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

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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 2nd 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.

Introduction

28

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- to30- 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

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) 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/ + /aˑ/) 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

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) 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 (η^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 twi-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   progam 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.

364 **REFERENCES**

365 1. Allen, G. (2011). *Early Intervention, The Next Steps: An Independent Report to Her*

366 *Majesty's Government*. The Stationery Office.

367 2. Alloway, T. P., Gathercole, S. E., Adams, A. M., Willis, C., Eaglen, R., & Lamont, E.

368 (2005). Working memory and phonological awareness as predictors of progress towards

369 early learning goals at school entry. *British Journal of Developmental Psychology*, *23*(3),

370 417-426. DOI: 10.1348/026151005X26804

371 3. Archer, K., Savage, R., Sanghera-Sidhu, S., Wood, E., Gottardo, A., & Chen, V. (2014).

372 Examining the effectiveness of technology use in classrooms: A tertiary meta-analysis.

373 *Computers & Education*, *78*, 140-149. DOI:10.1016/j.compedu.2014.06.001

374 4. Blachowicz, C. L., Bates, A., Berne, J., Bridgman, T., Chaney, J., & Perney, J. (2009).

375 Technology and at-risk young readers and their classrooms. *Reading Psychology*, *30*(5),

376 387-411. DOI: 10.1080/02702710902733576

377 5. Boscardin, C. K., Muthén, B., Francis, D. J., & Baker, E. L. (2008). Early identification

378 of reading difficulties using heterogeneous developmental trajectories. *Journal of*

379 *Educational Psychology*, *100*(1), 192. DOI: 10.1037/0022-0663.100.1.192

380 6. Brooks, G. (2016). What works for children and young people with literacy difficulties:-

381 The effectiveness of intervention schemes (5th ed.). The Dyslexia-SpLD Trust.

382 7. Brooks, G. (2013). What works for children and young people with literacy difficulties:-

383 The effectiveness of intervention schemes (4th ed.). The Dyslexia-SpLD Trust.

384 8. Campuzano, L., Dynarski, M., Agodini, R., & Rall, K. (2009). Effectiveness of Reading

385 and Mathematics Software Products: Findings From Two Student Cohorts. NCEE 2009-

386 4041. *National Center for Education Evaluation and Regional Assistance*.

387 9. Chambers, B., Slavin, R. E., Madden, N. A., Abrami, P., Logan, M. K., & Gifford, R.

388 (2011). Small-group, computer-assisted tutoring to improve reading outcomes for

389   struggling first and second graders. *The Elementary School Journal*, *111*(4), 625-640.

390   DOI: 10.1086/659035

391   10. Cheung, A. C., & Slavin, R. E. (2013). Effects of Educational Technology Applications

392   on Reading Outcomes for Struggling Readers: A Best-Evidence Synthesis. *Reading*

393   *Research Quarterly*, 48(3), 277-299. DOI: 10.1002/rrq.50

394   11. Duff, F. J., Hulme, C., Grainger, K., Hardwick, S. J., Miles, J. N., & Snowling, M. J.

395   (2014). Reading and language intervention for children at risk of dyslexia: a randomised

396   controlled trial. *Journal of Child Psychology and Psychiatry*, *55*(11), 1234-1243. DOI:

397   10.1111/jcpp.12257

398   12. Gibbs, S., & Bodman, S. (2014). Phonological Assessment Battery (2nd ed.). London: GL

399   Assessment.

400   13. Hatcher, P. J., Hulme, C., Miles, J. N., Carroll, J. M., Hatcher, J., Gibbs, S., ... &

401   Snowling, M. J. (2006). Efficacy of small group reading intervention for beginning

402   readers with reading-delay: a randomised controlled trial. *Journal of Child Psychology*

403   *and Psychiatry*, *47*(8), 820-827. DOI: 10.1111/j.1469-7610.2005.01559.x

404   14. Lankshear, C., & Knobel, M. (2003). New technologies in early childhood literacy

405   research: A review of research. *Journal of Early Childhood Literacy*, *3*(1), 59-82. DOI:

406   10.1177/146879.84030031003

407   15. Macaruso, P., Hook, P., & McCabe, R. (2006). The efficacy of computer-based

408   supplementary phonics programs for advancing reading skills in at-risk elementary

409   students. *Journal of Research in Reading*, *29*(2), 162-172. DOI: 10.1111/j.1467-

410   9817.2006.00282.x

411   16. Macaruso, P. & Rodman, A. (2011). Efficacy of computer-assisted instruction for the

412   development of early literacy skills in young children. *Reading Psychology*, 32 (2), 172–

413   196. DOI:10.1080/02702711003608071

414   17. Macaruso, P., & Walker, A. (2008). The efficacy of computer-assisted instruction for

415   advancing literacy skills in kindergarten children. *Reading Psychology*, *29*(3), 266-287.

