacher per class.

To assess the effect of the Berni software, the following research questions were raised:

1. Do the pupils who receive the Berni intervention programme show a greater degree of improvement in the difficulties indicated as early signs of dyslexia than those pupils who do not receive the same training?
2. Does the improvement in the pre-dyslexic manifestations lead to an improvement in their pre-reading skills in general?
3. Is Berni a useful tool from a child–computer interaction point of view?

2. Method

2.1. Participants

In total, 417 pupils aged 4 and 5 years old from 7 schools in the Basque Country (Spain) participated in this research study.

The school, teachers and parents/guardians of the children were informed about the objective and procedure of the research at common meetings in each school. Informed consents were collected from the parents/guardians of the children in those schools that agreed to participate in the study. The right to revoke consent and to know the results of each child was stated in the document signed by the parents/ guardians. Finally, the classroom teacher and the researchers were responsible for explaining the purpose and the voluntary nature of playing the game to the children.

To select the experimental sample, the teachers' judgement was taken into account, as their contributions have proven to be valuable in the assessment of language and literacy in children due to their observational experience and in their extensive direct contact with children (Lonigan & Purpura, 2009). Nonetheless, in order to provide a more uniform basis for assessment, the teaching staff underwent training sessions in which the skills that facilitate and predict reading were specified and in which they were shown how to identify the difficulties involved. At the same time, the teachers had a translated and adapted version of the *Teacher Rating of Oral Language and Literacy* (TROLL) scale (Dickinson et al., 2003), which had also been approved by experts to assist with the selection process. The teachers identified 43 pupils who looked to be potentially at risk of reading difficulties. As can be seen in Table 2, approximately half of the children at risk underwent the intervention programme (Experimental group — EG) and the other half did not (Control Group — CG). The groups were distributed according to an assignment criterion: the children identified with early signs of dyslexia were distributed according to their belonging to the same class, in the same school. The criterion was that, if intervention was considered necessary, all the children who had difficulties in that class ought to be subjects of the intervention. On the one hand, this did not generate differences between the responses given by the teacher to the children's similar difficulties, and on the other hand, it gave the option to the rest of the children to play with the software without interfering with the results of the research.

The control group were children with early signs of dyslexia in the same classroom. In total, 16 classes from 7 schools were involved, and in each class 2–4 children with signs of risk of dyslexia were detected. In the end, 23 children with dyslexia risk signs from 8 classes received intervention, and 20 children with dyslexia risk signs from 8 different classes did not receive intervention.

With the comparison of the control group we want to control the effect of the teaching–learning process in the classroom and discover which improvements are attributed to the software and which to the development of the curriculum.

2.2. Berni intervention software

The Berni educational software is based on the integration of three areas of knowledge: pedagogy, psychology and linguistics, and was developed to include the areas of perception, language and thinking. The early intervention programme offered through the Berni software aims at minimising difficulties in phonological awareness, naming speed, alphabetic principle, verbal memory, receptive–expressive language and print awareness skills. The software introduces an intervention based on the Response to Intervention (RtI) model. This approach focuses on the prevention of risk pupils' learning difficulties and includes monitoring processes and empirical-based interventions (Fletcher & Vaughn, 2009). The RtI model comprises three levels of intervention: (a) preventive and proactive, where generalised teaching is given to the class group and the pupils are assessed at an early stage to determine whether or not they show signs of having learning difficulties; (b) empirical-based prevention-intervention programmes in small groups for those pupils who are in a situation of risk and who are showing no signs of improvement; (c) intensive and individualised interventions for those students who are not making adequate progress (Jiménez, et al., 2011). The Berni software fits into the second phase of the RtI model.

The software has been designed over three design phases delimited by Londoño (Londoño, Alvarez, Chiappe, & Ramirez, 2002).

Phase I entailed the instructional design of the intervention programme. To do so, a team of psychologists and linguists defined and operationalised the warning signs of reading difficulties, setting out the skills to exercise, their dimensions and the achievement indicators, as shown in Table 3.

In turn, in order to design the type and quantity of activities and their time frame, the **predictive value** of each skill was taken into account as regards the presence of reading difficulties (Caravolas, et al., 2012; Snowling, 2013). So, the time frame for the intervention programme (40 min per week for 8 weeks) and the number of activities were distributed according to the predictive value of each skill. A greater number of activities were designed in the case of the phonological awareness (40%), verbal memory (27%) and alphabetic awareness (16%) variables; and fewer for all the other skills (10% receptive language, 7% concept of writing). To define the difficulty of each level, we refer to the linguistic and psycholinguistic literature that studies the process of acquisition of each variable and its dimensions in the learning of oral and written language (Lohvansuu et al., 2018; Ozernov-Palchik, et al., 2017; Snowling & Hulme, 2005). Appendix A lists the Berni Software Activities at each of its levels.

Phase II entailed the Communicative Design, which defined the level and types of interactivity, and the design of the interface, taking into account the language and navigation structures, as well as the interaction of users with the software.

The design of the educational software had to be simple, with a structure that allowed teachers to modify the contents (if needed in the future) and registers. In addition, it should allow for the data of each

Table 2
Distribution of the sample.

	Reading difficulties + Berni intervention EG[a]	Reading difficulties + NO intervention CG[b]
Number of pupils	23	20

[a] Experimental Group
[b] Control Group

Table 3
Variables, dimensions and achievement objectives to exercise in the Berni software.

