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The effects of educational computer game on low-performing children's early numeracy skills – an intervention study in a preschool setting

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ABSTRACT

The aim of this study was to determine the effects of an educational computer game, Lola's World, on low-performing children's early numeracy skills. Four preschools with 33 children from families of low socio-economic status ($M_{\text{age}} = 5.5$ years) took part in this study. Of the 33 children, 23 were split randomly into two groups: an intervention group playing a numeracy game (Lola's World) and an active control group playing an early reading skills game (Lola's ABC party). The remaining 10 children served as a passive control group. The intervention phase lasted three weeks, during which time the children played the games daily for about 15 min. The children's numeracy skills were measured using the Early Numeracy Test. Those children ($n = 22$) who exhibited low numeracy (i.e. at risk for learning difficulties in mathematics) were included in the analyses. The three groups did not differ in terms of parental educational levels or home languages. They were comparable in terms of nonverbal reasoning and the amount of time spent playing. The Lola's World group improved its early numeracy performance from pretest to post-test. No between-group differences were found. The results are discussed in relation to providing game-based support for low-performing preschoolers.

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At risk for learning difficulties; computer-assisted instruction; digital learning; early numeracy; intervention; low performance

Introduction

Digital learning is highly emphasised in Western cultures, and demands to include digital learning as a part of regular early childhood and comprehensive education are strong (Kavanagh and O'Rourke 2016). Although a large number of commercial educational games (i.e. apps) are available for (pre)schools to use in mathematics learning, only some appear to be research-based, and we have very little knowledge and mixed results concerning the effectiveness of digital environments and educational games for enhancing learning. In general, the effects of computer-assisted instruction (CAI) have been found to be small: $ES = 0.37$ (Hattie 2009).

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This study investigated the effectiveness of one educational game, *Lola's World*, on the early numeracy learning of children with low socio-economic family backgrounds and low early numeracy skills.

Early numeracy skills

Knowledge about the development of early numeracy skills and their relevance for later mathematics learning has increased rapidly over the last ten years (Aunio and Räsänen 2015; Fritz, Ehlert, and Balzer 2013; Krajewski and Schneider 2009). In general, numeracy performance in early childhood years adequately predicts later mathematics performance (Jordan, Glutting, and Ramineni 2010). Counting skills (Aunio and Niemivirta 2010; Hannula-Sormunen, Lehtinen, and Räsänen 2015; Jordan, Glutting, and Ramineni 2010; Krajewski and Schneider 2009; Nguyen et al. 2016), basic arithmetic skills (Aunola et al. 2004; Jordan, Glutting, and Ramineni 2010; LeFevre et al. 2010), number reading (Passolunghi, Vercelloni, and Schadee 2007; Vanbinst, Ghesquière, and De Smedt 2015), number line acuity (Friso-van den Bos et al. 2015; LeFevre et al. 2010), magnitude comparison (LeFevre et al. 2010; Toll et al. 2015; Vanbinst, Ghesquière, and De Smedt 2015), spontaneous focusing on numerosity (Hannula-Sormunen, Lehtinen, and Räsänen 2015) and numeracy-related logic (Aunio and Niemivirta 2010) have been found to be good predictors of later mathematics performance. Studies have shown that there are individual differences in early numeracy and that the differences in mathematics performance tend to continue in comprehensive school; thus, children who enter kindergarten with low performance in numeracy skills continue to lag behind their peers in future school years (Aunola et al. 2004; Duncan et al. 2007; Jordan et al. 2006; Jordan, Glutting, and Ramineni 2010; Morgan, Farkas, and Wu 2009). These results highlight the relevance of early interventions for low-performing children who are at risk for mathematical learning difficulties later at school.

