ARWAK: An Augmented Reality Wordbook Smartphone App for Kindergarteners

D. Jain[1], A. P. Patil[1], D. J. Nawal[1], P. Chakraborty[1, #]

[1]*Division of Computer Engineering, Netaji Subhas University of Technology, New Delhi*

[#]Corresponding Author, Email: *pinaki_chakraborty_163@yahoo.com*

***Abstract*— In the last two decades, augmented reality educational software tools have been used to teach various subjects to schoolchildren around the world. We developed a wordbook smartphone app and used it to teach new words to children in kindergartens in New Delhi between January and April of 2018. The app uses marker-based augmented reality technology and displays three dimensional pictures of objects whose names the children are learning blended in their immediate surrounding. The app was designed to make the learning process more interactive and intuitive. We found that children can learn slightly more number of words from the app than from a printed wordbook. However, the main benefit of the app was that it was able to increase participation by the children and keep them engaged. The teachers who used the app to teach felt that it was easy to integrate the app in the kindergarten environment and it presented information in a way suitable for young children. We recommend the use of augmented reality smartphone apps to teach children various concepts in kindergartens and schools.**

***Keywords*— Kindergarten, vocabulary, wordbook, smartphone app, augmented reality.**

1. INTRODUCTION

Smartphones became popular in the early 2000s. The availability of inexpensive handsets and fast Internet connections helped in the proliferation of smartphones. Today, smartphones are used by people of different age groups and professions, and for various purposes. Accordingly, a large number of smartphone apps are also being developed. Some of these apps connect to the Internet to access Web-based services while the others work offline.

Children get attracted to smartphones at an early age and they are more curious about them than other household electronic devices [1]. Children are fond of smartphones particularly because of their small size, stylish design and multimedia capabilities. Suitably designed smartphone apps can be used to foster informal learning and creativity in children [2]. Traditionally, kindergarteners are taught new words from pictorial wordbooks. Such a wordbook contains names and pictures of animals, birds, fruits, vegetables and other objects from daily life. Wordbooks can also be implemented as smartphone apps [3]. Wordbook apps can use multimedia and be more interactive than the traditional wordbooks.

Augmented reality is the blending of additional graphics and sound in the perception of a person about his/her surrounding and thus temporarily altering his/her understanding of the reality [4]. The additional graphics and sound may be generated by a computer and be purely artificial, or may have been extracted from another physical environment. Augmented reality can be implemented by an app by capturing and analyzing the live feed of the camera of the smartphone, generating graphics and sound according to the context, and displaying the combined scene on the screen in real time. The app may even allow the user to manipulate the virtual objects added to the scene by touching the screen appropriately. Augmented reality has been used in higher

education [5] and special education [6]. Augmented reality smartphone apps have been used successfully to teach mathematics [7,8] and engineering [9,10], and can also be used to teach other disciplines [11].

We developed an augmented reality wordbook smartphone app and used it to teach about animals, fruits, vegetables, food items and vehicles to kindergarten children. The app is meant to be operated by teachers in kindergarten classrooms in front of children. The teachers have to point the camera of the smartphone to a marker card on which the name of an object is written and a three dimensional picture of that object is displayed on the screen. The children can rotate and otherwise manipulate the object in the picture through simple touchscreen gestures.

2. Related Work

In the last two decades, several augmented reality educational tools have been developed for kindergarteners and schoolchildren. Some of these tools are available on desktop computers while others are distributed as apps for smartphones and tablet computers. These augmented reality educational tools use different learning methods, viz. inquiry-based learning, blended learning, collaborative learning and learning from stories.

2.1 Inquiry-based Learning

Some augmented reality educational tools facilitate inquiry-based learning. Students are presented with a problem or a scenario that they need to explore. This improves their abilities of reasoning and creative thinking. Fleck and Simon [12] and Fleck et al. [13] developed an augmented reality tool to help children learn the fundamentals of astronomy. The tool focused on the solar system, motions of the earth and the moon, phases of the moon and change of seasons. The tool was used to teach at a school in France where the teachers observed a significant increase in student participation. The tool was more interactive and proved to be a better instructional aid than a physical three dimensional model with which it was compared. Lazoudis [14] also developed an augmented reality tool to facilitate inquiry-based science learning and used it in a school in Greece. Barreira et al. [15] developed an augmented reality tool to enhance English vocabulary of schoolchildren in Portugal. The tool displayed three dimensional pictures of animals to the children in their surrounding and let them learn the names of the animals in both English and Portuguese.

