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## **A randomized controlled trial of an early-intervention, computer-based literacy program to boost phonological skills in 4- to 6-year-old children**

O'Callaghan, P., McIvor, A., McVeigh, C., & Rushe, T. (2016). A randomized controlled trial of an early-intervention, computer-based literacy program to boost phonological skills in 4- to 6-year-old children. *British Journal of Educational Psychology*, 86(4), 546. <https://doi.org/10.1111/bjep.12122>

**Published in:**  
British Journal of Educational Psychology

**Document Version:**  
Peer reviewed version

**Queen's University Belfast - Research Portal:**  
[Link to publication record in Queen's University Belfast Research Portal](#)

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## Running head: Early-intervention computer literacy program RCT

1 A randomised controlled trial of an early-intervention, computer-based literacy program to  
2 boost phonological skills in 4- to 6- -year-old children.

3

4 **Background:** Many school-based interventions are being delivered in the absence of  
5 evidence of effectiveness (Snowling & Hulme, 2011).

6 **Aims:** This study sought to address this oversight by evaluating the effectiveness of the  
7 commonly used the Lexia Reading Core5 intervention, with 4 to 6-year-old pupils in  
8 Northern Ireland.

9 **Sample:** A total of 126 Primary school pupils in year 1 and year 2 were screened on the  
10 Phonological Assessment Battery 2<sup>nd</sup> edition (PhAB-2). Children were recruited from the  
11 equivalent year groups to Reception and Year 1 in England & Wales, and Pre-kindergarten  
12 and Kindergarten in North America.

13 **Methods:** A total of 98 below- average pupils were randomised (T0) to either an 8-week  
14 block ( $\bar{x}$  = 647.51 minutes,  $SD$  = 158.21) of daily access to Lexia Reading Core5 ( $n$  = 49) or  
15 a waiting-list control group ( $n$  = 49). Assessment of phonological skills was completed at  
16 post intervention (T1) and at 2-month follow-up (T2) for the intervention group only.

17 **Results:** Analysis of Covariance which controlled for baseline scores found that the Lexia  
18 Reading Core5 intervention group made significantly greater gains in blending,  $F(1,95) =$   
19  $6.50$ ,  $p = 0.012$ , partial  $\eta^2 = 0.064$  (small effect size) and non-word reading,  $F(1,95) = 7.20$ ,  $p$   
20  $= 0.009$ , partial  $\eta^2 = 0.070$  (small effect size). Analysis of the 2-month follow-up of the  
21 intervention group found that all group treatment gains were maintained. However,  
22 improvements were not uniform among the intervention group with 35% failing to make  
23 progress despite access to support. *Post-hoc* analysis revealed that higher T0 phonological  
24 working memory scores predicted improvements made in phonological skills. **Conclusions:**  
25 An early-intervention, computer-based literacy program can be effective in boosting the

26 phonological skills of 4 to 6-year-olds, particularly if these literacy difficulties are not linked  
27 to phonological working memory deficits.

28 **Introduction**

29 Effective reading interventions incorporate training in letter–sound knowledge and phoneme  
30 awareness, explicit and systematic phonics instruction, and the application of these skills to  
31 the tasks of reading and spelling (Duff et al., 2014). This explicit teaching of blending,  
32 segmenting and non-word reading skills to increase efficacy and confidence in tackling  
33 unknown words is all the more essential for at-risk readers given the large body of evidence  
34 now showing the predictive value of letter-sound knowledge and some phoneme awareness in  
35 the development of ‘learning to read’ skills in the early stages (Snowling & Hulme, 2011).

36 Research indicates that the earlier an intervention occurs the greater the chance of  
37 remediation (Allen, 2011) and the higher the probability that more entrenched literacy  
38 difficulties in the future can be mitigated (Boscardin, Muthén, Francis, & Baker, 2008).

