

Running head: WORD LEARNING IN SLI AND ASD

**Do children with specific language impairment and autism spectrum disorders benefit  
from the presence of orthography when learning new spoken words?**

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**Word count:** 10228

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### Abstract

This experiment investigated whether children with specific language impairment (SLI), children with autism spectrum disorders (ASD) and typically developing children benefit from the incidental presence of orthography when learning new oral vocabulary items. Children with SLI, children with ASD and typically developing children ( $n = 27$  per group) aged between eight and 13 years were matched in triplets for age and nonverbal reasoning. Participants were taught 12 mappings between novel phonological strings and referents; half of these mappings were trained with orthography present, and half with orthography absent. Groups did not differ on the ability to learn new oral vocabulary, although there was some indication that children with ASD were slower than controls to identify newly learned items. During training, the ASD, SLI and typically developing groups benefited from orthography to the same extent. In supplementary analyses children with SLI were matched in pairs to an additional control group of younger typically developing children for nonword reading. Compared to younger controls, children with SLI showed equivalent oral vocabulary acquisition and benefit from orthography during training. Our findings are consistent with current theoretical accounts of how lexical entries are acquired and replicate previous studies that have shown orthographic facilitation for vocabulary acquisition in typically developing children and children with ASD. We demonstrate this effect in SLI for the first time. The study provides evidence that the presence of orthographic cues can support oral vocabulary acquisition, motivating intervention approaches (as well as standard classroom teaching) that emphasise the orthographic form.

*Key words:* Specific language impairment; autism spectrum disorders; word learning; orthographic facilitation; orthography

### **Do children with SLI and ASD benefit from the presence of orthography when learning new spoken words?**

Building rich oral and sight vocabulary knowledge is a life-long endeavour; vocabulary, a relatively unconstrained skill, continues to develop throughout adulthood (Paris, 2005). Learning oral vocabulary presents challenges for many children, including those with specific language impairment (SLI) and autism spectrum disorders (ASD; McGregor et al., 2012). Mounting evidence indicates that children learn new oral vocabulary items more readily when they are taught with the printed form (orthography) available (e.g., Ehri & Rosenthal, 2007; Ricketts, Bishop, & Nation, 2009). An experiment was conducted to investigate whether emphasising orthography would be an effective strategy for teaching new words to children with SLI and ASD, with potential therapeutic implications.

#### **The role of reading in vocabulary acquisition**

The Simple View of Reading (Gough & Tunmer, 1986; Tunmer & Chapman, 2012) emphasises the importance of oral language (e.g., vocabulary) in reading comprehension: both word recognition and oral language comprehension are seen as necessary prerequisites to reading comprehension. Equally, once rudimentary reading skills are in place, the reading process provides opportunities for children to learn new words, with incidental learning from written materials making a considerable contribution to vocabulary growth during childhood and adolescence (e.g., Nagy, Herman, & Anderson, 1985). Importantly, vocabulary acquisition is an incremental rather than all-or-none process and texts provide the reader with information that enables them to refine partial

representations of known words as well as establish new lexical representations (Schwanenflugel, Stahl, & McFalls, 1997; Steele, Willoughby, & Mills, 2013).

There is growing interest in investigating an additional way in which reading may impact on vocabulary acquisition. Following early work conducted by Ehri and Wilce (1979) and Reitsma (1983), two studies have demonstrated that typically developing children are more likely to learn new oral vocabulary items if they are trained in the presence of an orthographic representation (Ricketts et al., 2009; Rosenthal & Ehri, 2008). In Rosenthal and Ehri's study, 7 year olds ( $n = 20$ ) and 10 year olds ( $n = 32$ ) were exposed to the pronunciation and meaning of low-frequency nouns. In Ricketts et al.'s work, 58 children aged 8 – 9 years were taught 12 new mappings between referents and nonwords. In both studies, a repeated measures design was used to manipulate the presence of orthography such that half of the items were taught with orthography present and half with orthography absent. Further, the presence of orthography was incidental: children were not made aware of the orthographic form, or directed to use it. Across studies, typically developing children showed a learning advantage for phonology-semantic mappings that had been trained with orthography in comparison to those that were trained in isolation (for recent replications, see Jubenville, Sénéchal, & Malette, 2014; Lucas & Norbury, 2013; Mengoni, Nash, & Hulme, 2013). Further, this orthographic facilitation effect appeared greater for more advanced readers i.e. those children with greater orthographic knowledge.