Low performance in mathematics can be caused by several factors, including differences in cognitive functions or inadequate opportunities for learning essential mathematical skills (Geary 2013a). For instance, children from families with low socio-economic status (SES) have been shown to exhibit lower early numeracy performance than children from middle-income families (DeFlorio and Beliakoff 2015; Jordan and Levine 2009; Morgan et al. 2016). Low performance in early childhood numeracy skills can be seen, for instance, in poor and/or slowly developing counting, enumeration and numerical relational skills (Aunio and Niemivirta 2010; Jordan, Glutting, and Ramineni 2010).

To detect low performance – and, hence the risk for later mathematical learning difficulties – research has used various cut-off points (e.g. below the 15th percentile, below the 25th percentile and below the 35th percentile) in mathematical test performance (Geary 2013b). In particular, during early childhood, low performance is more relevant concept as mathematical learning difficulties refers to learning difficulties in school aged children (ICD-10: World Health Organization 2016). However, the early identification of those children at risk for learning difficulties (i.e. low performance) is highly essential, since research has shown that early intervention is an effective way of supporting learning in low-performance groups (Toll and Van Luit 2014; Wang et al. 2016), especially of children with low SES backgrounds (Ramani and Siegler 2011; Starkey, Klein, and Wakeley 2004), and of potentially preventing later learning difficulties.

CAI in mathematics

Reviews of the effects of CAI on enhancing mathematics learning in heterogeneous populations of children have revealed small to moderate effects. On an elementary school level (Slavin and Lake 2008), effects were found when CAI was used as supplementary instruction ($ES = 0.19$) in light and short practice (approximately 30 min, three times a week), with the biggest effects manifesting for lower grades and, especially, arithmetic. In a comprehensive school comprising grades K through 12, CAI's general effect was found to be small ($ES = 0.16$) (Cheung and Slavin 2013), particularly when used as supplementary education ($ES = 0.18$), as a computer management learning programme ($ES = 0.08$), or as a comprehensive programme, including CAI and non-computer activities ($ES = 0.07$). In addition, Cheung and Slavin (2013) reported similar effects for children of both low and high SES. With regard to intensity, instruction of over 30 min per week ($ES = 0.20$) was more effective than instruction of less than 30 min per week. Li and Ma (2010) found in their meta-analysis an overall moderate effect of CAI on mathematics achievement in grades K through 12 ($ES = 0.71$). They also found that the use of CAI further enhanced mathematics achievement when it was used in elementary school students, with special needs students, or in combination with a constructivist approach to teaching. Xin and Jitendra (1999) reported that CAI is effective in lower grades, especially in arithmetic and problem solving tasks. Furthermore, CAI has been found to be effective for students with learning difficulties (Chodura, Kuhn, and Holling 2015; Kroesbergen and Van Luit 2003; Li and Ma 2010; Miller, Butler, and Lee 1998; Xin and Jitendra 1999). The effects of CAI, compared to the effects of teacher-mediated instruction, have been mixed: Either CAI has been shown to be effective (Kroesbergen and Van Luit 2003) or no differences have been found between the two instruction formats (Bryant et al. 2015; Chodura, Kuhn, and Holling 2015). Although the number of intervention studies using CAI is increasing, there is still a lack of studies using comparable control groups, measuring the same skills with the same measurements (Räsänen et al. 2009).

Recently, only a few CAI intervention studies have focused on the early numeracy skills of young children (i.e. before the beginning of formal schooling) with mathematical learning difficulties (Baroody et al. 2012; Foster et al. 2016; Praet and Desoete 2014; Räsänen et al. 2009; Salminen et al. 2015a, 2015b; Schacter et al. 2016; Schacter and Jo 2016; Wilson et al. 2009). These studies (see supplementary material for detailed description) have primarily reported improved numeracy skills, at least in one of the measured numeracy skills, in the samples of children with low early numeracy skills. Their results show that children's numeracy skills can be improved through rather short interventions (3–6 weeks), although greater effect sizes have been found for longer intervention phases (10–15 weeks). The sample sizes in most of these studies have been rather small; thus, generalisation of the results is of concern.