Variable	Dimensions	Achievement objectives
Phonological awareness	Rhyme and alliteration Syllable awareness Intra-syllable awareness Word awareness Phonemic awareness	To identify and differentiate phonemes. To differentiate and identify the syllables that make up a word. To relate phonemes with spelling. To detect similarities and differences between sounds.
Alphabetic knowledge	Representation of objects Logographic stage Alphabetic stage	To work with pictographic images of objects to check that they have mastered the pictographic stage. To develop the logographic stage, analysing writing in general. To implement the first steps of phonological decoding, in order to start understanding the alphabetic principle through the grapheme-phoneme relationship.
Verbal memory	Enriching vocabulary Rapid verbal processing Oral comprehension Morphological awareness Verbal working memory	To develop and enrich vocabulary. To name objects and colours with the appropriate speed according to age (RAN). To understand oral instructions. To develop morphological awareness. To memorise word sequences.
Receptive language	Form Content Use	To strengthen comprehension capacity. To use the appropriate vocabulary according to age in expressive language. To develop and work on morphosyntactic structures.
Concept of writing	Concept of words Quantity hyp. Variety hyp. Start of syllabic hypothesis Directionality	To understand the objectives and functions of the written language. To interpret that text communicates messages. To differentiate words, assimilating the hypotheses of quantity and variables. To identify the direction of words, text and pages.

student to be collected, taking into account that different children could play on the same device, and that the profiles had to be updated every year. All the modifications in the programme would depend on the teachers, so we decided to create a folder structure, where teachers could easily update the profiles or even the images and sounds to adapt them to the school curriculum.

Thus, a teacher without programming skills could change the multimedia content of the game and change the number of activities per game.

A team of psychologists, linguists, teachers and computer specialists analysed the above-mentioned needs. Finally, Berni is installed as a main folder containing an executable file, a folder for each level, a folder for the users' registers, a folder for prizes with badges, drawings and diplomas for the children and the set sounds of the game.

The first requirement for the Berni software to work properly is to create profiles for teachers and students in the users' registers folder. The access interface has two steps: (1) access to the teaching staff, where each teacher types in their name; and (2) access to the student profiles, which may be up to 30 students per teacher. By selecting the name of a student, access is given to games, levels and exercises. This allows the game to record the student's achievements.

The Berni software has five levels of difficulty and five types of games in each level (see Fig. 1): an animated video, a game in which you have to choose the correct answer, a game involving dragging images, a game to match pairs and a game for working on naming speed. Appendix B compiles examples of game types and their contribution to the variables.

It is necessary to complete all the activities of each level to pass to the next one, but students can choose the type of game to play at any of the levels. In total, the software programme includes 98 activities and an animated character, Berni the dog, specifically designed to guide the child and encourage them in performing these activities. The dog explains what to do in the activities, congratulates them on their progress, and, if needed, encourages repetition through different messages. The purpose of this is to boost the pupils' autonomy and facilitate inclusive use in the classroom.

Finally, the game contains a folder with badges that the teachers give to the students upon completion of a level, and a diploma awarded to the children when they finish the game. Also attached are drawings by Berni to paint.

Lastly, **Phase III** entailed the computer design, defining the technical requirements and designing the system in its local version. Berni as executable file, has been created in Adobe Flash Professional 8 and ActionScript 2 and is available in a portable format. The source code of the game is available at: https://github.com/AinaraRomero/Juego-Berni

2.3. Assessment instruments

Two instruments were used to assess the Berni software: (1) the BIL 3–6 test (*Batería de Inicio en Lectura 3-6* [Series of tests for learning to read]) (Sellés, Martínez Vidal, & Gilabert, 2008) to assess the predictive and facilitating reading skills. This method comprises 15 sub-tests grouped into 5 factors and 143 items (phonological knowledge, alphabetic knowledge, metalinguistic knowledge, linguistic skills and cognitive processes). To interpret the results, "Summary Pages" were used, which compiled the percentiles corresponding to the scores in each sub-test (according to age) and the percentile $\leq$ 30 condition was taken to confirm the teachers' identification of pupils at risk. (2) The Dyslexia Early Screening Test-2 (DEST-2) (Nicholson & Fawcett, 2003), a brief set of screening tests for dyslexia, made up of 12 sub-tests. To interpret the results, "key risk rating scores" were used and the pupils who obtained the maximum risk indicator were taken into account to confirm the teachers' identification of pupils at risk.

With the different sub-tests in each method, the difficulties shown by the children in the EG and the CG were measured in each dimension of the pre-dyslexic variables, as well as the level of dexterity shown in the skills facilitating reading, before and after the intervention.

2.4. Procedure

After the teachers had selected the pupils at risk of dyslexia, BIL 3–6 and DEST-2 standardised tests were used to more specifically and sensitively mark out the identification of pupils at risk (Snowling, Duff, Petrou, Schiffeldrin, & Bailey, 2011), as well as to measure the degree of difficulty shown both in the EG and the CG. Furthermore, the pre-reading skills of the EG and the CG were also measured.

Non-discrimination, the need to avoid labels and respect for inclusion were central to this research. The groups were distributed according to the assignment criteria described in the Participants section. After selection, the software was installed, and a software guide was provided, along with some guidelines to assist the teachers. Each pupil in the experimental group received 2 weekly sessions lasting 20–30 min each, and they needed 12 weeks to complete the programme. Except for the first 2–3 sessions that the pupils needed to understand the game's dynamics and how to use the mouse (drag and click), the pupils completed the Berni programme autonomously. The intervention took place in the classroom with all the other students and in the computer corner. In order not to differentiate these children, in the classrooms where the intervention with Berni took place, the rest of the students were also able to play with Berni occasionally.

