# Cosmic sounds: A game to support phonological awareness skills for children with dyslexia

# Cosmic Sounds: A game to support Phonological Awareness skills for children with Dyslexia

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***Abstract*—Studies show that reduced literacy skills can negatively influence a child's self-esteem and future career opportunities. Literacy is significantly affected when problems exist understanding the phonological component or sound structure of language i.e. phonological awareness. Children with dyslexia in particular, experience difficulties in spelling and reading accuracy due to a deficit in this phonological component of language. To support children with dyslexia and reduced literacy skills, intervention programmes which focus on phonological awareness elements are recommended. Studies show that game based learning (GBL) interventions can enhance learning for children with dyslexia. The purpose of this pilot study was to partner with children with dyslexia aged between 9 to 12 years, to develop a game toolkit called Cosmic Sounds, to support the teaching of phonological awareness skills. The content for the Cosmic Sounds games was informed by a pedagogical expert in dyslexia. This pilot study addressed the following; "Can a toolkit of games, co-designed by children with dyslexia improve the teaching of phonological awareness skills?" Our findings showed that by including children and their teacher as part of the design team, they were more invested in using the games for learning. Furthermore, when children with dyslexia played Cosmic Sounds, there was a positive impact on their phonological awareness skills progress whilst their engagement in learning also increased.**

***Index Terms*— games, dyslexia, game based learning, phonological awareness skills, co-design**

## I. Introduction

GAME based learning (GBL) describes how gaming principles are incorporated into educational content to foster engagement, motivation and the learning experience [7-10]. Studies show that game based learning (GBL) interventions can enhance learning for children with dyslexia [13-15]. 10% of the population in literate countries are dyslexic, with 4% classified as severely dyslexic [17, 18]. Children tend to have a high degree of digital and game literacy as games are an intrinsic part of their lives [6, 19-21]. Game designers can leverage this digital literacy by involving a sample of the target audience as co-designers. Studies show that when the target audience participates as game co-designers, they become even more motivated and engaged [20, 24, 25].

Children with dyslexia tend to avoid reading activities, hence the inclusion of motivational components in the design of digital educational games are especially important [27]. Some of these motivational components include; rewards (e.g. money), levels (i.e. increasing difficulty), achievements (i.e. task completion), feedback and progress cues [7, 28, 29].

This prospective study contributes to the field of special education by developing a suite of games to support phonological awareness skills for children with dyslexia. Phonological awareness is critical to a child's literacy development, for if a child is unaware of the sound which the component parts of a word make, then they will not be able to pronounce that word correctly [30, 31].

In this pilot study, children with dyslexia aged 9-12 years and their teacher participated as co-designers in the development of Cosmic Sounds. Through the active participation of the children in design decisions, the authors gained an insight into their world view of game design and game mechanics.

## II. Background

The ability to read is critical for participation in modern life [7]. Despite commonly held assumptions, learning to read is a complex linguistic accomplishment and one of the most complicated feats of the brain [32, 33].

Studies show that when a child's reading and writing difficulties 'separate' them from their more literate peers, their disengagement from the learning process can result in reduced literacy skill [34, 35]. This can negatively impact the child's self-esteem and future career opportunities [4, 5, 7, 36, 37]. However, reading and writing abilities can be improved through the use of compensation strategies e.g. auditory therapies, language interventions and educational supports [38, 39]. Studies also show that educational games can benefit children with dyslexia by promoting engagement and enhancing the learning process [4, 13-15, 34, 40, 41]. However, despite such interventions, completely successful dyslexia remediation has not been fully achieved to date [42].

Dyslexia is one of the most presented of the learning disabilities [43], with approximately 70-80% of all learning disabilities relating to it [4]. There is a 33-66% chance that a

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child will develop dyslexia when there is a family history [4, 5, 44, 45]. Children presenting with dyslexia typically experience difficulties in reading and spelling due to a deficit in the phonological component of language [32, 45-48]. This component deals with the separate sound elements and their respective meaning. Consequently, phonological awareness