The number of CAI studies related to mathematics learning in children having difficulties in mathematics learning seems to be somewhat greater among school-aged children compared to pre-schoolers (see the meta-analyses of Chodura, Kuhn, and Holling 2015; Kroesbergen and Van Luit 2003; Li and Ma 2010; Miller, Butler, and Lee 1998; Seo and Bryant 2009; Xin and Jitendra 1999 and the recent studies of Baroody et al. 2013; Käser et al. 2013; Nordness, Haverkost, and Voberding 2011; Obersteiner, Reiss, and Ufer 2013; Ok and Bryant 2016). In summary, the number of CAI intervention studies is rather limited, and these studies

have mostly provided positive improvements among school-age children at risk for or having difficulties in mathematics learning.

The present study

There is a lack of scientific knowledge of the effects of early numeracy educational computer games on the learning of young children who are at risk of mathematical learning difficulties (i.e. showing low early numeracy performance). Mathematical skills interventions for children with low performance due to environmental risk factors (e.g. low SES) have been studied more commonly in the United States than in European countries (Dyson, Jordan, and Glutting 2011; Siegler and Ramani 2008). In addition, there is a shortage of studies integrating CAI into the daily learning routines of young children implementing an intervention-control group design with a pre-post-test design (Räsänen et al. 2009; Schacter and Jo 2016), thus increasing the ecological validity of the present study.

The research question in this study was as follows: What are the effects of playing the Lola's World educational game on low-performing children's early numeracy skills?

Method

Participants

The study was conducted in the metropolitan area of Helsinki, Finland. All three participating preschools were located in the area of positive discrimination. In the Finnish educational context, the positive discrimination index refers to poor environmental factors, such as low parental education levels, unemployment, single-parent families, and a high number of immigrant families. In the beginning of the study, teachers from the preschools identified a total of 33 children ($M_{\text{age}} = 5.7$ years, $SD = 5.1$ months) whom they thought would be low-performing in early numeracy skills. Their evaluation was based on their knowledge of early numeracy development received mostly during their university studies and experience in teaching children. One preschool wanted to participate in the study without the intervention as they were located further away from two other preschools; thus, the children in the two remaining preschools were divided randomly into the intervention group and the active control group. Of these 33 children, 23 were split into two groups: an intervention group playing the numeracy game Lola's World ($n = 12$) and an active control group playing a game for practising early reading skills, Lola's ABC party ($n = 11$). The remaining 10 children formed a passive control group ($n = 10$). When we compared the children's Early Numeracy Test performance (see the Measurement section for the test description) with the test norms, we found that the real number of low-performing children (-1.0 SD below the age-relevant mean score) was 22. Only these children were included in the analyses. The final groups were, thus, as follows: seven children playing Lola's World, eight children playing Lola's ABC party, and seven children forming a passive control group. Descriptive information is presented by group in Table 1.

Table 1. Background descriptives by group.

	Group		
	Lola's World	Lola's ABC	Controls
<i>N</i>	7	8	7
Age (months)			
<i>M</i>	65.71	67.13	67.86
<i>SD</i>	6.68	4.09	5.18
Gender			
Girl	4	6	5
Boy	3	2	2
Home Language			
Finnish	1	3	3
Finnish and some other	2	1	–
Kurdish	–	–	2
Turkish and Kurdish	1	–	–
English and Amhara	1	–	–
Somali	1	–	–
Chinese	–	1	1
Djula	–	1	–
Russian	–	1	–
Indonesian	–	–	1
Missing information	1	1	–
Mothers' highest education			
No education	2	–	–
Comprehensive school	1	1	1
Secondary School	2	3	4
University	1	2	2
Missing information	1	2	–
Fathers' highest education			
No education	1	–	–
Comprehensive school	2	1	1
Secondary School	1	4	3
University	2	1	3
Missing information	–	2	–