Once the intervention was over, an analysis was carried out to see if the children in the EG had made any improvement in the early signs of

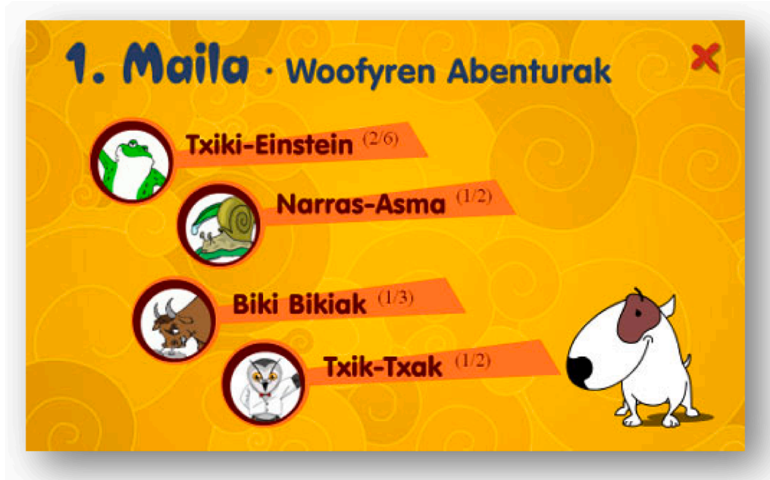

Fig. 1. First level game screen. Note: Main screen of the first level giving access to the four types of games. The activities carried out in each game are shown in brackets. The student only passes the level once they have completed all the activities of the four games correctly.

dyslexia and in their pre-reading skills in general, as regards the group that underwent no intervention. Furthermore, the improvements obtained as regards the group without any difficulties were also compared. For this purpose, the dimensions of the pre-dyslexic variables and the pre-reading skills of the EG and CG groups were once again measured.

Finally, in order to value the interaction between the children and Berni, we followed the guidelines proposed by Hourcade (Hourcade, 2015) and assessed how children can perceive and handle the user interface, and whether the interface is developmentally appropriate. In addition, to evaluate the inclusion of the software in the children's learning process, the framework developed by McKnight and Read (McKnight & Read, 2011) was taken into account. These authors distinguish between evaluating for play (considering fun, entertainment and experience), for learning (considering pedagogy, effectiveness and learning outcomes) and for use (considering usability, accessibility and efficiency). Bearing in mind that our participants are learners, the dimensions of curricular adaptation, effectiveness and learning outcomes have been addressed in the evaluation. The aforementioned dimensions (perceptibility, operability, developmental fit, pedagogy, effectiveness and learning) have been measured and contrasted through the answers given to questionnaires for 8 teachers and 23 students. For teachers, a Likert scale with 5 response options was used, and for children, a 3-point Smileyometer (Read & MacFarlane, 2006; Zhang-Kennedy, Abdelaziz, Chiasson, & S, 2017). Fig. 2 shows the aspects of each dimension that each informant was asked about.

3. Results

We first examined potential group differences in baseline pre-reading skills and training performance. Then, the effect of Berni training on articulation, phonological differentiation, rhyme, counting

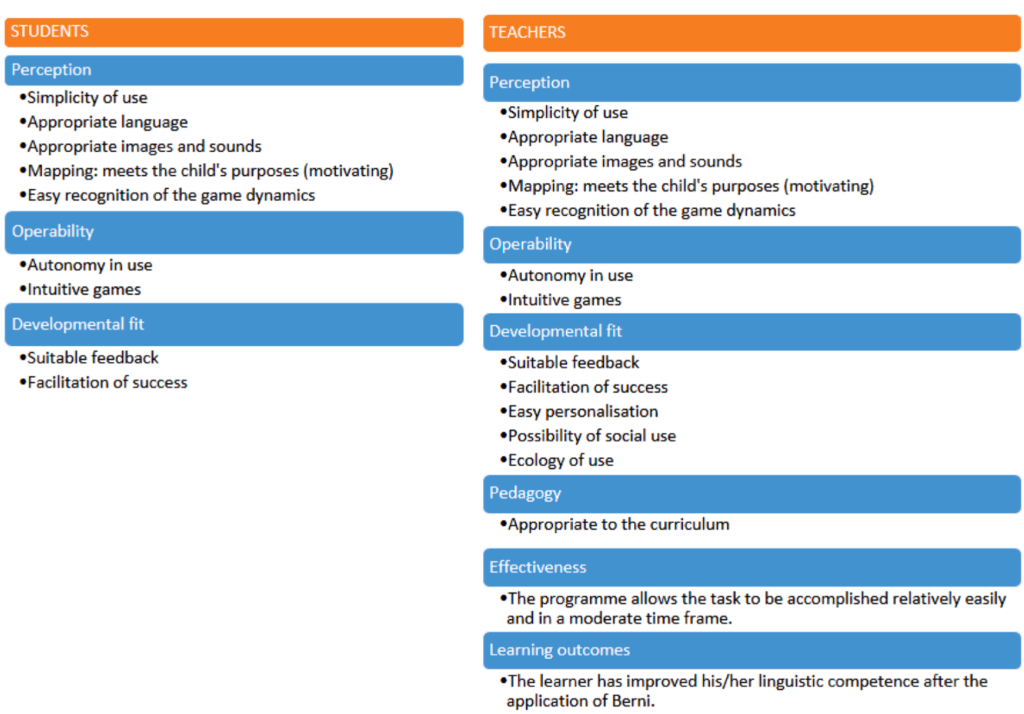

Fig. 2. Dimensions and variables of the teacher and student questionnaires to assess the usefulness of the software.