416   DOI: 10.1080/02702710801982019

417   18. McMurray, S. (2013). An evaluation of the use of Lexia Reading software with children

418   in Year 3, Northern Ireland (6-to 7-year olds). *Journal of Research in Special*

419   *Educational Needs*, *13*(1), 15-25. DOI: 10.1111/j.1471-3802.2012.01238.x

420   19. Rutter, M., Caspi, A., Fergusson, D., Horwood, L. J., Goodman, R., Maughan, B., ... &

421   Carroll, J. (2004). Sex differences in developmental reading disability: new findings

422   from 4 epidemiological studies. *Jama*, *291*(16), 2007-

423   2012.DOI:10.1001/jama.291.16.2007

424   20. IBM Corp. (2013). IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM

425   Corp.

426   21. Sakar, A., & Ercetin, G. (2005). Effectiveness of hypermedia annotations for foreign

427   language reading. *Journal of Computer Assisted Learning*, *21*(1), 28-38. DOI:

428   10.1111/j.1365-2729.2005.00108.x

429   22. Savage, R. S., Erten, O., Abrami, P., Hipps, G., Comaskey, E., & van Lierop, D. (2010).

430   ABRACADABRA in the hands of teachers: The effectiveness of a web-based literacy

431   intervention in grade 1 language arts programs. *Computers & Education*, *55*(2), 911-922.

432   DOI:10.1016/j.compedu.2010.04.002

433   23. Schechter, R., Macaruso, P, Kazakoff, E.R., & Brooke, E. (2015) Exploration of a

434   Blended Learning Approach to Reading Instruction for Low SES Students in Early

435   Elementary Grades, *Computers in the Schools*, 32:3-4, 183-200.

436   DOI:10.1080/07380569.2015.1100652

437

438   24. Schwartz, R. M. (2005). Literacy Learning of At-Risk First-Grade Students in the

439   Reading Recovery Early Intervention. *Journal of Educational Psychology*, *97*(2), 257.

440   DOI: 10.1037/0022-0663.97.2.257

441   25. Shannon, L. C., Styers, M. K., Wilkerson, S. B., & Peery, E. (2015). Computer-Assisted

442   Learning in Elementary Reading: A Randomized Control Trial. *Computers in the*

443   *Schools*, *32*(1), 20-34. DOI**:** 10.1080/07380569.2014.969159

444   26. Slavin, R. E., Lake, C., Davis, S., & Madden, N. A. (2011). Effective programs for

445   struggling readers: A best-evidence synthesis. *Educational Research Review*, *6*(1), 1-26.

446   DOI: 10.1016/j.edurev.2010.07.002

447   27. Snowling, M. J., & Hulme, C. (2011). Evidence-based interventions for reading and

448   language difficulties: Creating a virtuous circle. *British Journal of Educational*

449   *Psychology*, *81*(1), 1-23. DOI: 10.1111/j.2044-8279.2010.02014.x

450   28. Yeung, S. S. and Chan, C. K. K. (2013), Phonological awareness and oral language

451   proficiency in learning to read English among Chinese kindergarten children in Hong

452   Kong. *British Journal of Educational Psychology, 83*, 550–568. DOI: 10.1111/j.2044-

453   8279.2012.02082.x

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

	Lexia Group (n=49)	Wait-List Group (n=49)	F-value or Chi-Square	p-value[a]
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 [a] One-way ANOVAs (confidence interval: 95%) measured baseline differences of continuous

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

469

470

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

Variable	Intervention (n=49) Mean (SD)			Control (n=49) Mean (SD)			Value F (1,95)	p	Effect size (η^2) (Cohen's d*)
	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**

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

476

477

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

	Coefficients						
	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	B	Std. Error	Beta	t	Sig.	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

479

480

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

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