39 Currently, the evidence basis for computer-based literacy programs is limited  
40 (Brooks, 2013; Cheung & Slavin, 2013; Slavin, Lake, Davis, & Madden, 2011) and mixed  
41 (Archer et al., 2014, Campuzano Dynarski, Agodini, & Rall, 2009). This is even more  
42 evident in studies of technology-based literacy interventions for children under eight years of  
43 age (Lankshear & Knobel, 2003; Shannon, Styers, Wilkerson & Peery, 2015), which the  
44 current study is seeking to address.

45 Evidence for the effectiveness of computer-based literacy programs currently used in  
46 UK schools comes predominantly from single sample, unpublished, pre and post studies with  
47 no control group and no randomisation (Brooks, 2013). Brooks (2016) notes the importance  
48 of considering evidence from randomised controlled studies, and an increase in evidence  
49 from studies of this type is demonstrable in his recent review of 19 studies (Brooks, 2016).

50 Although research evidence is stronger in the United States, arising from a greater number of  
51 controlled studies and randomised trials, findings are ambiguous. One study program benefits  
52 of using a computer-based literacy program on letter identification, word attack skills and

53 passage comprehension skills for first but not second graders (Chambers et al., 2011), one  
54 found benefits on spelling but not basic literacy skills (Blachowicz et al., 2009) and another  
55 on the reading comprehension of low-achieving pupils using a blended approach to  
56 instruction (Schechter et al., 2015).

57 Similarly varied findings emerged for studies involving the Lexia computer-based  
58 reading skills program both in the United States and in the UK. In the United States, matched  
59 control studies demonstrated Lexia's efficacy for all pre-schoolers but only kindergarten  
60 children with difficulties (Macaruso & Rodman, 2011), improvements in phonological  
61 awareness particularly amongst children with low pre-test scores (Macaruso and Walker,  
62 2008) and in both the letter-sound correspondence and word recognition of low-achieving  
63 pupils (Macaruso, Hook, & McCabe, 2006). In the UK, a quasi-experimental, controlled  
64 study involving 106 children found that Lexia was successful in improving standardised  
65 scores in reading for up to 66% of the intervention group (McMurray, 2013).

66 Given the variability in research findings and the evidence of effectiveness on  
67 computer-based interventions on some, but not all variables, this study also sought to explore  
68 the different variables that accounted for success in phonological skills. Prior research,  
69 predominantly with older children, identified working memory (McMurray, 2012), gender  
70 (Rutter et al., 2004), and language proficiency (Yeung & Chan, 2013) as mediating factors in  
71 literacy difficulties and intervention response and this study sought to explore if these  
72 variables were also relevant for younger populations too.

73 In summary, many questions still remain regarding the effectiveness of computer-  
74 assisted literacy interventions. Given the variability in findings, the use of a randomised  
75 controlled trial (RCT) is an important contribution to the literature (Snowling & Hulme,  
76 2011). This study is, to the authors' knowledge, the first participant-level, RCT of Lexia with  
77 Year 1 and 2 pupils conducted to date.

78           The first research question sought to test whether the intervention group would show  
79 statistically significant improvements in blending, phoneme segmentation and non-word  
80 reading at T1 when compared to the control group. The second research question sought to  
81 examine if gains made on the intervention were uniform across all participants and if not, to  
82 determine the factors that would predict participant progress.

83 **Method**

84 *Trial design*

85 This was a parallel-group, randomised controlled trial with a no-treatment, wait-list control  
86 group. The study ran from December 2014 to June 2015. Every child who met eligibility  
87 criteria agreed to participate in the study (see Figure 1) and were randomised to either the  
88 Experimental group (8 weeks of daily 20- to 30- min sessions of the intervention) or a Wait-  
89 List Control group (standard classroom teaching in line with the statutory Northern Irish  
90 curriculum and supplemented with both synthetic and linguistic phonics programs). Children  
91 were assessed individually pre-intervention (T0), post-intervention (T1) and at 2-month  
92 follow-up (T2) (intervention group only). Ethical approval was given by the School of  
93 Psychology Research Ethics Committee at Queen's University, Belfast and written parental  
94 consent and verbal pupil assent was provided for all participants.