In terms of a specific mechanism, orthographic facilitation for oral vocabulary acquisition has been interpreted as follows (e.g., Ehri, 2014; Ricketts et al., 2009; Rosenthal & Ehri, 2008): since orthographic inputs are less transient across time and less variable across individuals and contexts than phonological inputs, the orthography of a word aids memory for its phonological form and specifies its stored phonological representation (for

similar arguments, see Frith, 1998; Hu, 2008; McKague, Davis, Pratt, & Johnston, 2008; Ventura, Morais, Pattamadilok, & Kolinsky, 2004). The influence of orthography on the acquisition of mappings between phonology and semantics is therefore seen as operating via phonology. Orthographic facilitation for oral vocabulary acquisition is consistent with the idea that presenting a word in visual as well as verbal modalities promotes learning (e.g., dual coding theory; Sadoski, 2005), and with the lexical quality hypothesis (e.g., Perfetti & Hart, 2002), which posits that a lexical representation that includes phonology, semantics and orthography will be of higher quality (i.e. more easily accessed) than one that includes only phonology and semantics.

### **Orthographic facilitation for vocabulary acquisition in children with developmental disorders of communication**

In a review of reading abilities in Down syndrome, ASD and SLI, Ricketts (2011) presented evidence that for some children in each group, oral language is more impaired (relative to typically developing children) than word reading (e.g., Bishop, McDonald, Bird, & Hayiou-Thomas, 2009; Nation, Clarke, Wright, & Williams, 2006; Roch & Levorato, 2009). This evidence led Ricketts to highlight, for these groups of children, the potential for relative strengths in orthographic knowledge (as indexed by word reading tasks) to be harnessed to circumvent weaknesses in oral language development. A similar proposal had previously been put forward by Buckley (1995) in relation to Down syndrome, and has since received some preliminary support (e.g., Laws & Gunn, 2002). Of particular relevance to the present study, Ricketts et al. (2009) hypothesised that presenting orthography could provide a compensatory strategy for children who find it difficult to learn words but have relatively good visual or orthographic skills. Mengoni et al. (2013) explored whether the presence of orthography supports oral vocabulary acquisition for 17 children with Down syndrome aged

7 – 16 years and 27 typically developing children aged 5 – 7 years. Groups were matched for word reading ability. Equivalent word learning (picture naming) was observed across groups, and children benefitted from the presence of the orthographic form to the same extent. This study therefore demonstrated, for the first time, orthographic facilitation for vocabulary learning in children with Down syndrome and in younger typically developing children than had been previously studied.

In a related study, Lucas and Norbury (2013) investigated this effect in ASD. Twenty children with ASD and 21 typically developing children aged 7 – 12 years were taught unknown science words with and without the presence of orthography. Groups were matched for age, nonverbal reasoning ability and nonword reading efficiency. Lucas and Norbury replicated findings that typically developing children show orthographic facilitation for vocabulary acquisition (Mengoni et al., 2013; Ricketts et al., 2009; Rosenthal & Ehri, 2008), and demonstrated an equivalently sized effect for children with ASD. Learning for the new words was broadly equivalent across groups, although there was some indication that the children with ASD found it easier than typically developing children to learn the novel phonological forms (cf. Norbury, Griffiths, & Nation, 2010).