TABLE I
UNITS FOR MAGNETIC PROPERTIES

| Phonological awareness skills | Description |
|---|---|
| Identifying sounds and symbols | Each individual phoneme must be identified in a word, before one can read [4, 5]. A phoneme is the smallest distinct unit of sound in a language [16]. As an example, bat has three distinct sounds: /**b**/ /**a**/ and /**t**/. |
| Syllabication | The division of words into syllables e.g. un-done. |
| Letter blends | Blending letter sounds is vital to reading [2]. Letter blends refer to the joining of phonemes to form words e.g. bat. |
| Consonant digraph | Consonant digraphs prevent reading mistakes. A consonant digraph refers to a pair of consonants which make a single sound. As an example the digraph /**sh**/ makes a single sound (e.g. shack). |
| Vowel digraph | Vowel digraphs are essential for the correct pronunciation and spelling of words. A vowel digraph refers to a pair of vowel letters is blended to make a single sound (e.g. the /**au**/ digraph makes an **aw** sound). |
| Open vowels | Vowels which have a long sound e.g. the /**u**/ in music. |
| Closed vowels | Vowels which have a short sound e.g. the /**e**/ in met. |
| CVC words | Consonant, vowel and a consonant (CVC) words are used as a starting point to learn how to decompose words into individual sounds, before blending these sounds to make a word. As an example, **mat.** |
| CVCe words | The silent e rule in Consonant, vowel, consonant and a silent e (CVCe) words, states that when an e is at the end of a word, it changes the sound of the previous vowel. For example, in the word **ha**t, the /**a**/ is a closed vowel but when an /**e**/ is added to the end of the word, it then becomes **hate**. |

skills are essential to a child's literacy development [2, 12, 49, 50]. The phonological awareness skills outlined in Table 1 are taught during first and second class in Irish primary schools [51].

Studies show that GBL is one of a number of tools which can be used to enhance the learning process of children with dyslexia especially within the context of; story, rewards, clear game goals and objectives and feedback [15]. Furthermore, the incorporation of task related activities in GBL assists in attention control in children with Dyslexia [52]. GBL has many advantages for children with dyslexia; from the manner in which the content is presented (visual, text based and aural) to the different learning situations, feedback, rewards, storyline etc. which can motivate, and inspire them to learn [53].

## III. METHODOLOGY

The research for this pilot study adopts an active research instrumental case study approach. In an instrumental case study, a particular case is used to attain a generalizable understanding of a phenomenon [34]. In this pilot study, twenty children with dyslexia and a pedagogical expert in dyslexia participated as co-designers of a toolkit of 11 games. Each child

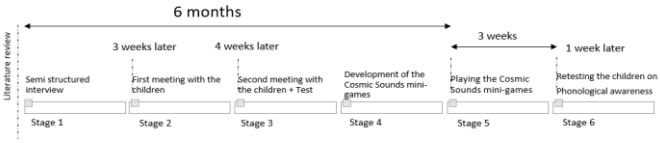



Fig. 1. Timeline for the Cosmic Sounds Pilot Study.

was given a description of the pilot study, outlining its aims and research approach. This pilot study comprised 6 stages (Fig. 1).

### A. Stage 1

A semi-structured interview was held with a pedagogical expert from the Dyslexia Association of Ireland [48]. The goal of the interview was to gain a deeper insight into the phonological awareness skills that children with dyslexia aged between 9-12 years need to have mastered for their literacy development. The semi-structured interview is a popular method for data collection due to its versatility [54]. In preparation for the interview, a literature review on dyslexia and the design of digital games for children with dyslexia was conducted. On the day of the interview, a pedagogocal expert certified by the Dyslexia Association of Ireland, was asked a series of open-ended questions regarding their opinion of essential literacy skills and sample exercises for teaching phonological awareness skills to children with dyslexia. The authors conducted the semi-structured interview in a manner which promoted dialogue.

### B. Stage 2

Twenty children (between the ages of nine and twelve years) who have all been diagnosed with dyslexia participated in this study. These children (19 of whom are boys) attended an evening workshop run by the Dyslexic Association of Ireland (DAI). This workshop helps dyslexic children improve their reading, writing and spelling skills. The severity of the dyslexia experienced by these children ranged greatly. All children were informed that they could absent themselves from the pilot study at any time [55]. With teachers from the DAI in attendance, the authors discussed sample storylines and exercises. The children

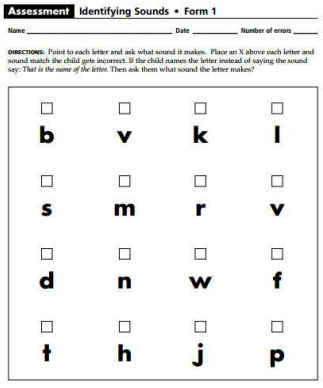



Fig. 2. Test 1: Identifying sounds [1].

were encouraged to engage through questions starting with words such as "what, who, where, when or how" (p. 2960) [54].