syllables and phonemes, omitting syllables, letter knowledge, naming digits, remembering digits, vocabulary, RAN, auditory sequential memory, perception, word recognition, sentence recognition, reading functions, counting words, grammar construction and basic concepts, and phonological awareness were measured by comparing the results of the experimental and control groups. All analyses were done using IBM SPSS Statistics 23. Corrected p values ≤.05 were considered significant and p values ≤.1 were reported as trends. Finally, we calculated effect sizes of the most relevant effects using analysis of covariance (ANCOVA).

Research question 1 asked: *Do the pupils who receive the Berni intervention programme show a greater degree of improvement in the difficulties indicated as early signs of dyslexia than those pupils who do not receive the same training?* With regard to this question, the EG and the CG have been compared in each of the dimensions of the warning signs of dyslexia. Intervention with the Berni programme was taken as the independent variable or A Factor, the results of the 19 sub-tests in the DEST-2 and BIL 3–6 were taken as dependent variables, which were used to measure the pre-dyslexic manifestations (articulation, phonological differentiation, rhyme, counting syllables and phonemes, omitting syllables, letter knowledge, naming digits, remembering digits, vocabulary, RAN, auditory sequential memory, perception, word recognition, sentence recognition, reading functions, counting words, grammar construction and basic concepts), and the score obtained in the pre-test as a covariate.

The results of the analysis of covariance (see Table 4) indicate that the intervention was effective in all the dimensions of phonological awareness, receptive language and print awareness. In the case of phonological awareness, the intervention was more effective in improving the dimensions of phonemic awareness (Phonological distinction F(2.39)=82.72, p=.000, η^2=.68) and syllable awareness (Isolating syllables and phonemes F(2.39)=53.26, p=.000, η^2=.57), and not so effective in improving word awareness (Counting words F(2.39)= 7.01, p=.0125, η^2=.15).

In the case of the verbal memory variable, the statistical analysis shows that the intervention with the Berni software was effective in improving the dimensions of RAN (RAN F(2.39)=65.37, p=.000, η^2=.63), verbal working memory (Auditory sequential memory F (2.39)=181.81, p=.000, η^2=.82) and morphological awareness (Knowledge of word structure F(2.39)=26.59, p=.000, η^2=.40), but not the vocabulary dimension (F(2.39)=.18, p=.741, η^2=.00).

Lastly, in the alphabetic awareness variable, both the EG pupils and the CG pupils improved their scores (EG x̄=13.22, SD=2.52; CG x̄=12.89, DT=3.17), so their improvement cannot be attributed to Berni (F(2.39)=.13, p=.716, η^2=.003).

Research question 2 asked: *Does the improvement in the pre-dyslexic manifestations lead to an improvement in their pre-reading skills in general?* With regard to this question, a comparison was carried out between the group of children with warning signs who received the Berni intervention programme (EG) and the group of children at risk who did not receive the programme (CG), in the 5 skills that facilitate reading, measured using the BIL 3–6 test. In these cases, the group of which they formed part (participating in Berni/not participating in Berni) was taken as the independent variable and the dependent variable was the score obtained in the post-test phase of each of the mentioned variables, and the pre-test phase of those variables as a co-variant. The results of the analysis of covariance (ANCOVA) show that the children with difficulties who underwent the Berni intervention improved their phonological knowledge (F(2.39)=94.19, p=.000, η^2=.71), metalinguistic knowledge (F(2.39)=51.19, p=.000, η^2=.57), linguistic skills (F(2.39)= 17.14, p=.000, η^2=.30), and cognitive processes (F(2.39)=164.20, p=.000, η^2=.81), when the pre-test scores were controlled (see Table 4). Of all the indicated skills, phonological knowledge is the skill that shows a greater level of improvement. However, in the case of alphabetic knowledge, as shown in the first analysis, the pupils at risk who underwent the intervention using Berni improved their results, but those who showed difficulties and did not undergo intervention also improved. For this reason, that improvement cannot be attributed to the Berni software (F(2.39)=.134, p=.716, η^2=.003) (see Table 5).

The BIL 3–6 test also measures the *total score* factor, associated with the extent to which the child develops the different skills together that facilitate the acquisition of language. With regard to the total score

Table 4
Differences in the pre-dyslexic variables in the post-test phase between the EG and the CG.