Measurement

Early numeracy skills

The standardised Early Numeracy Test (Van Luit, Van de Rijt, and Aunio 2006) was used in this study. The main purpose of the Early Numeracy Test is to identify children aged between four and seven years who are suspected of a delay in preparatory mathematics knowledge. The test takes a developmental perspective on children's early numeracy skills and seeks to tap eight aspects of numerical knowledge. The mathematical relational skills part of the test (ENT relational) includes tasks related to the concepts of comparison, classification, one-to-one correspondence and seriation. The counting skills part of the test (ENT counting) includes tasks related to the use of number words, structured counting, resultative counting, and a general understanding of numbers. There are five items for each topic, yielding a total of 40 items. The test is given individually and takes about 30 min for a child to complete. The items are scored by giving one point for a correct answer and zero for a wrong answer. The children are not given feedback on whether their responses are correct or incorrect. The reliabilities in this sample for the total score (ENT total) in terms of the Cronbach's α coefficient for three measurement times were .89, .89 and .87, respectively.

Nonverbal reasoning

Children's nonverbal reasoning skills were measured using Raven's Coloured Progressive Matrices (Raven 1965) to be able to control the variability in domain-general skills in different groups of children. The test included three sets of 12-item series. For each item, the child was tasked with identifying, from among the six choices, the missing element to complete the pattern. Two practice items were not included in the analyses; thus, the maximum score was 34 points. The Cronbach's α determined from a previous study with a larger sample was acceptable ($\alpha = .77$).

Observation logbook

Preschool teachers observed the children while they were playing the educational games. The teachers had blanket to guide their observations. She marked the date, place and the minutes used in playing. In addition, she answered with yes or no to following questions: (a) the child was concentrated on solving the tasks, (b) the child was mostly surfing in various parts of the game, and (c) the child refused to play (if yes, please explain).

Family background information

Using a questionnaire, in the beginning of the study, we asked parents about their education level (i.e. no education, comprehensive school, secondary school, university) and home language (Table 1). In both the total sample and the subsamples, the maternal and paternal educational levels were lower than those of the average Finnish population (Finnish Official Statistics 2013). Several different native languages (e.g. Finnish, Kurdish and Chinese) were used in children's homes. Kruskal–Wallis tests with *post hoc* comparisons showed no statistically significant differences between the groups (Lola's World, Lola's ABC, controls) in terms of home language or maternal or paternal education level.

Intervention games

In this study, two Lola Panda games (Beiz: <http://www.lolapanda.com/index.html>) were used. Lola's World [Lolan suuri seikkailu] focuses on the practice of early numeracy skills, and it was played in the intervention group. Lola's ABC Party [Lolan ABC-juhlat] targets early reading skills, and it was used in the active control group.

Lola's World is designed for three- to six-year-old children. The focus is on early numeracy skills in number range from 1 to 10. More specifically, the game includes practice activities for the comparison of size, the categorisation of objects, the recognition of shapes and colours, the understanding/recognition of number symbols, numerosity and number symbols, the seriation of quantities and numbers, enumeration, and simple addition problems with number symbols. Most of the task instructions are given to the child verbally or visually. In the game, the child travels from island to island with the assistance of Lola Panda. The child solves tasks and receives rewards, which take the form of pieces of treasure maps. Some of the explicit teaching features were existing in the game's tasks, such as using number symbols, concrete number of objects and number words to teach children to enumerate. After collecting all pieces of the map, the child can open the treasure box. As a break time activity in the game, the child can, for example, decorate his/her house, change the clothes worn by his game avatar or draw a picture. The game is adaptive, and its starting level can be easy, medium or difficult.

Lola's ABC Party is designed for children aged four to seven years. It is designed to help children practice foundational reading skills through interactive tasks. The game is adaptive. The child begins with the recognition and writing of vowels. Then, after successful practice, the child proceeds to tasks for practising the same skills with consonants. After practising the alphabet, the child begins to practise with words. Like Lola's World, this game includes break time activities.