2.2 Blended Learning

Augmented reality software can also be used to implement blended learning. The teacher and the students are co-present in the classroom and use the software to enhance the interaction. Teichner [16] developed an augmented reality smartphone app to teach about DNA to schoolchildren in Georgia. Chen et al. [17] developed an augmented reality smartphone app to teach schoolchildren in Taiwan about the role of plants in daily life. Similarly, Bodén et al. [18] developed an augmented reality tool to teach schoolchildren in Australia about animals and their habitats. Alakärppä et al. [19] developed an augmented reality smartphone app to sensitize schoolchildren in Finland about nature.

2.3 Collaborative Learning

Augmented reality software can help students to learn collaboratively. They may share information and opinion through the tool. Some tools even allow a teacher to participate in the activities. Tallyn et al. [20] developed an augmented reality encyclopedia tool that schoolchildren can use collaboratively to learn various concepts. A printed booklet is distributed with the tool. The booklet contains barcodes that may be scanned by the

camera of the computer to display information. The tool was used to teach in a school in UK. Schrier [21] developed collaborative educational games for schoolchildren which use GPS to implement augmented reality. The games were available as smartphone apps and were used by schoolchildren in USA. Freitas and Campos [22] developed a quizzing tool to teach children about daily life objects like animals and vehicles using their three dimensional pictures. The tool has been used to teach in schools in Portugal. Radu [23], Radu et al. [8] and Bujak et al. [7] developed augmented reality smartphone apps to teach fundamental of mathematics. The tools cover geometry, clock reading, currency denominations and similar topics. The tools have been used in schools in USA. Zund et al. [24] developed augmented reality smartphone apps like a digital coloring book and physical interaction game applications which a number of schoolchildren can use collaboratively. The apps were used by schoolchildren in Switzerland.

2.4 Learning from Stories

Digital storybooks can be used to teach children literature and about history. Digital textbooks can be made more appealing to children using augmented reality. Zhou et al. [25] developed a desktop based augmented reality tool to narrate stories to schoolchildren. The tool used speech and three dimensional graphics to tell stories. Zhou et al. [26] used a state transition model of storytelling in which the content of one scene is played before moving on to the next. The tool was used to teach schoolchildren in Singapore. Another augmented reality storytelling tool was developed Balog et al. [27] and was used in several countries in Europe. Table I compares the four learning methods.

TABLE I
A COMPARISON OF THE LEARNING METHODS

Leaning method	**Advantage**	**Suitable subjects**
Inquiry-based learning	Improves reasoning and creative thinking in children.	Science, vocabulary.
Blended learning	Enhances classroom participation of children.	Science, environment.
Collaborative learning	Allows children to interact among themselves.	Mathematics, general knowledge.
Learning from stories	Improves attention of children.	Literature, value education.

3. MATERIALS AND METHODS

3.1 Marker-based Augmented Reality

Marker-based augmented reality is a technique in which a camera is use to capture the scene and identify a marker. The marker can be in the form of a barcode or a symbol or a short text. Computer generated content is added to the scene according to the markers identified in it. The markers are also used to position the computer generated graphics in the scene.

A barcode can encode information efficiently and may be used as a marker in a system dealing with a large number of computer generated items. Alternatively, text markers are not efficient in encoding information but are easy to use by human beings. For simple educational tools, text markers are more suitable.

3.2 The App

We developed a smartphone app that we call Augmented Reality Wordbook App for Kindergarteners (ARWAK). ARWAK implements marker-based augmented

reality. Names of daily life objects are printed on plain paper. The camera of the smartphone is pointed toward that paper and ARWAK detects the name of the object. Then ARWAK displays a three dimensional picture of the object on the screen blended with the real surrounding. A child can rotate the object in the picture by touching it on the screen. ARWAK has five modules that can be used to teach children about animals, fruits, vegetables, food items and vehicles (Fig. 1). Care has been taken to include a wide range of objects. The objects covered by ARWAK include tiger, horse, cow, duck, apple, banana, grape, strawberry, carrot, tomato, cake, ice cream, car, boat and aeroplane. Kindergarten-aged children often get to see these objects in daily life and are interested in them. Some of the pictures are animated while short audio clips are played with the others. ARWAK runs on all smartphones with Android operating system and is available for free in the Google Play online app store. We recommend ARWAK for teaching new words to three to five year old children in both kindergarten and home environments.