Variables	Subtest used	Pre-test				Post-test					
		CG		EG		CG		EG		F	η^2
		n = 19		n = 23		n = 19		n = 23			
		x̄	SD	x̄	SD	x̄	SD	x̄	SD		
Phonological awareness	Articulation	6.84	1.42	6.83	3.34	8.84	1.26	10.30	1.43	14.49***	.27
	Rhyme	2.95	1.22	2.57	2.07	3.84	1.92	6.30	1.49	26.04***	.40
	Counting syllables	6.32	2.43	6.74	3.31	8.74	1.91	11.39	1.85	20.21***	.34
	Isolating syllables and phonemes	3.68	1.20	3.61	1.98	3.79	1.08	6.04	3.68	53.26***	.57
	Skipping syllables	1.47	0.90	1.48	1.46	1.89	0.94	3.22	1.47	39.87***	.50
	Counting words	2.84	1.21	2.78	1.80	3.63	0.83	4.48	1.16	7.01**	.15
	Phonological distinction	4.47	1.07	4.52	2.33	4.79	1.03	7.39	0.94	82.72***	.68
Alphabetic awareness	Knowledge of the names of letters	5.11	1.70	5.13	1.84	12.89	3.11	13.12	2.52	0.13	.00
Verbal memory	Vocabulary	3.21	1.13	3.39	1.98	4.89	1.05	5.04	0.93	0.181	.00
	Naming digits	3.68	1.16	4.09	3.13	4.63	1.12	5.61	1.20	8.02**	.17
	RAN	51.11	7.70	50.04	14.42	73.89	9.49	56.87	4.13	65.37***	.63
	Auditory sequential memory	14.05	3.89	14.09	4.13	16.32	1.49	24.13	2.20	181.81***	.82
	Memory of digits	3.53	0.77	3.61	1.68	3.84	0.76	4.22	0.90	2.35	.06
	Knowledge of word structure	5.63	1.01	5.74	2.43	6.79	1.08	8.57	1.12	26.59***	.40
Receptive language	Basic concepts	4.42	0.90	4.13	2.03	4.42	0.84	5.52	1.04	12.62***	.24
	Grammar structure	2.26	0.99	2.22	2.00	2.26	0.73	3.87	0.81	9.44**	.19
Concept of print	Knowledge of sentences	3.32	1.11	3.48	2.25	3.37	0.76	4.17	0.89	43.46***	.53
	Reading functions	1.16	1.01	1.57	1.58	1.32	0.67	2.00	0.74	6.98*	.15

Note: in each comparison, the effect of the pre-test score was controlled.
* $p < .05$,
** $p < .01$,
*** $p < .001$.

Table 5
Differences in pre-reading skills in the post-test phase between the EG and the CG.

	Group									
	EG Pre-test		EG Post-test		CG Pre-test		CG Post-test		F	η^2
	x̄	SD	x̄	SD	x̄	SD	x̄	SD		
Phonological knowledge	13.80	5.09	25.74	2.66	14.11	3.45	17.53	2.99	94.19***	.71
Alphabetic knowledge	5.13	1.84	13.22	2.52	5.11	1.70	12.89	3.11	.134	.003
Metalinguistic knowledge	6.65	2.69	10.15	1.49	6.24	1.97	6.97	1.27	51.19***	.57
Linguistic skills	14.41	3.92	19.89	2.43	14.37	1.90	17.11	1.81	17.14***	.30
Cognitive processes	22.65	6.18	34	2.61	21.95	4.65	24.25	3.49	164.20***	.81
Total score	39.64	7.96	67.52	4.40	39.34	5.37	51.85	6.09	95.99***	.71

Note: in each comparison, the effect of the pre-test score was controlled.
*$p < .05$,
** $p < .01$,
*** $p < .001$

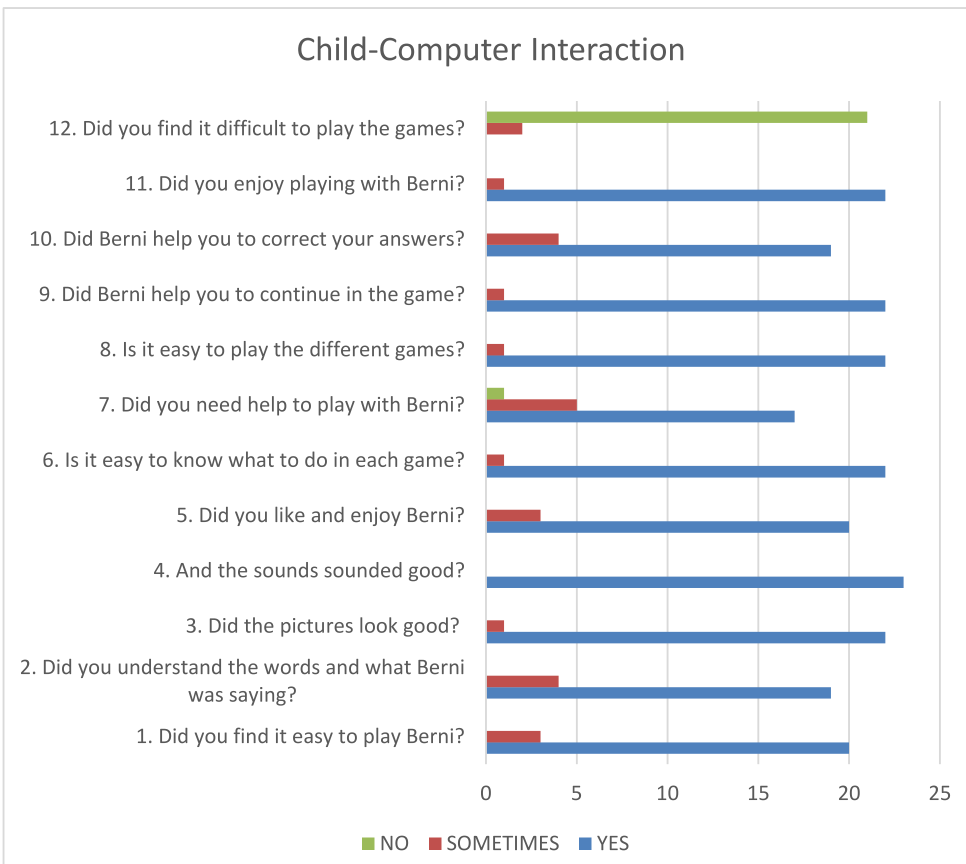

Fig. 3. Student (N=23) responses in the evaluation of their interaction with Berni.

factor (see Table 5), the results indicate that the children who underwent the intervention significantly improved their precursor reading skills in general (F(2.39)=95.99, p=.000, η^2=.71).