95 *Participants and setting*

96 The study took place in two town-based primary schools in Northern Ireland. Schools were  
97 chosen based on their ability to provide pupils with access to a multi-computer information  
98 and communications technology (or ICT) suite and their focus on raising whole-school  
99 literacy levels in their school development plan. School A had a registered pupil population  
100 of 250, 46% of whom were eligible for free school meals. School B had a registered  
101 population of 547, 44% of whom were eligible for free school meals. The study was run in  
102 conjunction with the Educational Psychology Service and the School of Psychology and was  
103 overseen by a qualified Educational and Child Psychologist with research experience as lead  
104 investigator in school-based randomised controlled trials in the past. In keeping with previous  
105 research which showed the benefit for staff training and support on the efficacy of computer-  
106 based interventions (Archer et al., 2014), pre-intervention set-up and product introductory  
107 tutorials and on-going technical support were provided to both schools by LexiaUK Ltd.

108

109

110 Participant details are listed in Table 1. 126 children were screened to identify those  
111 with the weakest reading skills. Inclusion criteria for the study were (1) being in a  
112 mainstream Year 1 or Year 2 class, (2) having a standard score of 90 or less on any of the  
113 four subtests of the four Phonological Assessment Battery (PhAB-2) subtests assessed (low  
114 average to below average range). In Northern Ireland, the compulsory school age is 4.  
115 Therefore children in Years 1 & 2 there are within the same age-range as those in Reception  
116 & Y1 in England & Wales, and in Pre-kindergarten and Kindergarten in North America.  
117 Exclusion criterion was having scores of zero on all four subtests (due to concerns about floor  
118 effects). The 14 excluded pupils were then offered a more intensive, separate program of  
119 literacy support. To keep the trial naturalistic, children with English as an Additional  
120 Language or pupils on the school's SEN register were not excluded. Of the 126 children  
121 screened, 98 met inclusion criteria and all were invited to participate in the RCT study. All  
122 agreed and provided parental consent. The pupils ranged in age from 4 to 6 ( $\bar{x}$  = 63 months,  
123  $SD = 9.5$ ).

124 Based on the post-intervention group outcome means in a quasi-experimental study of  
125 Lexia in Northern Ireland (McMurray, 2012) we calculated the minimum sample size to  
126 adequately power the study to be 40 per group, at a power level of 0.80 and an alpha value of  
127 0.05 (ClinCalc.com).

### 128 ***Procedure***

129 Classroom assistants and the school SENCo were trained by the second author in the  
130 administration of the PhAB-2 (Gibbs & Bodman, 2014) in the week prior to the scheduled  
131 testing. During this training, staff were provided with video tapes of standardised  
132 administration, and were given an opportunity to administer the four subtests and have any



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133 questions on test administration answered. The importance of consistency was stressed and  
134 assessors were observed administering the subtests to ensure consistency of administration  
135 across assessors.

136 Tests were administered over three days in December (T0), April (T1) and June (T2)  
137 in private reading rooms in each school to keep disruptions and external noise to a minimum.  
138 To ensure consistency throughout the intervention, data collection at each time period was  
139 allocated to the same assessor. The first author enrolled participants while the second author  
140 used simple randomisation to generate the allocation sequence ([www.random.org](http://www.random.org)) and  
141 assigned participants to the two groups. There were no changes to the methods or outcomes  
142 after trial commencement and the trial proceeded as per the protocol.