The proposal that orthographic cues might be used to support language learning in SLI has yet to be explored; indeed, very few studies have investigated word learning in children with language impairments using paradigms where participants have access to print. Existing studies indicate that children with language impairments are able to learn new words incidentally through the process of reading; however, a direct instruction approach is more effective for teaching them (and typically developing children) new words (e.g., Nash & Donaldson, 2005). Across word learning studies, a consistent finding is that the learning of phonological and semantic information is significantly reduced in children with

language impairments compared to same-age peers (Alt, Plante, & Creusere, 2004; Nash & Donaldson, 2005; Oetting, Rice, & Swank, 1995; Steele & Watkins, 2010). Based on evidence that phonological interventions impact on semantic as well as phonological processing (Zens, Gillon, & Moran, 2009), Steele et al. (2013) have argued that approaches to vocabulary teaching that promote phonology should be emphasised. If the presence of orthography during teaching supports the establishment of well-specified and stable phonological representations (e.g., Ehri, 2014), emphasising orthography as well as phonology when teaching new words may provide added therapeutic benefit for children with language impairments. Some children with language impairments acquire age-appropriate decoding or word reading skills (Bishop et al., 2009; Catts, Fey, Tomblin, & Zhang, 2002; McArthur, Hogben, Edwards, Heath, & Mengler, 2000); for these children orthographic input may be a particularly important aid to oral vocabulary learning. Alternatively, these studies also indicate that most children with language impairments experience difficulties with word reading; therefore, children with SLI may show reduced support from orthographic cues.

### **The present study**

Children with SLI exhibit impaired oral language in the absence of physical impairment or deficits in other areas of cognition. Children with ASD are characterised by impairments in social interaction and communication, and repetitive and restricted behaviours and interests. Both SLI and ASD are associated with markedly heterogeneous populations and there has been substantial interest in probing behavioural overlap between these groups (Ellis Weismer, 2013), particularly in terms of oral language profiles (for a review, see Williams, Botting, & Boucher, 2008). By definition, structural oral language (e.g., vocabulary, grammar) is depressed in SLI. In contrast, structural language shows great

variation in ASD, with some individuals exhibiting very limited or no evidence of functional language, whilst others demonstrate high proficiency on some language tasks (Boucher, 2012; Ellis Weismer, 2013). Pragmatics, the social use of language, is characteristically impaired in ASD but not SLI (Loucas et al., 2008).

The present study aimed to explore whether children with SLI and ASD benefit from the presence of orthography when learning new words, replicating this effect for ASD (Lucas & Norbury, 2013) and extending it to SLI. Oral vocabulary is not always an area of weakness in ASD. Nonetheless, poor oral vocabulary knowledge is commonly observed in both ASD and SLI (Kjelgaard & Tager-Flusberg, 2001; Loucas et al., 2008; McGregor et al., 2012), providing a clear rationale for research that considers effective ways to support vocabulary acquisition in these groups. The study was further motivated by reports that orthographic knowledge may be an area of strength relative to oral language (including vocabulary) in both groups (for a review, see Ricketts, 2011). To approximate oral vocabulary learning, children with SLI, ASD and typically developing controls were taught nonword-referent mappings using an existing paradigm (Ricketts et al., 2009). The presence of orthography was manipulated such that half of the items were trained with, and half without, a plausible orthographic form present. While teaching real words is arguably a more naturalistic approach, all words will behave like nonwords until they are known. We chose to use nonwords to minimise pre-existing knowledge of the verbal stimuli. In addition, doing so allowed us complete control over the characteristics of the stimuli and meant that we could manipulate phonology to orthography mappings, thus simulating the complexity of written English. As well as completing the experimental task, participants completed standardised measures of existing orthographic (word reading) and oral vocabulary knowledge.



Based on previous studies, we anticipated that typically developing children and children with ASD would show greater learning for words trained in the incidental presence of an orthographic form, and that benefit from orthography would be greater for children with more advanced orthographic knowledge (as indexed by word reading; Lucas & Norbury, 2013; Mengoni et al., 2013; Ricketts et al., 2009; Rosenthal & Ehri, 2008). To our knowledge, this is the first investigation of orthographic facilitation for vocabulary acquisition in SLI. Thus, a direct hypothesis was not possible. Nonetheless, we were keen to investigate whether children with SLI would show greater learning with the orthographic form present, providing evidence for emphasising orthography when teaching new oral vocabulary items to children with language learning impairments.