3.3 An Assessment of the App

We distributed ARWAK among teachers who teach in kindergarten classes in several schools in New Delhi. The teachers used ARWAK to teach in their classroom between January and April of 2018. The teachers used slips of papers with names of objects printed on them as flashcards (Fig. 2). They pointed the camera of their smartphones towards a flashcard and a three dimensional picture of the object appeared on the screen. The teachers then taught the children about that object and let them manipulate the picture by touching the screen. Kindergarten-aged children have limited capability of using smartphones and we do not expect them to use ARWAK by themselves.

We observed teachers using ARWAK to teach children in the kindergarten class of one school. The test group consisted of 15 children who were taught new words using ARWAK and the control group

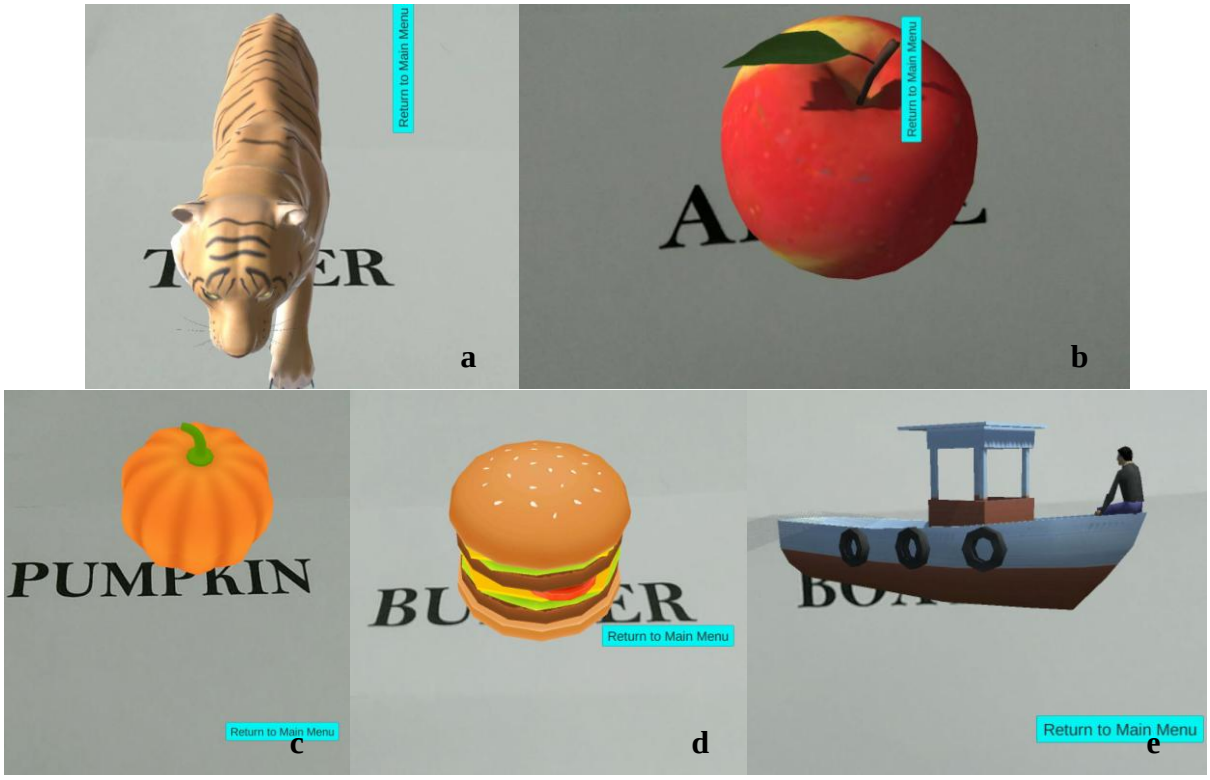

Fig. 1: Screen shots of ARWAK showing (a) an animal, (b) a fruit, (c) a vegetable, (d) a food item and (e) a vehicle.

consisted of 15 other children who were taught the same words from a printed wordbook. All children were three years old and belonged to Indian families which typically use English as their second language. Some children already knew some of the words that were being taught. We allowed the children to study like this for two weeks and then evaluated their progress. We asked the children to identify 10 objects selected by the teachers in ARWAK or in the printed workbook from which they have studied. The number of objects that each child could identify was recorded.