### C. Stage 3

In Stage 3, the authors presented sample games. Given that

children with dyslexia have literacy issues [56], a mixture of participatory methods (i.e. story-telling, drawing, and audio) was used to present each mini-game and elicit feedback. Through participatory research, "the adult researcher is no longer mimicking an 'outside observer' but aims to develop rapport" (p. 7) [20]. After collecting the children's feedback, the authors conducted the first round of phonological awareness paper based tests. As these tests involved reading nonsense words, each child had to be tested individually. These tests comprised; Identifying sounds (Figure 2)(Test 1), Identifying symbols (Test 2), Blending sounds (Test 3), Consonant digraphs (Test 4), Vowel digraphs (Test 5), Syllabication (Test 6), Open vowels (Test 7), Closed vowels (Test 8), Consonant, Vowel, Consonant (CVC) and Vowel, Consonant (VC) words (Test 9), Consonant, Vowel, Consonant, silent e (CVCe) words (Test 10) and a combination of all elements/skills (Test 11).

### *D. Stage 4*

Stage 4 involved the development of the Cosmic Sounds games to incorporate findings from literature and the feedback from the children and the DAI pedagogical expert. The resultant games (Tables 2-7) also reflect the phonological awareness elements as described by [5, 32, 57].

### *E. Stage 5*

The authors attended the weekend workshops whilst the children played Cosmic Sounds. The DAI workshop was held once a week for three weeks. The children were allocated thirty minutes/workshop to play Cosmic Sounds. As they only had ninety minutes of workshop time to play Cosmic Sounds, they were offered a copy of the game to bring home. All twenty children accepted.

### *F. Stage 6*

The children were re-tested on their phonological awareness skills using the same set of paper based tests from Stage 3. 15 children were present. Of those, seven children had previously played Cosmic Sounds at home outside the workshop. After the 15 children had completed the phonological awareness re-tests, the authors held two short focus group sessions comprising eight children in one session and seven in the other. Each focus group session was approximately 15 minutes in duration [58]. Consent had already been elicited in advance from the DAI and the children's parents. This form of data collection is valid as "small focus groups are one of the best ways to obtain data from children" (p. 150) [55]. Furthermore, the use of focus group sessions helps in the creation of "a safe peer environment for children" (p. 2) [59]. The questions for the focus group sessions were approved in advance by the DAI. Based on a Usability and User Experience survey, these questions elicited the children's views of the Cosmic Sounds set of games.

## IV. Cosmic Sounds Toolkit

The Cosmic Sounds toolkit is a narrative of 11 adventure games to support the teaching of phonological awareness skills. Under the guidance of the DAI pedagogical expert, the following elements of phonological awareness skills were included in the games; consonant digraphs, identifying sounds, letter blends, CVC (Consonant, Vowel, Consonant) and CVCe (Consonant, Vowel, Consonant, silent e) words, syllabication, vowel digraphs and open vowels and closed vowels. These elements are suitable for children aged between 9-12 years. They are also crucial to a child's reading and spelling abilities and cannot be avoided when learning English both orally and in written form [5, 32, 57] [51].

Cosmic Sounds is set in 2500. As the Earth has become over polluted, the player lives in the Martian city of Avalon. They

TABLE 2
GAMES FOR PHONOLOGICAL SKILL: CONSONANT DIGRAPH

| | |
|---|---|
| Teaching objective: If a child is unaware of the sound which a consonant digraph /**sh**/ makes, they will not be able to pronounce the word **shark** correctly. Although the primary aim of the *Building Site* and *Flying to the Desert games* is to teach the sounds of common consonant digraphs, identifying sounds and symbols, blending and phoneme manipulation are also taught. | |
| Building Site game   | In the Building Site *game*, the player has to combine words using building blocks. These words must only contain the letters that are written in the yellow blocks e.g. **A, T, R, P, C, Sh, E** and **K**. The player can click the relevant block if they need to hear the phoneme made by the associated letter/consonant digraph. The player receives feedback and a clue each time they spell the word incorrectly. Feedback is considered to be one of the factors which underpins the appeal of digital games [6]. |
| Flying to the Desert game   | In the Flying to the Desert game, the player is presented with a word with a missing consonant digraph (e.g. **–ark**) and must fly through the hoop of the correct consonant combination e.g. **sh**. The use of warm background colour such as yellow positively affect reading performance for children with dyslexia [26]. |

TABLE 3
GAMES FOR PHONOLOGICAL SKILL: IDENTIFYING SOUNDS AND IDENTIFYING SYMBOLS

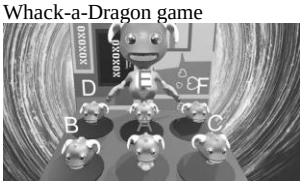
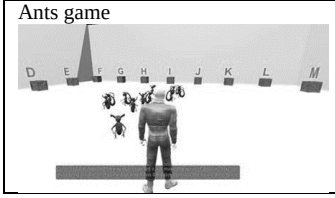
| | |
|---|---|
| Teaching objective: The ability to identify sounds and symbols is critical in reading and spelling. If they lack these skills, they will not be able to identify words or comprehend reading [11, 12]. | |
| Whack-a-Dragon game   | In the Whack-a-Dragon game, each dragon is associated with a letter. The player has to select a letter which makes the presented sound, e.g. what letter makes the **B** sound in **bush**? The player has to then click the **B** dragon before it returns to its hole. |
| Ants game   | In the Ants game, the ant makes the sound of a letter when it is picked up. The player has to then bring the ant to the box associated with its letter.. |