## Method

### Participants

Participants ( $N = 81$ ) comprised 27 children with SLI, 27 children with ASD and 27 typically developing controls aged 8 – 13 years ( $M = 11.31$ ,  $SD = 1.66$ ). Group matching and identification procedures are outlined below. Twenty-three younger typically developing children ( $M_{age} = 8.19$ ,  $SD = .23$ ) that took part in a previous study (Ricketts et al., 2009) were also included in supplementary analyses (see Results section for further details). Ethical agreement for the study was provided by the University of Warwick Humanities and Social Sciences Ethics Committee, which adheres to the British Psychological Society guidelines.

**Group matching.** Participants were matched in triplets for age and nonverbal reasoning. In order to achieve this, children had nonverbal reasoning scores that were roughly in the average range or above (all  $T \geq 39$ , where average range = 40 – 60, for one triplet  $T = 39$ , for all other children  $T > 40$ ). For each triplet, the maximum age difference

(max = .88 years,  $M = .52$ ,  $SD = .23$ ) and nonverbal reasoning  $T$ -score difference (max = 10 i.e.  $1SD$ ,  $M = 4.96$ ,  $SD = 2.97$ ) was calculated. Table 1 summarises age and nonverbal reasoning scores for the three groups, confirming our matching procedure. An attempt was also made to match for gender, with a preponderance of boys in all groups (SLI: 23, ASD: 24, controls: 21). There was no significant association between group and gender,  $\chi^2(2) = 1.28$ ,  $p = .53$ .

Table 1. *Participant characteristics*

Measure	SLI			ASD			Controls			<i>F</i>	<i>p</i>	$\eta^2$
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range			
Age <sup>1</sup>	11.31	1.69	8.53-13.47	11.24	1.67	8.55-13.62	11.39	1.70	8.67-13.43	.05	.91	.00
Nonverbal reasoning <sup>2</sup>	51.67	7.41	39-65	53.78	8.02	39-72	53.85	7.22	39-67	.73	.49	.02
CELF-4 UK RS <sup>3</sup>	3.33	2.37	1-9	7.07	4.24	1-17	-	-	-	16.00	<.001	.24
CELF-4 UK WC <sup>3</sup>	6.00	2.17	1-10	9.19	3.39	3-18	-	-	-	16.95	<.001	.25
Oral vocabulary <sup>2</sup>	29.70 <sup>a</sup>	7.51	20-46	40.33 <sup>b</sup>	14.79	20-78	46.22 <sup>b</sup>	9.10	34-67	15.86	<.001	.29
Word reading <sup>4</sup>	89.48 <sup>a</sup>	12.62	59-110	95.11 <sup>a</sup>	14.03	73-126	105.67 <sup>b</sup>	7.85	94-121	13.09	<.001	.25
Nonword reading <sup>4</sup>	88.19 <sup>a</sup>	15.33	59-130	101.19 <sup>b</sup>	22.01	67-142	109.33 <sup>b</sup>	10.87	89-131	11.00	<.001	.22
SRS total <sup>2</sup>	56.27	10.96	37-91	65.15	12.07	45-94	-	-	-	7.12	<.01	.13

Notes. <sup>1</sup>in years; <sup>2</sup>*T*-score (*M* = 50, *SD* = 10); <sup>3</sup>Scaled score (*M* = 10, *SD* = 3); <sup>4</sup>Standard score (*M* = 100, *SD* = 15); CELF-4 UK RS = Clinical Evaluation of Language Fundamentals (4<sup>th</sup> UK edition) Recalling Sentences subtest; CELF-4 UK WC = Clinical Evaluation of Language Fundamentals (4<sup>th</sup> UK edition) Word Classes subtest; SRS = Social Responsiveness Scale; <sup>ab</sup>where an ANOVA comparing three groups revealed a significant main effect, superscript letters are used to indicate significant differences between means according to tests of simple effects (with Bonferroni correction), equivalent means are denoted by the same letter, different means by different letters