Fig. 2: Recommended way of using ARWAK.

We also sought feedback from the teachers who used ARWAK in their classroom. We asked them if it was easy to use ARWAK in a kindergarten environment, if the presentation of ARWAK was appropriate and if ARWAK improved participation among the children. The teachers were asked to rate these three aspects of ARWAK on a 5-point Likert scale. We received feedback from 12 teachers.

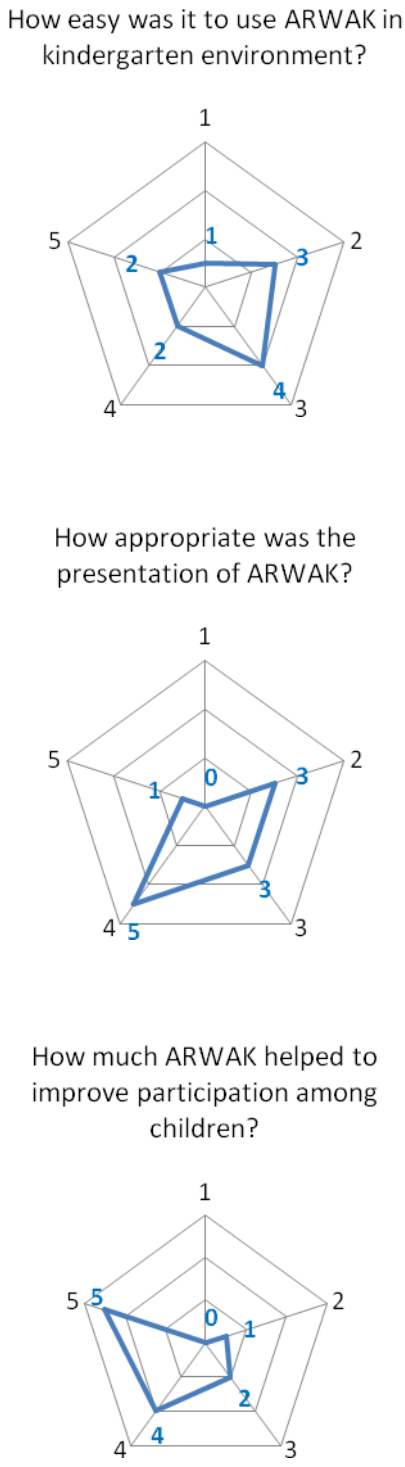

Fig. 3. Ratings provided by the teachers (N = 12). A vertex in a polygon represents the number of teachers who gave a particular rating to ARWAK according to a particular criterion.

4. Results

The children who studied from ARWAK performed slightly better in the

evaluation than the children who studied from the printed wordbook.

The children who studied from ARWAK were able to identify 7.07 objects on an average (SD = 0.88) in the evaluation. Alternatively, the children who studied from the printed wordbook were able to identify 6.67 objects on an average (SD = 0.98). There was no significant difference in the performances of female and male children.

We observed that the children were particularly interested in the animals and the vehicles when they studied using ARWAK. Most children liked the tiger more than the other objects. The children also wanted to see objects that are not currently included in ARWAK like an orange, a dragon, a parrot and a rocket. The children used their thumbs and index fingers to touch the screen when their teachers allowed them to do so.

The feedback we received from the teachers was encouraging. The teachers awarded ARWAK mean ratings of 3.08 for ease of use, 3.33 for appropriateness of its presentation and 4.08 for its ability to improve participation among the children in a 5-point scale (Fig. 3).

5. Discussion

There are several reasons for using augmented reality smartphone apps to teach children in kindergartens and schools. Children can hold a smartphone in their hands firmly by the age of two years and play with it [28]. Children are attracted towards software tools that use augmented reality more than those that do not. Augmented reality smartphone apps can present information in a way that is both interesting and understandable by children [25,26]. Augmented reality software, especially if implemented as smartphone apps, provides a flexible and accessible interface for learning to children [20]. Augmented reality smartphone apps can be used in a kindergarten or school environment. They can be easily integrated with the existing framework [15] and are safe. Augmented reality software is known to be able to motivate children to study [21,22] and keep them engaged [21,24]. We had similar experience with ARWAK. We observed that ARWAK drew the children and increased participation among them. Hornecker and Dunser [29] observed that augmented reality software can even help children to overcome their initial hesitation to study from books.