TABLE 4
GAME FOR PHONOLOGICAL SKILL: LETTER BLENDS

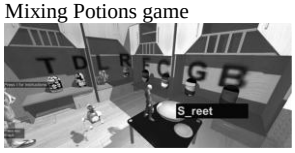
| | |
|---|---|
| Teaching objective: To read a whole word, the child must be able to blend individual sounds [2]. Similar to the Ants game, the player interacts with the Mixing Potions game through movement, sight and sound. This level of interactivity creates a more immersive environment leading to enhanced engagement and deeper learning [22, 23]. | |
| Mixing Potions game   | In the Mixing Potions game, a word having a missing letter is presented (e.g. **s-reet**). The player must fly the Zoomie to the capsules (each of which has a letter overhead) and correctly select the letter which is missing from the blend (e.g. **t**). The player can click on the incomplete word to hear the full word, thereby allowing them to listen closely for the missing letter of the blend. |

TABLE 5
GAME FOR PHONOLOGICAL SKILL: CVC/CVCE WORDS

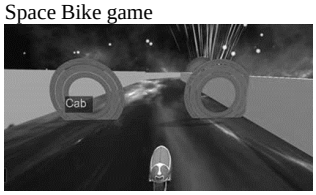
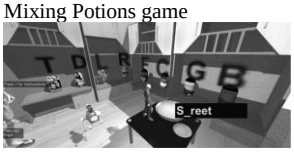
| | |
|---|---|
| Teaching objective: CVC and CVCe words teach dyslexic children how to decompose words into individual phonemes and then blend these sounds to make a word. CVCe words are also used to teach the silent e rule. The silent e rule says that when an e is at the end of a word, it changes the sound of the previous vowel. The ability to pronounce and spell words correctly shows the use of blending letters and the ability to identify individual sounds. | |
| Space Bike game   | In the Space Bike game, the player is presented with two hoops. One hoop when clicked, correctly plays the word presented on the screen (e.g. **Cab**). The other hoop when clicked, plays a very similar but different word (e.g. **Cap**). The goal of this game is for the player to drive the space bike through the hoop which plays the correct word. |
| Flying to Earth game   | In the Earth game, the player must identify which of the vortices' audio (when clicked) correctly matches the CVC word presented on the screen (e.g. **pug**). |

TABLE 6
GAME FOR PHONOLOGICAL SKILL: LETTER BLENDS

| | |
|---|---|
| Teaching objective: To read a whole word, the child must be able to blend individual sounds [2]. Similar to the Ants game, the player interacts with the Mixing Potions game through movement, sight and sound. This level of interactivity creates a more immersive environment leading to enhanced engagement and deeper learning [22, 23]. | |
| Mixing Potions game   | In the Mixing Potions game, a word having a missing letter is presented (e.g. **s-reet**). The player must fly the Zoomie to the capsules (each of which has a letter overhead) and correctly select the letter which is missing from the blend (e.g. **t**). The player can click on the incomplete word to hear the full word, thereby allowing them to listen closely for the missing letter of the blend. |

live with a helper known as a Zoomie, who follows the player in a mini-spaceship. As Cosmic Sounds is an open world game, the player is able to roam freely throughout Avalon as they complete their missions, each of which is associated with a mini-game (Tables 2-7).

While the primary purpose of each game is to focus on a single phonological awareness skill, additional phonological awareness skills are also taught to support the player in generalising and transferring knowledge between activities [60-63]. Furthermore, repetition provides the practice which a child needs in order to master new skills, increase their confidence in a topic and improve their speed and ability to retain information [62, 63].

TABLE 7
GAME FOR PHONOLOGICAL SKILL: OPEN AND CLOSED VOWELS

| | |
|---|---|
| Teaching objective: Open vowels are vowels which have a long pronunciation i.e. the /**u**/ in **pug** is an open vowel. Closed vowels are vowels which have a short pronunciation e.g. the **/i/** in **win** is a closed vowel. An understanding of open and closed vowels aids in pronunciation [3]. | |
| Spaceship Flying game   | In the Spaceship Flying game, a word having either open or closed vowels is displayed (e.g. **pug**). When the player clicks a vortex, different pronunciations of the word are played. The player must fly to the vortex which correctly plays the word displayed. If the player flies through the correct hoop, more hoops appear and the words change |

Cosmic Sounds has been designed so that the player is supported when they submit an incorrect answer/guess. Hints encourage engagement and support deeper understanding [64]. As an example, in the Building Site game (relating to Consonant Digraphs), the first time a player spells the word 'ash' incorrectly, the clue they receive is the word itself sounded out. If the player spells the word incorrectly a second time, they receive the first letter of the word (i.e. 'a'). If they spell the word incorrectly a third time, they receive the next letter of the word (i.e. 's'). If they spell it incorrectly a third time, they are presented with the word. On average there are five clues given for each word, this varies depending on the size of the word. The number of words to be spelt per digraph varies from four words to eight. All results are stored in a database.