**Identification of children with SLI and ASD.** Children were selected for participation in the experiment from a larger sample of 157 children with primary language impairments or ASD (for more details, see Charman, Ricketts, Dockrell, Lindsay, & Palikara, 2014; Dockrell, Ricketts, Charman, & Lindsay, 2014) on the basis of age and nonverbal reasoning ability. The sample was recruited from mainstream primary and secondary schools across five Local Authorities (equivalent to school districts) in the South East of England. For the SLI and ASD groups, children were identified who had speech, language and communication needs or ASD as their primary Special Educational Need (area of difficulty), according to their school. All children spoke English as a first language and had no history of hearing impairment or uncorrected eyesight. In the UK, the pupil level School Census requires schools to identify and notify the Department for Education of pupils with special educational needs. Schools provide information about type and level of primary need. Children with a School Census primary classification of ASD would have received a medical diagnosis of an ASD using ICD-10 (WHO, 1993) or DSM-IV (APA, 2000) criteria via a community or specialist clinical service.

For speech, language and communication needs, identification would include a range of needs and diagnoses relating to speech, language and/or communication difficulties and from this group, we were interested in recruiting children with oral language impairments. Given the lack of an agreed measure for identifying language impairment (Bishop & McDonald, 2009), we conducted a screening phase to ensure children had clinically-relevant oral language impairments according to the fourth UK edition of the Clinical Evaluation of Language Fundamentals (CELF-4 UK; Semel, Wiig, & Secord, 2006). Children were identified as having language impairments if they obtained a standardised score that was at least one standard deviation below the test mean ( $< 1SD$ ) on either the recalling sentences or word

classes (total score) subtest from the CELF-4 UK (see below for more details of screening measures). Note that when scores on our oral vocabulary measure were taken into account, 26/27 children with SLI showed scores  $< 1SD$  on two of the three language measures (recalling sentences, word classes, vocabulary), with the remaining child showing one score  $< 1SD$  and both other scores  $< .5SD$ . Table 1 summarises performance on screening (ASD and SLI groups only) and oral vocabulary measures. The SLI group showed greater impairment than the ASD group on the two CELF-4 UK subtests. Poorer existing oral vocabulary knowledge was observed in the SLI group compared to the ASD and control groups, with the two latter groups not differing significantly.

During the screening phase, the teachers of pupils with SLI and ASD were asked to complete the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005) to confirm the clinical diagnosis of ASD. The SRS was completed for 26/27 of the children in each group. On this measure, the ASD group showed greater impairment (significantly higher scores) than the SLI group (see Table 1). Of the participants with ASD, 88% obtained scores that were above the test mean ( $T > 50$ ;  $n = 23$ ) and 65% obtained scores  $> 1SD$  ( $T > 60$ ;  $n = 17$ ). For children with SLI, 54% obtained scores above the test mean ( $n = 17$ ) and 35% obtained scores  $> 1SD$  ( $n = 9$ ).

### **Materials and procedure**

With the exception of the word learning task, all measures were standardised and were administered according to manual instructions. Screening measures were completed by the SLI and ASD groups (but not control group) approximately 12 months before the other tasks. Other standardised measures and the experimental word learning task were completed in one or two additional sessions.

**Screening measures.** Recalling Sentences and Word Classes subtests from the CELF-4 UK (Semel et al., 2006) were used to clarify oral language impairments in SLI group. The Recalling Sentences subtest, in which participants repeated orally presented sentences, is a measure of expressive language and is considered to be a reliable clinical marker of SLI (e.g., Conti-Ramsden, Botting, & Faragher, 2001). In the Word Classes subtest, children were asked to select which two of four verbally presented words were related, and to explain the semantic relationship between the two selected words. The Word Classes task indexes receptive as well as expressive language. The CELF-4 UK produces scaled scores ( $M = 10$ ,  $SD = 3$ ). The SRS (Constantino & Gruber, 2005) was completed as a measure of autism symptomatology. Teachers were presented with a series of statements relating to autism symptomatology and indicated the frequency of their occurrence. The SRS yields  $T$ -scores ( $M = 50$ ,  $SD = 10$ ).