Research question 3 asked: *Is Berni a useful tool from a child–computer interaction point of view?* Regarding the evaluation of the child's interaction with Berni, children who have played with Berni report that they perceive the game as simple to use (83% of respondents), with appropriate language (80%) and with fitting images and sounds (90%). In addition, they find the game motivating (83%) and it is easy for them to recognise the dynamics of the game (92%). 20% of the children indicate that they needed help on certain occasions to play the game. Fig. 3 shows the number of pupils per answer for each question.

On the other hand, teachers perceive Berni (see Fig. 4) as simple to use (x̄=4.12), with appropriate language (x̄=4.87), and with audio files and graphic design suitable for the target children (x̄=5). It also considers that the interface adapts to the user (x̄=4) and that students can easily recognise the dynamics of the games (x̄=4). In terms of operability, the autonomous use is not entirely adequate (x̄=3.6), although the games are intuitive (x̄=4). In terms of adequate software development, Berni facilitates the successful development of the game (x̄=4.25) and collaborative use (x̄=4.87) could be carried out in different environments of use (x̄=5). However, teachers do not find the personalisation possibilities of the software easy (x̄=3.25). Finally, teachers find it suitable for the curriculum they are developing (x̄=4.87), effective for its target objective (x̄=3.87) and they have perceived an improvement in the linguistic competence of the children who have used it (x̄=3.87).

From all the above we can conclude that the Berni software is a

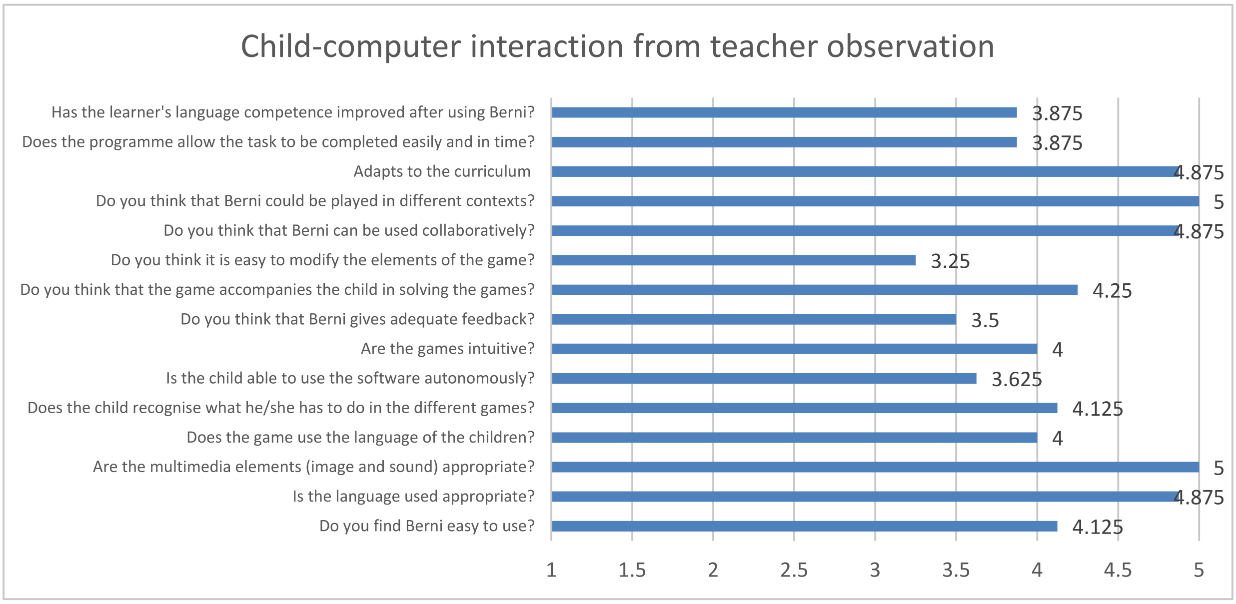

Fig. 4. Level of agreement (average) between the teachers (N=8) in the areas of ease of use, usefulness, satisfaction, and integration in the classroom. Notes: 1=Very poorly, 2= Poorly, 3=Adequately, 4=Well, 5=Very well.

suitable and useful tool for working on the skills that have shown to be best linked with a successful start to reading.

4. Discussion

The main objective of this research was to design and measure the efficacy of the Berni software as an early prevention and intervention measure for the risk signs of dyslexia. It was designed to respond to the second level of the RtI model and has 98 exercises spread over five levels of complexity and aimed at improving difficulties in phonological awareness, verbal memory, alphabetic principle, print awareness and receptive language in preschoolers.

The responses to the research questions raised in this study are clear. With regard to research question 1, the results determine that the children who show risk signs of dyslexia and who receive intervention sessions using the Berni software achieve better results in the assessment of most of the pre-dyslexic signs than those children who do not receive the intervention. In other words, the results show that the Berni software is effective in improving the difficulties related to the main early manifestations of dyslexia. In fact, the children in the EG improved the variables and dimensions that best predict dyslexia (Caravolas, et al., 2012; Ozernov-Palchik, et al., 2017; Snowling, 2013): phonological awareness and verbal working memory. Furthermore, the improvements in the dimensions of each variable coincide with the dimensions that have the greatest predictive value in the development of reading: syllable awareness, phonemic awareness, RAN, morphological awareness and verbal working memory (Chang, et al., 2011).