### 143 *Measures*

144 To assess phonological skills the Phonological Assessment Battery, Second Edition (PhAB-  
145 2) were used. The PhAB-2 was chosen because (a) it was recently standardised for the age  
146 range of interest (b) it measures both phonological processing (e.g. blending subtest) and  
147 phonological production (e.g. non-word Reading)(c) it provides standardised scores of  
148 Phonological Working Memory (we were interested in seeing if this variable could predict  
149 improvements made on the intervention over time) (d) it contains a standardised protocol for  
150 both test administration and scoring, detailed in the test manual (Gibbs & Bodman, 2014) .  
151 We used four subtests on the PhAB-2: Blending subtest (combining sounds to make a spoken  
152 word e.g. /k/, /æ/, /t/ = cat), Phoneme Segmentation subtest (separating spoken words into  
153 their constituent phonemes e.g. car = /k/ + /a-/) The retroflex ('r-coloured') version of this  
154 phoneme is provided here as in Northern Ireland the majority of regional dialects are rhotic.  
155 In addition, the Phonological Working Memory subtest (repeating a series of non-words e.g.  
156 narraf) and Non-Word Reading subtest (decoding unfamiliar strings of letters as sounds that  
157 might form a word e.g. tib) were administered also. In line with McMurray (2013) eligibility

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158 criteria were set as having a standard score of less than 90 on any of the variables measures at  
159 T0 and improvements over time were measured using raw score changes. This was done  
160 because it was felt that raw scores were a more objective measure of change in outcomes over  
161 time than standardised scores with populations at the lowest end of the normative sample  
162 range.

163 In 2013, the PhAB-2 was standardised with a sample of 773 (4- to 11-year-olds)  
164 children in England, Scotland and Wales (Gibbs & Bodman, 2014). Internal consistency for  
165 the four subtests used ranged from .76 (Phonological Working Memory) to .96 (Blending).  
166 Evidence of construct validity was shown in increases of score with age and inter-correlations  
167 between the PhAB-2 Primary tests, while strong correlations of 0.721 and 0.738 were found  
168 between the test of non-word Reading and the York Assessment of Reading Comprehension  
169 and Single Word Reading Test, respectively.

### 170 *Intervention*

171 The intervention group received daily, individual, adult-supervised, 20-30 minute blocks of  
172 computer-based support on Lexia Reading Core5 program for 8-weeks ( $\bar{x}$  = 647.51 minutes,  
173 SD = 158.21). Lexia was chosen due to its growing use in UK schools by children with  
174 literacy needs and English as an Additional Language ([www.lexiauk.co.uk](http://www.lexiauk.co.uk)) and its  
175 preliminary research findings suggesting its effectiveness (Brooks, 2013, 2016). This reading  
176 skills program allows pupils to work independently in a structured, sequential manner. When  
177 pupils log-on to Lexia for the first time, they take an Auto Placement test to determine their  
178 level and then progress through graded exercises in phonological awareness, phonics,  
179 fluency, vocabulary and comprehension. However, to ensure even progress, the Lexia  
180 program blocks advancement to higher levels until a prescribed set of minimum units in all  
181 five areas are completed correctly. In addition to tracking the time an individual child spends  
182 on Lexia it also tracks the number of units each child correctly completes and flags areas of

183 difficulty where a pupil fails to grasp a concept or make progress despite access to additional  
184 activities to remediate this difficulty. The Lexia program targets skills in rhyming, blending  
185 and segmenting, letter-sound correspondence, 'b', 'd', 'p' confusable letters, short and long  
186 vowels, spelling rules, high-frequency sight words, fluency, vocabulary development, timed  
187 silent reading and listening and reading comprehension.

188 The Lexia online program can be supplemented with offline, teacher-led resources for  
189 individual or small group instruction. Lexia lessons consist of structured, teacher-delivered  
190 lessons which are designed to address skills based on performance on the online activities, as  
191 identified by the teacher using online reports generated by the program. Skill Builders are  
192 offline, pencil and paper activities which can be completed at the end of each online activity.  
193 These are designed to complement and extend work completed through the online Lexia  
194 program. This study examined use of the online Lexia program only.

#### 195 *Data Analysis*

196 To control for baseline differences between the intervention and wait-list control group, an  
197 Analysis of Covariance (ANCOVA), controlling for baseline scores was used and partial eta  
198 squared ( $\eta^2$ ) and Cohen's d effect sizes were recorded.

199 Comparisons between the intervention group and control group were conducted at T0  
200 (baseline testing) and T1 only. Results indicated equivalent performance at baseline testing.  
201 The control group received their intervention after T1 analysis was conducted and  
202 demonstrated the effectiveness of the intervention.