Augmented reality educational software, apart for being attractive, improves learning among children. We observed that children learned new words slightly better from ARWAK than from a printed wordbook. Previous studies [17,22] have also shown that better results can be achieved using augmented reality educational software especially among weaker students [22]. Barreira et al. [15] reported that augmented reality educational software helps children to learn better than traditional methods and improves their communication skills. Fleck and Simon [12] concluded that augmented reality educational software enhances science learning among children.

Like most software, augmented reality smartphone apps are cost effective [27]. Once developed, they require either little or no maintenance, and can be distributed among any number of children not constrained by geopolitical borders.

6. Conclusion

Computer-based techniques are now being used increasingly for improving vocabulary and reading skills [30,31]. Educational software can be made more engaging using technologies like augmented reality and virtual reality [32]. We developed an augmented reality wordbook smartphone app and used it to teach new words to kindergarteners. We

found that children can learn slightly better from the app in comparison to a printed wordbook. The teachers who used ARWAK felt that it is easy to integrate it in a kindergarten environment and it presented information in a way suitable for teaching young children. More importantly, ARWAK has an ability to improve participation among children and keep them engaged.

Children are attracted towards smartphones and suitably designed apps can be used to teach them a wide range of concepts [33]. Augmented reality can be used to enhance educational apps and make them more intuitive. We believe that smartphone apps using augmented reality can be effectively used to teach new words and about numbers to children in kindergartens, and concepts of science and mathematics to older schoolchildren.

REFERENCES

[1] Eisen S, Lillard AS. Young children's thinking about touchscreens versus other media in the US. Journal of Children and Media, 11(2), 167-179, 2017.

[2] Yadav S, Chakraborty P. Using smartphones with suitable apps can be safe and even useful if they are not misused or overused. Acta Paediatrica, 107(3), 384-387, 2018.

[3] Cahill M, McGill Franzen, A. Selecting "app"ealing and "app"ropriate book apps for beginning readers. The Reading Teacher, 67(1), 30-39, 2013.

[4] Shneiderman B, Plaisant C, Cohen M, Jacobs S, Elmqvist N, Diakopoulos N. Designing the User Interface: Strategies for Effective Human-Computer Interaction, 6th ed., Pearson, 2016.

[5] Wójcik M. Potential use of augmented reality in LIS education. Education and Information Technologies, 21(6), 1555-1569, 2016.

[6] Lorenzo G, Gómez-Puerta M, Arráez-Vera G, Lorenzo-Lledó A. Preliminary study of augmented reality as an instrument for improvement of social skills in children with autism spectrum disorder. Education and Information Technologies, in press, 2018.

[7] Bujak KR, Radu I, Catrambone R, MacIntyre B, Zheng R. A psychological perspective on augmented reality in the mathematics classroom. Computer and Education, 68, 536-544, 2013.

[8] Radu I, Doherty E, DiQuollo K, McCarthy B, Tiu M. Cyberchase shape quest: pushing geometry education boundaries with augmented reality. Proceedings of the Fourteenth International Conference on Interaction Design and Children, 430-433, 2015.

[9] Monroy-Reyes A, Vergara-Villegas OO, Miranda-Bojórquez E, Cruz-Sánchez VG, Nandayapa M. A mobile augmented reality system to support machinery operations in scholar environments. Computer Applications in Engineering Education, 24(6), 967-981, 2016.

[10] Reyes-Aviles F, Aviles-Cruz C. Handheld augmented reality system for resistive electric circuits understanding for undergraduate students. Computer Applications in Engineering Education, 26(3), 602-616, 2018.

[11] Jain D, Chakraborty P, Chakraverty S. Smartphone apps for teaching engineering courses: Experience and scope. Journal of Educational Technology Systems, 47(1), 4-16, 2018.