## V. CO-DESIGN OF THE COSMIC SOUNDS GAMES

"Despite a growing interest in player-centred methods for serious games, little is known on how to achieve this goal in practice when prospective users are children" (p. 1)[52]. In this pilot study, oral feedback and visual data were collected from the children to facilitate co-design and to promote engagement in design decisions. "Although visual data may be difficult to analyse, if paired with spoken feedback from children (often recorded), such data can convey in-depth information. Visual methods can be used with children of all ages" (p. 9) [20]. Furthermore, studies show that many children with dyslexia have a tendency to be visual learners [53]. The children's feedback is categorised as follows:

- Genre: 70% (n=20) of the children preferred open world games. Cosmic Sounds is an open world game.
- Background: The following storylines were presented; (1) a Cats and Dogs game where the player takes on the role of a kitten/puppy and has to collect bones/cat treats; (2) a Space game where the player lives on Mars and has to complete flying missions and an Adventure game, where the player explores a town. 60% (n=20) of the children voted for the Space Game, with the

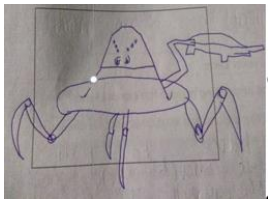


Fig. 3. Zoomie 1.

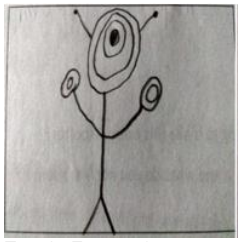


Fig. 4. Zoomie 2.

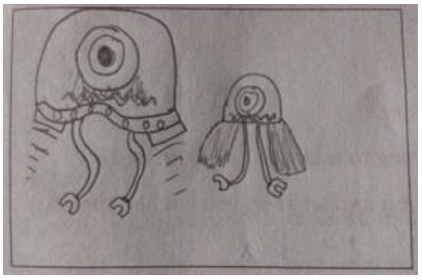


Fig. 5. Zoomie 3.

Cats and Dogs and Adventure games receiving 30% and 10% of the votes respectively.

- Rewards: The use of currency as a reward for completing exercises was suggested by all of the children. "*Get money for doing the mini games*" [Male child, aged 11 years]. Once the player successfully completes each mini-game, they are awarded with star-dust, the currency in Cosmic Sounds. Studies show that "receiving virtual items in the game for successful completion of a task can show children their progress and achievement. Experiencing success this way can boost children's self-esteem and pride" (p. 307) [21]. Rewards can also result in a modification of behaviours and mind-sets [66].
- Zoomie: The children asked for a helper character which they called a Zoomie. Studies show that helper characters can positively affect engagement and comprehension [67, 68]. Collaboratively, three drawings were created (Fig.s 3-5). 35% (n=20) of the children selected Zoomie 1, 35% selected Zoomie 2 and 30% choose Zoomie 3. "*I think it's cute*" [Female child, aged 11 years] in response to Zoomie 1. "*You will most likely see something like that in a game*" [Male child, aged 9 years] in response to Zoomie 2. "*It's funny*" [Male child, aged 9 years] in response to Zoomie 3. As there was no outright winner, the Zoomie design incorporated a mix of features.
- Text: The children requested "*Bigger letters and words*" [Male child, aged 9 years]. As children with dyslexia have different learning requirements, game design guidelines for children with dyslexia include the use of cream or soft pastel colours [4, 69] [15]; a font size of 14pts [4] and a dark font colour.
- Graphics: "*It should look realistic*" [Male child, aged 12 years]. A game's visual style can influence whether or not the player (especially a dyslexic player) will want to play the game [53, 70, 71]. Cosmic Sounds has realistic 3D graphics.
- Mechanics: The games which were explicitly requested by the children included; Destroying Space Invaders (Vowel digraphs) and Collecting Gold from Whales (Identifying sounds and symbols). Other games were adapted and revised based on the children's feedback. "*The whale should say the word when you click it*" [Male child, aged 9 years]. When a game object (e.g. dragon) is clicked, the player hears the associated/respective word/sound. The original Whack-a-Mole game was adapted based on feedback. "*Change it from a mole to something else like a dragon*" [Male child, aged 11 years]. A number of the children recommended the inclusion of "*Bad aliens*" [Male child, aged 10 years] whilst others requested explosions. "*You have to explode other spaceships*" [Male child, aged 9 years]. Include "*whales and sharks*" [Male child, aged 10 years]. Whilst some games contain explosions, they were still suitable for children over the age of 7years based on the Pan European Game Information guidelines [72]. One child asked for "*No blood*" [Female child, aged 11 years], whilst another requested that there be "*No babyish games*" [Male child, aged 12 years]. Requests which were not fulfilled included; "*Can you buy guns?"* [Male child, aged 11 years]. Requests for celebrities and cartoon characters were also not included. "*Can Shane Long, Neymar, Robbie Keane and Ronaldo be in it*?" [Male child, aged 10 years], "*I want batman in it*" [Male child, aged 9 years].