203 Repeated measures ANOVAs were used to measure within subject effects for the  
204 intervention group on all three variables over time from T0 to T1 and then at T2 while linear  
205 regression analysis was used to identify the demographic, procedural and baseline variables  
206 that could predict improvements in phonological skills.

207           Four pupils were unable to be tested at T1 and 4 pupils from the Intervention Group  
208 were unable to be tested at T2 but were included in the outcome analysis (intention-to-treat  
209 analysis. Except in the case of the participants mentioned above who were absent for T1 or  
210 T2 testing, there were no other missing values in this study. Bonferroni adjustment of  
211 significance levels was applied for all multiple comparisons ( $p < 0.0167$ ). Statistical analyses  
212 were conducted using IBM SPSS version 22 (IBM, 2013).

213 **Results**

214 *Baseline Characteristics*

215 Baseline characteristics of participants in the two groups are presented in Table 1.

216 Randomisation resulted in no significant difference on age, gender, year group, English as an

217 Additional Language status (or EAL status) or any T0 measure.

218 Recruitment began in December 2014, with T1 testing in April 2015 and P2 testing in

219 June 2015. The trial was ended after the intervention group had received one block of

220 intervention support. Two pupils discontinued the intervention (due to difficulties using a

221 mouse and frustration and anxiety caused by this and the other one due to poor attendance)

222 having accessed 23 and 51 minutes respectively. However, in order not to compromise the

223 integrity of the randomisation, the pupils' scores were still included in T1 and T2 analysis of

224 the intervention group. Meanwhile, three pupils at T1 and four pupils from the intervention

225 group at T2 were absent on the day of testing and their scores were included using a 'last

226 value carried forward' method.

227 Prior to analysis, scatterplots were used to measure linearity and Levene's test

228 indicated homogeneity of variance for all variables.

229 An ANCOVA (co-varying for baseline scores) found that the Lexia Intervention

230 group were better able to blend sounds,  $F(1,95) = 6.50$ ,  $p = .012$ , partial  $\eta^2 = 0.064$  and read

231 nonsense words,  $F(1,95) = 7.20$ ,  $p = .009$ , partial  $\eta^2 = .070$  than the wait-list control group

232 after the intervention with medium effect sizes reported ( $\eta^2 > .0588$ ) (see Table 2).

233 Furthermore, these gains were maintained at T2 with Repeated Measures ANOVAs

234 (see Table 3) demonstrating an 'Intervention Over Time' effect for the Lexia group on all

235 blending, phoneme segmentation and non-word reading respectively,  $F(2,47) = 27.09$ ,  $p <$

236  $.001$ , partial  $\eta^2 = .535$ ,  $F(2,47) = 30.70$ ,  $p < .001$ , partial  $\eta^2 = .566$  and  $F(2,47) = 22.88$ ,  $p <$

237  $.001$ , partial  $\eta^2 = .493$ .

238            Inspection of the data of the intervention group at T1 testing indicated that the gains  
239 made by the intervention group as a whole were not evenly distributed and that 35% of the  
240 intervention group (17/49) made no improvements on two out of the three outcome variables.

241            Regression analysis (see Table 4) indicated that phonological working memory scores  
242 successfully predicted improvements in blending scores in the Lexia group ( $p = .001$ ).

243            Meanwhile, the intervention was shown to be equally successful for boys and girls, pupils  
244 from School A or School B, pupils who had English as a first or as an additional language or  
245 pupils that spent a large or small amount of time on the intervention.

246 **Discussion**

247 *Interpretation*

248           This RCT supports the findings of previous quasi-controlled studies, which found  
249 that Lexia can be effective in helping reading delayed children (Macaruso et al., 2006) and  
250 children with literacy difficulties linked to phonological deficits (McMurray, 2013). It adds to  
251 the growing evidence basis for the effectiveness of both early-intervention (Hatcher et al.,  
252 2006; Macaruso and Walker, 2008; Schwartz, 2005;) and computer-based literacy programs  
253 (McMurray, 2013, Shannon et al., 2015). However, unlike previous studies, this study tested  
254 the effectiveness of a phonics-based computer-based literacy program with children in their  
255 first and second year of school, using an RCT, which makes these findings an important  
256 addition to the field of early-intervention, literacy support programmes.