**Nonverbal reasoning.** Nonverbal reasoning was measured using the Matrix Reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999), a pattern completion task that yields a  $T$ -score ( $M = 50$ ,  $SD = 10$ ).

**Oral vocabulary.** Oral vocabulary knowledge was measured using the Vocabulary subtest of the WASI (Wechsler, 1999) in which children are asked to verbally define words. The WASI yields a  $T$ -score ( $M = 50$ ,  $SD = 10$ ).

**Word-level reading.** Word-level reading was assessed using the Sight Word Efficiency (SWE) and Phonetic Decoding Efficiency (PDE) subtests of the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999). In these subtests, children are asked to read a list of words (SWE) or nonwords (PDE) of increasing length and difficulty as quickly as they can. Efficiency is indexed by the number of items produced correctly in 45 seconds. The TOWRE produces standard scores ( $M = 100$ ,  $SD = 15$ ).

**Word learning task.** A pre-existing paradigm from Ricketts et al. (2009) was used.

**Stimuli.** Stimuli comprised 12 nonwords containing four or five letters and three or four sounds (CVC, CVVC or CVCC; see Appendix A for nonword stimuli). Each child was exposed to six nonwords without orthography (orthography absent condition) and six with orthography (orthography present condition) and this was counterbalanced across participants such that all nonwords appeared in both orthography conditions for approximately the same number of children.

Each nonword was paired with a 'novel' 3D object, so the same nonword-referent pairs were used for all children. Colour photos of 3D objects (e.g., unfamiliar tools, an antique telephone, a rare musical instrument) were used as referents. An example of one of the objects (a bell tree) is presented in Appendix B. In a pilot study with 14 adults, none of the objects were identified by name but at least one adult identified a function for each object. Therefore, it was assumed that objects would be novel to children, while also affording some kind of function or use.

Nonwords were constructed to capture the inconsistency between spelling and sound that is present in the English language. Consistency was defined in terms of the number of potential spellings for a sound (feedback consistency), as it occurs in monosyllabic words (data taken from the Children's Printed Word Database; Masterson, Dixon, & Stuart, 2002). For example, the sound /b/ is consistent i.e. it is always spelled using the letter b, whereas the sound /eɪ/ is inconsistent i.e. it can be spelled ai as in tail or a\_e as in tale (for an accessible discussion of consistency in English monosyllables, see Kessler & Treiman, 2001). Four items were made up of consistent consonants and vowels (e.g., bilp). No individual sound occupied the initial, medial or final position twice and a double s was used at the end of luss to make this item longer and thus more orthographically similar to

the other items. The inconsistent items were constructed in the same way as the consistent items, except that one sound was represented using an inconsistent spelling. For four of these items, consonants that can be spelled with a silent letter were used (e.g., the /m/ sound in pimb spelled with mb rather than m). The remaining four items included an inconsistent vowel that can be spelled using different letters or letter combinations (e.g., the /eɪ/ sound in baip spelled with ai rather than a\_e as in bape). For each of the orthography conditions (orthography present vs. orthography absent), only two items with each consistency pattern (consistent, with an inconsistent consonant, with an inconsistent vowel) was presented to children. Therefore, we decided to collapse across consistency condition for all analyses reported below. For reference, we include performance by item in Appendix A.

***Summary of experimental procedure.*** At the beginning of the task the experimenter explained to children that they would be learning “some made up words... they are things that an alien might use”. Children were pre-trained to pronounce nonwords correctly, and then completed a training phase, followed by two post-tests to assess learning for nonword-referent mappings (nonword-picture matching) and orthographic forms (spelling). All tasks were presented using a computer screen and headphones. Stimulus presentation was controlled by the E-Prime program (Schneider, Eschman, & Zuccolotto, 2002a, 2002b), which randomised order of presentation and recorded the speed and accuracy of children’s responses. Figure 1 depicts the experimental procedure.