## VI. RESULTS

Table 8 presents the summary results of Stages 3 and 6 before and after playing Cosmic Sounds. During Stage 6, five of the children who took part in Stage 3 were absent. Note: all 15 children played the games independently. Prior to playing Cosmic Sounds, the children's main problem areas were consonant and vowel digraphs (Tests 4 and 5), open vowels (Test 7) and Consonant, Vowel, Consonant, silent e (CVCe) words (Test 10). To a lesser degree, the children struggled with syllabication (Test 6) and blending sounds (Test 3). If children with dyslexia have difficulty with consonant and vowel digraphs and fail to understand that these digraphs make one sound, the learning of new words becomes even more difficult [73, 74]. According to the Primary English curriculum, at the age of eight years (this equates to second class in an Irish primary school) children are expected to be able to identify sounds, perform syllabication, understand letter blends and consonant and vowel digraphs as well as identify when a vowel is an open or a closed vowel [51]. Failure to be able to complete these tasks typically results in problems with reading and spelling. CVC (consonant, vowel, consonant) and CVCe (consonant, vowel, consonant and silent e) words are recommended in the teaching of blending and decoding

phonemes [75]. By the age of nine years, children in primary school are no longer learning the basics of reading. Instead, they are using their reading and writing skills in order to learn other subjects and/or enhance their knowledge of the English language.

TABLE 8
RESULTS OF THE PHONOLOGICAL AWARENESS TESTS **BEFORE** AND **AFTER** PLAYING COSMIC SOUNDS

| | | **Tests** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| | #Qs | 16 | 10 | 24 | 24 | 24 | 18 | 24 | 24 | 96 | 24 | 24 |
| **STAGE 3: BEFORE** | Mean | 16 | 10 | 11.6 | 10.05 | 8.5 | 8.4 | 9.9 | 16.3 | 70.55 | 9.3 | 10.3 |
| | Median | 16 | 10 | 11 | 8 | 8 | 7.5 | 9 | 16.5 | 74.5 | 9 | 6.5 |
| | S. Dev | 0 | 0 | 7.39 | 6.06 | 5.86 | 4.63 | 6.14 | 5.60 | 22.9 | 7.12 | 6.91 |
| **STAGE 6 : AFTER** | **Mean** | **16** | **0** | **11.8** | **11.66** | **9.33** | **9.66** | **11.06** | **16.46** | **73.266** | **10.46** | **10.8** |
| | **Median** | **16** | **10** | **10** | **8** | **11** | **9** | **10** | **17** | **86** | **7** | **10** |
| | **S. Dev** | **0** | **9** | **6.8** | **6.42** | **6.0** | **4.5** | **6.4** | **5.95** | **23.03** | **7.3** | **6.39** |

The overall change in the number of correct answers after playing Cosmic Sounds is shown in Table 9. The final column entitled δ, shows the change between Stages 3 and 6.

TABLE 9
DIFFERENCES IN THE RESULTS **BEFORE** AND **AFTER** PLAYING COSMIC SOUNDS (STAGE 6 RESULTS – STAGE 3 RESULTS)

| | **Tests** | | | | | | | | | | | δ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | |
| #Qs | **16** | **10** | **24** | **24** | **24** | **18** | **24** | **24** | **96** | **24** | **24** | |
| Child 1 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 0 | 9 |
| Child 2 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 0 | 8 |
| Child 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 6 |
| Child 4 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 7 |
| Child 5 | 0 | 0 | 0 | 2 | 3 | 0 | 2 | 3 | 4 | 2 | 2 | 18 |
| Child 6 | 0 | 0 | 1 | 1 | 0 | 5 | 1 | 0 | 0 | 0 | 3 | 11 |
| Child 7* | 0 | 0 | -1 | 0 | 3 | -1 | 3 | 0 | 0 | 2 | 0 | 6 |
| Child 8 | 0 | 0 | 2 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 7 |
| Child 9 | 0 | 0 | 0 | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -2 |
| Child 10 | 0 | 0 | -1 | 2 | 0 | 1 | -1 | 0 | 0 | 0 | 3 | 4 |
| Child 11 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 5 |
| Child 12 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 17 |
| Child 13 | 0 | 0 | 2 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Child 14 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 4 | 1 | 2 | 12 |
| Child 15 | 0 | 0 | 0 | 3 | 2 | -1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Sum of δ | 0 | 0 | 10 | 15 | 17 | 13 | 9 | 8 | 15 | 13 | 13 | 113 |