257           Secondly, while the intervention was shown to improve blending and non-word  
258 reading skills, it was less effective for phoneme segmentation skills. This is in line with  
259 previous research which found that the kindergarten Lexia group made greater progress than  
260 the control group on reading accuracy but not on phoneme segmentation (Macaruso &  
261 Walker, 2008). One hypothesised explanation for this lack of evidence is visual channel  
262 overload (Sakar & Ercetin, 2005). Visual channel overload occurs when verbal, auditory and  
263 visual information obtained from a text becomes too much for a person's working memory to  
264 process. Although all of the subtests in this study were administered orally, phoneme  
265 segmentation was the only subtest which contained both aural and visual input.

266           Thirdly, although nearly two-thirds of the intervention group found the Lexia  
267 intervention to be beneficial, 35% of this group failed to make progress despite access to this  
268 intensive phonics-based intervention. This finding of a significant minority of children whose  
269 literacy difficulties are persistent despite remediation was also found in both the McMurray  
270 (2013) and Hatcher et al. (2006) studies and offers further evidence for the obstructive role of

271 working memory deficits in early literacy acquisition (Alloway et al., 2005; McMurray,  
272 2013). It also demonstrates the importance of a multi-modal literacy intervention where ICT  
273 is supplemented by the mediation of a skilled adult (Brooks, 2013) who can remediate pupil-  
274 specific literacy problems identified by the ICT program.

275 Finally, the finding that time spent on the program was not a significant predictor of  
276 outcome is in line with the finding of McMurray (2013). McMurray (2013) also found that  
277 time spent on Lexia did not significantly contribute to the amount of variance in final reading  
278 scores. Instead, the findings of the present study and those of McMurray (2013) indicate that  
279 children's progress on the Lexia program contributed to the amount of variance in final  
280 reading scores, as indicated in McMurray's study by level and in the present study by score.  
281 The present authors postulate that a ceiling period of time can be reached within a session and  
282 once this is reached a pupil cannot make more progress within a session. This suggestion is  
283 strengthened by the views of the children in McMurray's (2013) study who note that they  
284 reach a point where they become 'stuck' on a Level. The authors also postulate that the  
285 optimal period of time spent on the program is likely to be developmentally appropriate and  
286 in line with a child's attention span, and individual differences.

### 287 *Limitations*

288 This current study had some important limitations. Firstly, it used a wait-list control  
289 design which meant that only within-treatment effects were available at T2. This decision  
290 was taken because the authors felt an ethical responsibility to provide literacy support to the  
291 wait-list control group identified with literacy difficulties as soon as we possibly could. Given  
292 the restricted time-frame of the study and the restricted access to individual user licences  
293 from Lexia for the duration of the study, the only available time to provide the wait-list group  
294 with support was after the intervention group had received their 8-week block.



295           The restricted time-frame for the study also limited the length of time available for  
296 follow-up. While the authors accept a 2-month timeframe falls short of the 6- to 24- month  
297 follow-up of other literacy intervention studies (Duff et al., 2014), we felt that it was better to  
298 include a follow-up test at least equivalent to the length of time of the intervention in order to  
299 monitor progress or fall-back.

300           Thirdly, participants did not access the adult-mediated support using the scripted  
301 lesson plans (Lexia Lessons) and practice worksheets (Skill Builders) generated by the Lexia  
302 program to help pupils who had not grasped a literacy concept being taught electronically.  
303 This was an omission, which occurred due to timetable limitations, but which could be  
304 planned for in future research through an examination of the use of these supplementary  
305 resources in conjunction with the online program. Importantly, the role of the teacher must be  
306 stressed in critically evaluating the most effective use of any such resources at an individual  
307 pupil level. This may be particularly important given the growing evidence of the impact of  
308 adult-mediation in determining the success of computer-based programs (Brooks, 2013;  
309 Savage et al., 2010). Whilst the present results are positive in terms of the efficacy of the  
310 program for the majority of participating children, it may be noted that the expertise and  
311 critical professional judgement of the class teacher is likely to be a crucial factor in its most  
312 effective deployment.