In the comparison of the results obtained in this research project, no studies have been found that focus on measuring the efficacy of a multimedia intervention for the early signs of dyslexia in children as young as those in our study. In contrast, there are studies that prove the efficacy of computer-assisted instruction in the intervention of dyslexia for children above the age of 6 years old. Torgesen, Wagner, Rashotte, Herron, and Lindamood (2010) compare the LIPS and RWT intervention programmes for Year 2 children, concluding that both are an effective form of supplementary instruction in reading. Along the same lines, there are studies that prove the efficacy of using technological means for the intervention of dyslexia in children aged 6 years and older, such as the Lexia (McMurray, 2013), Dyswebxia (Rello et al., 2014), Easylexia (Skiada et al., 2014) and Graphogame (Lyytinen et al., 2007) programmes, to name but a few. Also, in the comparison of the results, studies aimed at proving the efficacy of conventional interventions (without multimedia resources) in children under the age of 6 years with a risk of dyslexia can also be considered. Although the majority of these research studies are in keeping with this present study and show positive results in the measurement of the efficacy of these interventions, there are also studies showing the opposite. Duff, Hulme, Grainger, Hardwick, Miles, and Snowling (2014) have found that the 9-week intervention undergone by children at risk of dyslexia does not produce any effect on improvements in phonological awareness, alphabetic awareness or vocabulary. These authors attribute that lack of efficacy to the short training period. However, in this research study, the short intervention time has not been an obstacle to improvements in the variables, with the suggestion that the use of a multimedia intervention may be what has made the difference.

In response to research question 2, the results show that the children in the experimental group improved their skills that facilitate reading in general. In fact, the factors that show a higher level of improvement after the intervention are the factors that have a greater influence over the acquisition of reading: phonological knowledge and metalinguistic knowledge. Nevertheless, the existing debate on the extent to which the variables that predict reading differ from one language to another must be taken into consideration, mainly due to the fact that there are differences in the way in which phonology is coded through each language's spelling (Share, 2008). Be that as it may, studies analysing the skills that facilitate reading and writing in Spanish also underline phonological awareness and RAN as the main predictors of reading (Pérez & Zayas, 2008; Serrano, Defior, & Jiménez, 2005; Suárez-Coalla, García-de Castro, & Cuetos, 2013). Although no studies have been found that analyse the relationship and the predictability of these variables for the Basque language, given the similarities in the orthographic transparency of Spanish and Basque, prior studies are considered to be relevant and, consequently, the Berni software is believed to be an appropriate tool for training the main variables that predict reading in Basque.

As regards alphabetic awareness, the effect of the intervention on this variable has not been demonstrated in any of the analyses. Both groups receiving training and those that did not, improved their levels in the assessment of alphabetic knowledge. This improvement is thought to be due to the influence of the teaching–learning process developed in the classroom, as all the class schedules in the 7 schools included the alphabet in their content. This leads us to consider that the systematic, intensive and progressive inclusion of training in other pre-reading skills as part of the curriculum could strengthen the precursor reading skills and reduce the risk of difficulties in all the pupils, as suggested in the National Early Literacy Panel (Lonigan, Schatschneider, & Westberg, 2008) report or the report on teaching reading in Europe (De Coster, Baidak, Motiejunaite, & Noorani, 2011).

Finally, regarding research question 3, the evaluation of the software from a CCI perspective, we conclude that students and teachers consider Berni software to be perceptible, operable and adequately developed (Hourcade, 2015). From a pedagogical point of view (McKnight & Read, 2011), teachers consider it appropriate to the curriculum, effective and that it promotes learning. However, there are areas such as the autonomy of use, the feedback the child receives, and the possibilities for adaptation that need to be improved.

Therefore, the most noteworthy feature of the Berni game is that it offers a specialised intervention but it is developed in the classroom and in a relatively autonomous way. On the one hand, it includes games with a psycho-pedagogical basis that work on the risk signs for dyslexia. On the other hand, children and teachers highlight the following features of the game design: it has a simple structure that is arranged by levels of complexity, it offers feedback that directs the learner, it is simple, intuitive, motivating, and feasible for implementation in the classroom.

4.1. Limitations

The main limitation in this study was the sample size. A range of conditions in the study significantly reduced the number of cases: (a) the condition of Basque being a mother tongue in a population in which only 20% meet this requirement; (b) the inclusive measures that were carried out to boost the programme's set-up in the classrooms; and (c) the availability of technological and personnel resources in the schools.

On the other hand, although Berni has proven to be a viable and effective tool to be implemented in a classroom to improve the early difficulties of children at risk of dyslexia, in the future, the particular sections of Berni's interventions should be further explored in comparison with other specialised interventions.

Lastly, the language in which the software has been developed limits the extrapolation of the results to another context. However, the file structure allows teachers without programming knowledge to adapt the images, sounds and videos. Thus, they can adapt Berni to any other language, to the characteristics of their school and to the needs of the students with special difficulties. In these cases, it would be necessary to replicate the study.