[12] Fleck S, Simon G. An augmented reality environment for astronomy learning in elementary grades: an exploratory study. Proceedings of the Twenty-fifth Conference on l'Interaction Homme-Machine, 14-22, 2013.

[13] Fleck S, Hachet M, Christian-Bastein JM. Marker-based augmented reality: instructional design to improve children interaction with astronomical concepts. Proceedings of the Fourteenth International Conference on Interaction Design and Children, 21-28, 2015.

[14] Lazoudis A. The "science centre to go" project. Proceedings of the "Science Center To Go" Workshops, 7-11, 2011.

[15] Barreira J, Bessa M, Pereira LC, Adao T, Peres E, Magalhaes L. MOW: augmented reality game to learn words in different languages. Proceedings of the Seventh Iberian Conference on Information Systems and Technologies, 1-6, 2012.

[16] Teichner AM. Augmented education: using augmented reality to enhance K-12 education. Proceedings of the ACM Southeast Regional Conference, article 45, 2014.

[17] Chen CH, Huang CY, Chou YY. Integrating augmented reality into blended learning for elementary science course. Proceedings of the Fifth International Conference on Information and Education Technology, 68-72, 2017.

[18] Bodén M, Dekker A, Viller S, Matthews B. Augmenting play and learning in the primary classroom. Proceedings of the Twelfth International Conference on Interaction Design and Children, 228-236, 2013.

[19] Alakärppä I, Jaakkola E, Väyrynen J, Häkkilä J. Using nature elements in mobile AR for

education with children. Proceedings of the Nineteenth International Conference on Human-Computer Interaction with Mobile Devices and Services, article 41, 2017.

[20] Tallyn E, Frohlich D, Linketscher N, Signer B, Adams G. Using paper to support collaboration in educational activities. Proceedings of the Conference on Computer Supported Collaborated Learning, 559-563, 2005.

[21] Schrier K. Using augmented reality games to teach 21st century skills. Proceedings of the ACM SIGGRAPH Educators Program, article 15, 2006.

[22] Freitas R, Campos P. SMART: a system of augmented reality for teaching 2nd grade students. Proceedings of the Twenty-second British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction, volume 2, 27-30, 2008.

[23] Radu I. Augmented reality in education: a meta-review and cross-media analysis. Personal and Ubiquitous Computing, 18(6), 1533-1543, 2014.

[24] Zünd F, Ryffel M, Magnenat S, Marra A, Nitti M, Kapadia M, Noris G, Mitchell K, Gross M, Sumner RW. Augmented creativity: bridging the real and virtual worlds to enhance creative play. Proceedings of the Eighth ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia, article 21, 2015.

[25] Zhou Z, Cheok AD, Pan J, Li Y. Magic Story Cube: an interactive tangible interface for storytelling. Proceedings of the ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, 364-365, 2004.

[26] Zhou Z, Cheok AD, Pan J, Li Y. An interactive 3D exploration narrative interface for storytelling. Proceedings of the Conference on Interaction Design and Children: Building a Community, 155-156, 2004.

[27] Balog A, Pribeanu C, Lordache D. Augmented reality in schools: preliminary evaluation results from a summer school. International Journal of Educational and Pedagogical Sciences, 1(6), 215-218, 2007.

[28] Yadav S, Chakraborty P. Children aged two to four are able to scribble and draw with a smart phone. Acta Paediatrica, 106(6), 991-994, 2017.

[29] Hornecker E, Dunser A. Supporting early literacy with augmented books-experiences with an exploratory study. Proceedings of the German Society of Informatics Annual Conference, 555-559, 2007.

[30] Brown HQ. Examining the effects of school-provided e-readers on middle school students' reading ability. Journal of Educational Technology Systems, 44(4), 404-410, 2016.

[31] Rinehart SD, Ahern TC. Toward a new model of usability: guidelines for selecting reading fluency apps suitable for instruction of struggling readers. Journal of Educational Technology Systems, 45(1), 124-136, 2016.

[32] Johnston E, Olivas G, Steele P, Smith C, Bailey L. Exploring pedagogical foundations of existing virtual reality educational applications: a content analysis study. Journal of Educational Technology Systems, 46(4), 414-439, 2018.

[33] Yadav S, Chakraborty P. Smartphone apps can entertain and educate children aged two to six but should be used with caution. Acta Paediatrica, 107(6), 1834-1835, 2018.