### 313           *Generalisability*

314           Despite the limitations above, the study had many important strengths. Firstly, it  
315 sought to subject well-intentioned educational practices to vigorous evaluation (Duff et al.,  
316 2014) using practitioner-led evidence-based research. The study adopted the most rigorous  
317 research method available (Snowling & Hulme, 2011), something sorely lacking in the field  
318 of literacy interventions (Brooks, 2013, Snowling & Hulme, 2011). To improve the external  
319 validity of the study, children with English as an Additional Language and pupils on the SEN

320 register were also included. The study sought to target literacy difficulties as early as  
321 possible, something that research has identified as both achievable (Hatcher et al., 2006) and  
322 cost-beneficial (Allen, 2011).

323         With recent cuts in school budgets, pupils are now less likely to access within school  
324 literacy support, placing an even greater strain on external literacy support services,  
325 lengthening waiting lists and further delaying access to much needed assistance. Although  
326 not a panacea for all literacy difficulties, computer-based interventions can provide a strategic  
327 opportunity for children to access early-intervention, intensive, phonics-based support in a  
328 format that children report to be enjoyable and motivating (McMurray, 2012). If literacy  
329 difficulties are caused by underlying phonological deficits in the absence of significant  
330 working memory deficits, access to computer-based support could just provide the literacy  
331 boost some children need to catch-up with peers and access class-based literacy instruction.  
332 This prevents difficulties becoming entrenched and offers a quick and early solution allowing  
333 classroom literacy learning to continue.

334         Future research is needed to examine which components of the Lexia Reading Core5  
335 program are most successful in boosting phonological and letter-sound knowledge, the  
336 impact of additional adult mediation on progress made on the program, the impact of Lexia  
337 on subsequent reading and spelling skills of participants and whether progress in  
338 phonological skills is sustained by children engaging with this computer based intervention  
339 over a longer period of time.

#### 340 ***Conclusion***

341 This RCT demonstrated that a computer-based, early intervention literacy program boosted  
342 the phonological skills of children, resulting in significantly higher performance on blending  
343 and non-word reading tasks as compared with the control group. Furthermore, these gains in  
344 performance were maintained by the intervention group when assessed again at 2-month

345 follow-up. However, *post-hoc* analysis showed that effect sizes were small and that gains  
346 made by the intervention group were not spread evenly across participants with  
347 approximately 35% of the intervention group failing to make significant gains despite access  
348 to the intervention. Future research should investigate the cognitive factors impacting on the  
349 performance of children who are not seen to make progress on such interventions. In  
350 considering why this may be the case, it may be noted that multiple regression analysis  
351 conducted for this research indicated that pre-intervention phonological working memory  
352 scores were a key predictor of gains made within the intervention group. The findings overall  
353 show promising initial results from a randomised controlled trial of a computer-based literacy  
354 intervention for young children.

355         However, it also demonstrates that while a majority of children involved will make  
356 progress, there are significant minorities of children who do not make gains on this type of  
357 program, which has been reported elsewhere in the literature (McMurray, 2012; Hatcher et  
358 al., 2006).

359         Finally, in deciding whether or not to utilise such a program with a pupil, practitioners  
360 may wish to consider phonological working memory scores when deciding on the specific  
361 literacy support package offered to struggling pupils, as pre-intervention phonological  
362 working memory scores were seen to be a key predictor of gains made in reading skills  
363 within the intervention group.