Procedure

This study follows a quasi-experimental intervention research protocol with a pre-test and immediate and delayed post-tests. The research permits were requested and received from the city, the preschools and the parents of the children. At the beginning of the study (February 2015), the children's early numeracy and nonverbal reasoning skills were measured. These measurements were done individually with each child in a separate room in his or her own preschool, and they were taken by the second author and a trained research assistant. During intervention phase the game was played for 15 mins very day for three weeks. The goal was to have, together, approximately four hours of game time for each child. The Beiz company provided the preschools with ten tablet computers with headphones. Two to three children used each tablet, and each child had his/her own profile in the game. The game play was integrated as part of the preschool day. The teachers were instructed briefly on how the tablet computers and the games worked before the intervention phase. When the children were playing the games, the teachers were asked to observe the children's motivation and interest using an observation blanket. After the intervention phase, the children's early numeracy skills were measured immediately and then one month after intervention.

Data analysis

Due to the small sample size of this study, non-parametric tests were used in the data analysis. We used raw scores of the tests in the analysis. Kruskal–Wallis tests with *post hoc* comparisons were performed to determine the between-group differences (Lola's World, Lola's ABC, controls) in maternal and paternal education level and home language (see the Family background information section), in Raven, and in Early Numeracy Test scores (i.e. ENT total, ENT relational, ENT counting) at three different time points. Furthermore, Kruskal–Wallis tests were used to compare the groups' ENT gains between the time points of the pretest and the immediate post-test and the pretest and the delayed post-test. The Wilcoxon signed-rank test was used to analyse the within-group effects in ENT performance (Lola's World, Lola's ABC, controls), which were interpreted with exact, one-tailed *p* values. Effect sizes for statistically significant results were calculated as Pearson's correlation coefficient (*r*) using the following formula (Rosenthal 1991): $r = z/\sqrt{N}$, where *z* is the *z*-score value produced from the analysis and *N* is the total number of observations.

Results

The performance means and group differences in Raven, ENT total score and ENT subscale scores by group at the three measured time points are reported in Table 2. The Kruskal–Wallis test confirmed that there were no statistically significant differences (all *p*-values >0.05)

Table 2. Group performance scores in Raven, ENT total score and ENT subscale scores at three time points and between-group comparisons.

Test	Time	Lola's World (A) (n = 7)		Lola's ABC (B) (n = 8) ^a		Controls (C) (n = 7) ^b		Kruskal-Wallis	p
		M(SD)	Mdn	M(SD)	Mdn	M(SD)	Mdn		
Raven	1	12.00 (4.32)	13.00	12.25 (2.25)	12.00	12.57 (4.16)	12.00	0.022	.989
ENT Relational (max. 20 p.)	1	10.14 (3.24)	11.00	9.25 (2.61)	9.50	11.29 (1.98)	12.00	2.098	.350
	2	11.29 (2.43)	10.00	10.13 (3.14)	10.00	12.43 (3.91)	10.00	1.36	.507
	Gain 1–2	1.14 (1.95)	1.00	0.88 (3.18)	0.50	1.14 (3.08)	1.00	0.104	.949
	3	11.17 (3.76)	11.50	11.67 (2.94)	13.00	12.57 (3.15)	13.00	0.510	.775
	Gain 1–3	0.67 (2.34)	0.50	2.17 (1.17)	2.00	1.29 (1.70)	0.00	1.956	.376
ENT Counting (max. 20 p.)	1	3.86 (2.12)	4.00	2.88 (1.89)	3.00	2.86 (1.68)	3.00	0.940	.625
	2	4.57 (2.37)	5.00	4.25 (3.54)	3.00	5.57 (2.23)	5.00	2.293	.318
	Gain 1–2	0.71 (0.95)	1.00	1.38 (2.67)	1.50	2.71 (2.69)	2.00	2.347	.309
	3	4.83 (3.13)	4.00	4.50 (1.97)	4.00	4.14 (1.68)	4.00	0.118	.943
	Gain 1–3	0.83 (1.17)	1.00	1.83 (2.48)	1.50	1.29 (2.14)	0.00	0.675	.713
ENT Total (max. 40 p.)	1	14.00 (4.51)	12.00	12.13 (3.80)	12.50	14.14 (3.13)	15.00	1.12	.571
	2	15.86 (3.49)	15.00	14.38 (5.90)	13.50	18.00 (5.16)	15.00	1.87	.393
	Gain 1–2	1.86 (1.68)	1.00	2.25 (5.26)	2.50	3.86 (5.34)	2.00	0.333	.847
	3	16.00 (5.55)	16.00	16.17 (4.40)	17.50	16.71 (3.99)	18.00	0.062	.969
	Gain 1–3	1.50 (1.87)	1.50	4.00 (1.41)	4.00	2.57 (3.10)	3.00	3.540	.170