TABLE 10
RESULTS AFTER COMPARISON OF THE Δ FOR THOSE WHO PLAYED COSMIC SOUNDS AT HOME AND THOSE WHO DID NOT

| | | **Tests - δ** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | δ |
| **Played the game at home and at the DAI workshops** | Child 1 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 0 | 9 |
| | Child 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 6 |
| | Child 4 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 7 |
| | Child 5 | 0 | 0 | 0 | 2 | 3 | 0 | 2 | 3 | 4 | 2 | 2 | 18 |
| | Child 8 | 0 | 0 | 2 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 7 |
| | Child 12 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 17 |
| | Child 15 | 0 | 0 | 0 | 3 | 2 | -1 | 0 | 0 | 0 | 0 | 0 | 4 |
| | **Mean** | *0* | *0* | *.85* | *1.71* | *1.57* | *.57* | *.71* | *1.14* | *1.57* | *.86* | *.71* | *68* |
| | **SD** | *0* | *0* | *1.07* | *1.49* | *1.27* | *1.13* | *.95* | *1.21* | *1.61* | *1.07* | *.95* | |
| | | **Tests - δ** | | | | | | | | | | | |
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | δ |
| **Played the game for 30 mins/week for 3 weeks** | Child 2 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 0 | 8 |
| | Child 6 | 0 | 0 | 1 | 1 | 0 | 5 | 1 | 0 | 0 | 0 | 3 | 11 |
| | Child 7 | 0 | 0 | -1 | 0 | 3 | -1 | 3 | 0 | 0 | 2 | 0 | 6 |
| | Child 9 | 0 | 0 | 0 | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -2 |
| | Child 10 | 0 | 0 | -1 | 2 | 0 | 1 | -1 | 0 | 0 | 0 | 3 | 4 |
| | Child 11 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 5 |
| | Child 13 | 0 | 0 | 2 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Child 14 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 4 | 1 | 2 | 12 |
| | **Mean** | *0* | *0* | *.5* | *.375* | *.75* | *1.125* | *.5* | *0* | *.5* | *.875* | *1* | *45* |
| | **SD** | *0* | *0* | *1.41* | *1.41* | *1.16* | *1.89* | *1.19* | *0* | *1.41* | *1.46* | *1.4* | |

In Stage 3, Child 5 achieved the lowest scores (100 in total). However, they answered 18 additional correct answers in Stage 6. Test 5 (vowel digraphs) saw the greatest improvement after playing Cosmic Sounds. The predominant problem areas from Stage 3 (Tests 4, 5 and 10) showed improvements after playing Cosmic Sounds with vowel digraphs (Test 5) displaying the greatest overall improvement in the number of correct answers (Table 9). However, it still remains a significant problem with the children. Issues with vowel digraphs typically tend to be the root of most reading and spelling errors [73, 74]. Open vowels (Test 7) also saw an improvement in the number of correct answers. As can be seen in Table 8, all tests showed an increase in the number of correct answers after the children had played Cosmic Sounds. Despite this, the children still experienced the most difficulty with Test 4 (Consonant digraphs) and Test 10 (Consonant, Vowel, Consonant, silent e (CVCe) words). In order to prevent reading mistakes, it is important for children to know consonant digraphs and CVC/CVCe words.

Table 10 presents a comparison of the change in the numbers of correct answers from those who played Cosmic Sounds at home and those who did not. As expected, those who played Cosmic Sounds at home have 68 additional correct answers (with a mean of 9.71). This compares to 45 additional correct answers (with a mean of 5.62) for those who only played Cosmic Sounds during the DAI workshops. Between Stages 3-6, the DAI teachers did not include workshop content on the phonological awareness skills covered by Cosmic Sounds.