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454 Key Points

- 455 • Lexia is an effective early-intervention program for literacy difficulties for children  
456 with low average to below average phonological skills
- 457 • The intervention group made statistically significant improvements in blending and  
458 non-word reading when compared to the control group
- 459 • Approximately 35% of the intervention group failed to make progress despite access  
460 to an intensive, literacy intervention
- 461 • Phonological working memory predicted gains made in blending by the intervention  
462 group

463



464 **TABLES AND FIGURES**

465

466 **Table 1** Descriptive data for the intervention and wait-list control group in the study

	<b>Lexia Group (n=49)</b>	<b>Wait-List Group (n=49)</b>	<b>F-value or Chi-Square</b>	<b>p-value<sup>a</sup></b>
Number of Boys (n,%)	26 (53%)	21 (43%)	1.022	0.312
Number of Year 1 children (n,%)	23 (47%)	25 (51)	0.163	0.686
Number of EAL children (n,%))	16 (33%)	18 (37%)	0.180	0.671
Age of Participants ( $\bar{x}$ , SD)	62.78 (10.75)	63.76 (8.17)	0.258	0.613
T0 Blending Scores ( $\bar{x}$ , SD)	4.45 (5.87)	4.61 (6.24)	0.018	0.894
T0 Segmentation Scores ( $\bar{x}$ , SD)	4.00 (4.18)	3.12 (3.87)	1.163	0.284
T0 NW Reading Scores ( $\bar{x}$ , SD)	2.18 (4.68)	2.27 (4.38)	0.008	0.929

467 <sup>a</sup> One-way ANOVAs (confidence interval: 95%) measured baseline differences of continuous

468 variables and Chi-Square tests measured baseline differences for categorical variables

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471 **Table 2** Analysis of covariance for blending, segmentation and non-word reading at T1

Variable	Intervention (n=49)			Control (n=49)			Value F (1,95)	p	Effect size ( $\eta^2$ )  (Cohen's d*)
	Mean (SD)			Mean (SD)					
	T0	T1	Diff	T0	T1	Diff			
Blending	4.45 (5.87)	9.18 (6.51)	4.74 (4.78)	4.61 (6.24)	7.02 (6.68)	2.41 (4.38)	6.50	0.012	0.064  (d=0.36)
Phoneme Segmentation	4.00 (4.18)	5.61 (4.49)	1.61 (3.46)	3.12 (3.87)	3.78 (4.01)	0.65 (3.78)	3.467	0.066	0.035  (d=0.23)
Non-Word Reading	2.18 (4.68)	5.63 (6.73)	3.45 (4.82)	2.27 (4.38)	3.57 (5.57)	1.31 (2.82)	7.20	0.009	0.070  (d=0.35)

472 \*Cohen's d was calculated using the difference in gains scores divided by the pooled

473 post-test standard deviations

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474 **Table 3** Descriptive data for intervention group on blending, segmentation and NW reading  
 475 at T0, T1, T2

N	Variable	Mean	SD	Variable	Mean	SD	Variable	Mean	SD
49	BlendT0	4.45	5.87	SegT0	4.00	4.18	NWRT0	2.18	4.68
49	BlendT1	9.18	6.51	SegT1	5.61	4.49	NWRT1	5.63	6.73
49	BlendT2	10.9	6.65	SegT2	7.53	4.04	NWRT2	7.55	6.93

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478 **Table 4** Regression analysis for intervention group on difference in blending scores at T1

Coefficients							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-7.361	5.594		-1.316	0.196	-18.659	3.937
Age	-0.021	0.77	-0.048	-0.277	0.783	-0.177	0.134
School	0.531	1.518	0.056	0.350	0.728	-2.535	3.597
Gender	1.539	1.352	0.162	1.138	0.262	-1.191	4.269
EngOrEAL	1.752	1.553	0.174	1.128	0.266	-1.385	4.888
Class	-1.165	1.773	-0.123	-0.657	0.515	-4.745	2.416
Time	0.007	0.005	0.219	1.436	0.159	-0.003	0.016
Phonological WM Score, T0	0.578	0.163	0.479	3.554	0.001	0.249	0.906

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481 **Figure 1** Consort Diagram Showing Flow of Participants through the trial

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