Notes: Significant within-group effects are shown in boldface.

^aAt time 3: $n = 6$.

^bAt time 3: $n = 6$.

among the three groups at the beginning of the intervention in Raven, ENT total, ENT relational, or the ENT counting scales.

The effects of game playing on early numeracy performance

The Kruskal–Wallis test revealed no statistically significant differences ($p > .05$) among the three groups in terms of ENT total, ENT relational, or the ENT counting scales at either the immediate or the delayed post-test times. Neither were differences in gain scores found from pretest to immediate post-test or from pre-test to delayed post-test in any of the scales between the groups.

The only statistically significant results were found when analysing the within-group effects. The Wilcoxon tests showed a significant group-level improvement between the pre-test and the post-test in the ENT whole scale for the Lola's World group ($Z = -2.226, p = .016, r = .59$) and for the controls in the ENT counting scale ($Z = -2.207, p = .016, r = .59$) (Table 2). No other statistically significant improvements were found within the groups.

Concentration and time of playing the games

The teachers reported the children were concentrating on playing for 99% of their playing time. There was no 'restless surfing' during their playing time with the game. The only distraction during playing occurred when a child wanted to show an educator or a peer how he was playing (1% of playing time). The teachers reported that the children's total time playing Lola's World was 186.57 min ($SD = 20.21$) and that their total time playing Lola's ABC was 183.50 min ($SD = 22.70$). There were no statistically significant differences ($p > .05$) between the intervention group and the active control group in terms of playing time.

Discussion

The aim of this study was to investigate the effects of the educational game Lola's World on low-performing children's early numeracy skills. The intervention phase lasted three weeks (15 min daily game time). The study was conducted in public preschools in the positive discrimination area (i.e. low SES-area). We found that the early numeracy skills of low-performing children in the intervention group using the Lola's World educational computer game increased statistically significantly from pretest to immediate post test. However, between-group comparisons (i.e. among the numeracy intervention Lola's World group, the active control Lola's ABC group and the control group) revealed no statistically significant differences between early numeracy scores or in gains scores at any of the three time points. Although children's group were small, as has been common in CAI interventions with low performing children (Salminen et al. 2015a, 2015b), they were comparable in terms of non-verbal reasoning, early numeracy skills before intervention and time of playing. To be able to contribute to the existing knowledge we used the same early numeracy measurement in all measurement times (Räsänen et al. 2009). To secure the ecological validity of the study we did the study in preschools as part of children's daily activities (Räsänen et al. 2009; Schacter and Jo 2016). It can be that our results demonstrated that it is quite challenging to get good intervention effects on children's skills with short term game intervention when several methodological requirements are fulfilled.