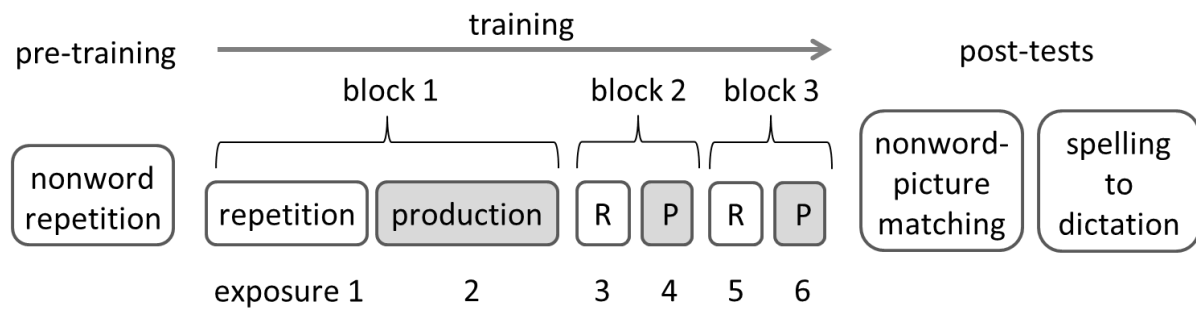


Figure 1. Diagram of experimental procedure

**Pre-training.** Children were familiarised with the sound pattern for all 12 nonwords, with sounds presented in a random order one at a time and repeated until children produced correct pronunciations. The number of nonwords correctly repeated at the first attempt was recorded. Cronbach's  $\alpha$  was calculated as a measure of reliability for each experimental measure (Cronbach's  $\alpha = .62$ ).

**Training.** There were three blocks of training trials, with each block comprising a set of repetition trials followed by a set of production trials. Production trials were included in order to promote learning by actively engaging children in the learning task (cf. McKeown & Beck, 2004). In each block, children were exposed to each item twice, in the context of a repetition trial and a production trial. Within each set of repetition/production trials, items were presented in a random order. Thus, by the end of training children had been exposed to each item six times.

During repetition trials, children were presented with a picture and after a short delay (700 ms) they also heard the associated nonword. For items trained with orthography, the spelling additionally appeared above the picture, in black Comic Sans MS font, font size 40. Attention was not drawn to the presence of orthography, and children were not instructed to use it. In both orthography present and orthography absent conditions, children were required to repeat the nonword, any incorrect pronunciations were

corrected, and the experimenter initiated the next trial.<sup>1</sup> In the production trials children were presented with a picture and asked to produce the appropriate nonword. At this stage orthography was never presented. Following this, all children heard the correct pronunciation (irrespective of the accuracy of their response); for orthography present trials, this was accompanied by the orthography (as above). Cronbach's  $\alpha$  for training blocks 1, 2 and 3 was .49, .64 and .72 respectively.

***Nonword-picture matching post-test.*** Children were presented with the nonword-picture matching task immediately after training to assess whether they had learned nonword 'meanings', or nonword-referent pairings. For each trial, children heard a stimulus nonword and saw an array of four pictures. The target object was presented with three of the other trained objects in a 2 x 2 grid. The position of the target was counterbalanced and each picture was used as a distracter for an equal number of trials. Children were required to select the target using a key press. Instructions and practise trials ensured that children understood the demands of the task before targets were presented. Cronbach's  $\alpha$  was .78.

***Spelling post-test.*** Children were given a piece of paper and a pencil and were instructed to spell each nonword to dictation. Each nonword was presented, in a random order, by a computer via headphones. Cronbach's  $\alpha$  was .61.

## Results

### Reading ability

Table 1 summarises performance on standardised measures of word-level reading. Mean performance for all three groups was within one standard deviation of the test mean for both measures. For nonword reading, a lower mean score was observed for the SLI group compared to the ASD and control groups, with the two latter groups not differing

significantly. For word reading, the SLI and ASD groups showed equivalent means, and these means were significantly below that observed for the control group.