4.2. Implications

The outcomes of the present study indicate that, after a 12-week intervention, the children who undergo multimedia training significantly reduce the risk signs of dyslexia. Consequently, this study provides evidence to demonstrate that a systemised, individualised and intensive intervention such as that offered in the case of the Berni software, has a positive impact on the pre-reading difficulties shown by children at risk of dyslexia in a Basque-speaking context. This helps to reduce the frequency and severity of future learning difficulties and strengthens the skills needed to learn to read (Mayer & Motsch, 2015; Poulsen et al., 2017; Suárez-Coalla et al., 2013).

Moreover, the launch of the Berni software, along with a process of monitoring each child's progress, enables us to see the development of emerging literacy and determine the type and amount of instruction required. With this system, we can offer individualised teaching that meets the needs of each pupil and boost attention to diversity.

The evidence-based Berni software offers a viable and effective option for teachers to intervene promptly in the classroom when faced with any sign of risk of dyslexia, without labelling or discriminating, and offering opportunities for improvement.

Moreover, it is worth highlighting the importance of developing and assessing an intervention programme, in a free software format and in the main language of the Basque Country's education system, i.e. the Basque language. This will help to broaden the range of tools available for a small but nonetheless important collective, whose mother tongue is one of the oldest living languages in Europe.

Lastly, user experience and usability need to be considered, not only for typically developing children, but also for children with different sensory, physical or cognitive abilities such as children at risk of dyslexia (Venkatesh, Phung, Duong, Greenhill, & Adams, 2013).

Table A.1

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
PHONOLOGICAL AWARENESS (39 activities)	AUDITORY DIFFERENTIATION (5) - Auditory memory - Sound sensitivity PHONEMIC PERCEPTION (3) - Phonemic perception	RHYME AND ALLITERATION (3) - Articulation - Rhyme and alliteration PHONEMIC PERCEPTION (3) - Phonemic perception	RHYME AND ALLITERATION (3) - Articulation - Rhyme and alliteration PHONEMIC PERCEPTION (5) - Phonemic perception	SYLLABLE AWARENESS (6) - Syllable distinction - Phoneme distinction PHONEMIC PERCEPTION (2) - Phonemic perception	SYLLABLE AWARENESS (4) - Syllable distinction - Phoneme distinction INTRA-SYLLABIC AWARENESS (5)
VERBAL MEMORY (26 activities)	LISTENING COMPREHENSION (2) VERBAL WORKING MEMORY (2) RAPID NAMING SPEED (2)	LISTENING COMPREHENSION / VOCABULARY (2) VERBAL WORKING MEMORY (2) RAPID NAMING SPEED (2)	LISTENING COMPREHENSION / VOCABULARY (2) VERBAL WORKING MEMORY (1) RAPID NAMING SPEED (3)	LISTENING COMPREHENSION (2) VERBAL WORKING MEMORY (2) MORPHOLOGICAL AWARENESS (1)	LISTENING COMPREHENSION (1) MORPHOLOGICAL AWARENESS (2)
ALPHABETIC AWARENESS (14 activities)	PICTOGRAPHIC STAGE (2)	PICTOGRAPHIC STAGE (3)	LOGOGRAPHIC STAGE (3)	LOGOGRAPHIC STAGE (2)	ALPHABETIC STAGE (4)
RECEPTIVE LANGUAGE (10 activities)	Repeated activities (10)				
CONCEPT OF WRITING (9 activities)			HIP. QUANTITY (2) HIP. VARIABLE (2)	HIP. QUANTITY (3) DIRECTIONALITY (1)	HIP. SYLLABIC (1)

The number of activities is indicated in brackets.

5. Selection and participation

This research study involved 16 teachers and 417 pupils – aged between four and five years old – from seven schools in the Basque Country (Spain). Forty three children made up the sample of individuals potentially at risk of experiencing reading difficulties. School boards, teachers and parents/guardians of the children were verbally informed about the objective, procedure and data collection. In addition, the researchers provided written information letters and consent forms to be signed by legal guardians before children started to play. Parents/Guardians had the right to know the results of each child and revoke their consent at any moment.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Berni software activities at each of its levels

See Table A.1.

Appendix B. Examples of game types and their contribution to the variables

The Berni game is made up of five types of game: an animated video (Woofy's adventures), a game in which you have to choose the correct answer (Txiki-Einstein), a picture dragging game (Narras-Asma), a matching game (Biki Bikiak) and a game to work on naming speed (Txik-Txak). The animated video aims to improve verbal memory. Likewise, the Txik-Txak game tries to develop Rapid Automated Naming (RAN). However, the other games – choosing the correct answer (Txiki-Einstein), matching pairs (Biki bikiak) and dragging images (Narras-asma) – address objectives of different dimensions.

Some activities of each type of game and the variables they work are shown below.

NARRAS-ASMA (Dragging images)

Drag and drop game. In this case, Berni tells the children that he needs some objects for his excursion and asks for their help to identify and put them in order in his backpack. The aim of this particular game is to exercise verbal working memory.

Other activities of this type of game work on vocabulary, phonological awareness, verbal memory and other dimensions of the different variables.

BIKI BIKIAK (Matching game)

In this particular activity, the student has to join words that begin with the same sound. They work on the perception of phonemes.

TXIKI-EINSTEIN (Choosing the correct answer)

In this case, the student has to count the syllables in the name of each image and choose the one with four syllables. Children practice syllabic awareness.

TXIK-TXAK (Naming speed)

The child has to name the images that come up before the time runs out. The objective is working on naming speed.

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