Low-performing children need extensive explicit and structured instruction

Our results are in line with the study of Salminen and her colleagues (2015a), who showed within-group improvements for the intervention group, but no between-group differences. The reason for this lack of statistically significant effects between groups may be that low-performing children need a great deal of practice to learn basic skills (Geary 2013b). Although previous studies having three weeks to practise, as was used in this study, have indicated similar learning effects (Salminen et al. 2015a), increasing the practice time might yield better effects (Schacter et al. 2016b). The Lola's World game was originally developed to help

average-performing children practice basic early numeracy skills (Beiz). In this study, it was used with children from families with low SES; furthermore, within this sample, we concentrated on children identified as low-performing in early numeracy skills. Using an educational game in different types of populations of children showing low performance, such as populations with different measured numeracy performance levels (Praet and Desoete 2014) or SES (Schacter and Jo 2016a), may yield different results, since the reasons behind the low performance may differ (Geary 2013a). For some children, the reason for low performance may have been a lack of adequate early childhood numeracy experiences (i.e. for children with low SES) (Morgan et al. 2016), while for others, the reason may be cognitive (Geary 2013b). In the first case, exposure to quality numeracy instruction may yield a more rapid increase in learning than in the latter case.

In order to support early numeracy learning in low-performing children, educational games should have a good research-based structure (Aunio and Räsänen 2015), so that the most essential skills are practised enough and so that tasks follow one another in a developmentally valid order (Foster et al. 2016). In addition, effective mathematics educational games have been found to include specific instructional elements that are considered beneficial for low-performing children's learning, such as explicit and structured instruction (Seo and Bryant 2009). In order to make *Lola's World*, and any other CAI programme, more suitable for low-performing children, these elements should be taken into consideration.

Child's interest and motivation in playing and shared learning experiences

Both games used in this study, *Lola's World* and *Lola's ABC*, were interesting and motivating for the children. Teachers reported no need to motivate the children to play the games during the preschool day (15 min per day for three weeks). In fact, the teachers reported the interesting phenomenon that the children often wished to show their educator or peer show they were playing. This kind of shared learning using tablet computers has been previously reported in the early childhood context (Khoo et al. 2015). The related term is peer-assisted learning, which has shown some positive results in supporting learning in mathematically low-performing children (Baker, Gersten, and Lee 2002; Kunsch, Jitendra, and Sood 2007) however, so far, most results come from older students.

Limitations of the study and future challenges for game-based learning

The main limitation of this study was its small sample size, which limits the generalisability of the results. In future it would be valuable to combine data-sets made with similar design, as it would allow the use a more sophisticated statistics as was possible in this piloting study. Another limitation related to statistics used was the comparison of the gain scores, by which we lose the variability associated with each time point. To inform the reader about the variability of the scores in each time points we have reported the standard deviations in Table 2. However, the study represents a valuable attempt to integrate game-based support into the average preschool days of low-performing children, as proposed in a recent review (Räsänen 2015). The study also gives us guidelines for future research. In future studies with bigger samples, it might be interesting to either increase the instruction time (weeks) or combine the use of the *Lola's World* game with small-group supplemental instruction. Also of interest would be to investigate the possibility of increasing the children's play time outside

preschool hours, so that they could practise relevant skills at home. This would, however, require the children to have access to digital equipment (either a tablet computer or a smart phone) and, possibly, an Internet connection. This might be a problem for children coming from families with low SES.

Developing educational games requires good collaboration among game developers and researchers. It is essential to apply good research designs to investigate the effects of playing games on not only children's performance, but also their motivation and interest. Although, in this study, there were few positive results to report, future research should continue to explore who will benefit from educational games and what is the most efficient way to use these games with children.

Conclusion

Playing the Lola's World numeracy computer game daily for three weeks improved the within-group early numeracy skills of low-performing children; however, no statistically significant differences among this group, the group playing a game practising early reading skills, and the passive control group, were found in either the post-test scores or the gain scores. The Lola's World game might work better with increased instruction time or in a different type of population (e.g. children with no problems in learning numeracy skills); therefore, further research on the effects of this game in these scenarios would be highly interesting.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Pirjo Aunio works as a professor in University of Helsinki. Her research focus on learning of mathematical skills, mathematical learning difficulties, assessment and educational interventions.

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