The Wilcoxon Signed-Rank test was applied to the pre and post results from Tests 3 – 11 (Stage 3 and Stage 6), to check whether there was any statistical significance for Cosmic Sounds as a support for Phonological Awareness skills. As there was no difference in the results of Tests 1 and 2, these specific tests were excluded. The results of the Wilcoxon Signed-Rank tests are as follows;

- Test 3: p-value of 0.0543959; there was no statistical significance in the results of Test 3 (Blending sounds) after Cosmic Sounds.
- Test 4: p-value of 0.0378985; there was a statistical significance in the results of Test 4 (Consonant digraphs) after playing Cosmic Sounds.
- Test 5: p-value of 0.0132131; there was a statistical significance in the results of Test 5 (Vowel digraphs) after playing Cosmic Sounds.
- Test 6: p value of 0.0403374; there was a statistical significance in the results of Test 6 (Syllabication) after playing Cosmic Sounds.
- Test 7: p value of 0.0578313; there was no statistical significance in the results of Test 7 (Open vowels) after playing Cosmic Sounds.
- Test 8: p value of 0.0975125; there was no statistical significance in the results of Test 8 (Closed vowels) after playing Cosmic Sounds.
- Test 9: p value of 0.05676; there was no statistical significance in the results of Test 9 (Consonant, Vowel, Consonant (CVC) and Vowel, Consonant (VC) words) after playing Cosmic Sounds.
- Test 10: p value of 0.03103; there was a statistical significance in the results of Test 10 (Consonant, Vowel, Consonant, silent e (CVCe) words) after playing Cosmic Sounds.
- Test 11: p value of 0.03351; there was a statistical significance in the results of Test 11 (a combination of all elements/skills) after playing Cosmic Sounds.

## VII. Discussion

After collating and anlaysing the children's feedback during the focus group sessions; 100% (n=15) of the children said they liked the Cosmic Sounds games. Of those, 53% (n=15) said that they really 'loved' the games. 87.5% (n=8) of these children had played Cosmic Sounds at home. All children (n=15) agreed that being involved in the game design increased their engagement. 100% of the children (n=15) said that they liked that their ideas were incorporated into Cosmic Sounds. They especially liked that they had design decision control over the location, games and the Zoomie character design. When children have been involved in the design of game characters, there is a greater likelihood that as players, they will form linkages with these characters [6].While the results of this pilot study showed that the Cosmic Sounds toolkit of co-designed games resulted in increased engagement (in line with findings from [52]) and a positive impact on the children's phonological awareness skills, specifically in the areas of Consonant digraphs, Vowel digraphs, Syllabication, Consonant, Vowel, Consonant, silent e (CVCe) words and a combination of all elements/skills, this study has limitations such as the sample size. The findings of this study are based on a semi-structured interview with a DAI pedagogical expert and fifteen children (although twenty children participated as co-designers). While no generalizations can be derived from the accruing results, expanding the study's scope and the scale and duration of game play, will improve the reliability and validity of the findings in future research. Furthermore, as this is a pilot study, there is only one level of difficulty in the games. Future refinements to the suite of games in Cosmic Sounds will take into consideration the literacy skills and abilities of the individual players.

## VIII. Conclusions

As a neuro-biologically based learning disability, dyslexia is frequently "characterised by difficulties in literacy acquisition affecting reading, writing and spelling" (p. 5) [56]. As phonological awareness skills are necessary in the identification and manipulation of the units of oral language (i.e. words and syllables), they are critical to a child's reading development [49]. Studies show that effective early intervention programmes which have been designed to augment literacy development also help children 'catch up' with their peers [76]. As part of this prospective study, the children collaborated with the authors to develop a toolkit of games to support the teaching of phonological awareness skills to children with dyslexia aged between 9 to 12 years. By participating as co-designers, the children expressed their world view of game design and game mechanics.

The pedagogical underpinning of these games was informed by literature and a DAI pedagogical expert. As co-designers, the feedback from the children with dyslexia, concerning the character design, setting and the game mechanics was incorporated into Cosmic Sounds. This resulted in participant 'buy-in' from the outset. The resultant Cosmic Sounds games employed a game based learning approach and positively impacted the players' phonological awareness skills. After playing Cosmic Sounds, the children improved in all of the phonological areas being tested, excluding identifying sounds and symbols (as all questions were answered correctly during both testing stages).

The areas whose improvement was statistically significant were; Consonant digraphs, Vowel digraphs, Syllabication, Consonant, Vowel, Consonant, silent e (CVCe) words and a combination of all elements/skills. Through GBL, children have the possibility to overcome difficulties in learning basic reading subskills e.g. phonological (letter-sound) decoding, recognizing a word accurately and poor spelling. The .Cosmic Sounds games which have been developed as part of this pilot study

could be part of a larger toolkit to enhance phonological awareness training. This is important as phonological awareness skills have been demonstrated to positively influence a child's literacy development [77].

This pilot study contributes to the field as it uses game based learning to help children with dyslexia to enhance their phonological awareness skills. By inviting the children to collaboratively design the resultant games, their engagement in and motivation to play Cosmic Sounds was enhanced.

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