### **Word learning task**

**Pre-training.** Accuracy to repeat each nonword at the first attempt was recorded. A one-way ANOVA revealed a marginally significant main effect of group on this measure,  $F(2,78) = 3.04, p = .054, \eta_p^2 = .07$ . Children with SLI ( $M = .77, SD = .18$ ) showed poorer repetition than controls ( $M = .86, SD = .13$ ) and children with ASD ( $M = .85, SD = .14$ ). Tests of simple effects with Bonferroni correction indicated a trend for a difference between children with SLI and controls,  $p = .099$ ; other group comparisons were not significant.

**Training.** Figure 2 summarises performance for control, SLI and ASD groups in the production trials of the training phase. Performance was scored as correct if children produced the correct nonword pronunciation in response to the target referent. The training phase comprised three blocks of trials; within each, children were exposed to nonword-referent pairings with orthography absent and orthography present. Figure 2 indicates that performance improved across blocks and was superior in the orthography present compared to orthography absent condition. Though differences between groups appeared small, children with SLI showed the lowest overall performance, followed by children with ASD and then the controls. Overall, substantial learning occurred but this was a difficult task, with children correctly labelling approximately half of the items correctly by the end of training (block 3). Further, large error bars indicate great variation in performance across participants.

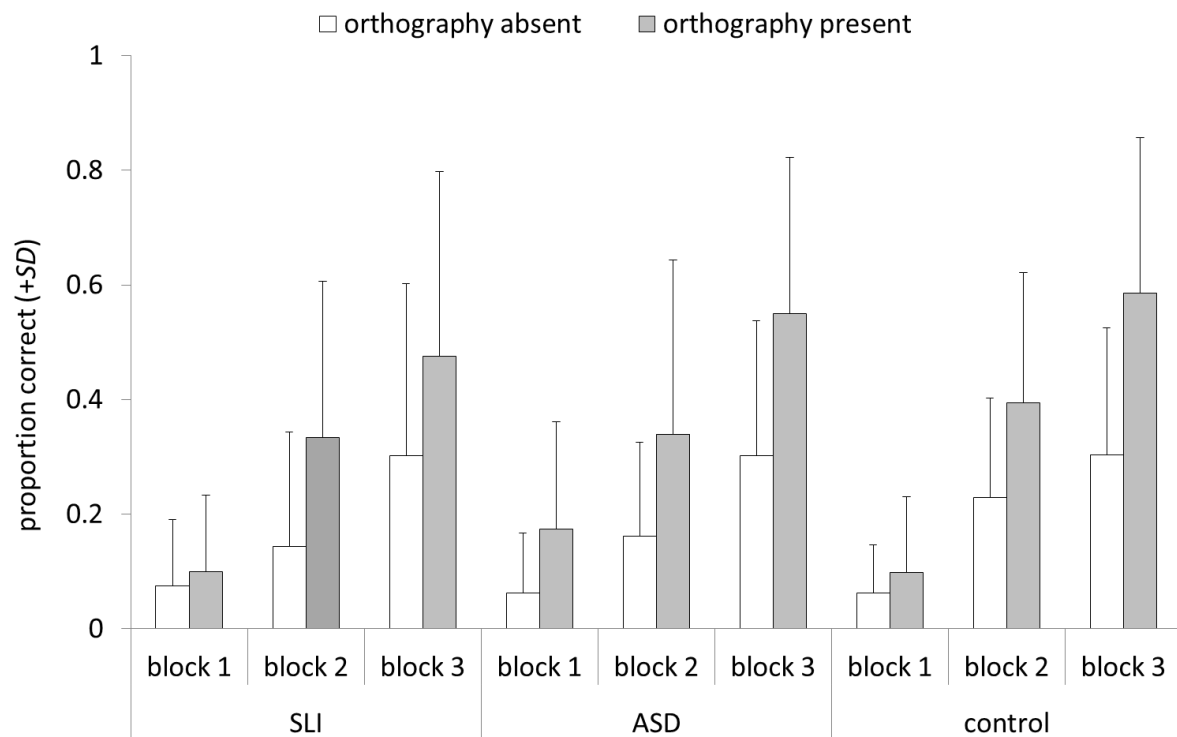


Figure 2. Mean proportion of nonwords (+SD) learned in production training trials across group, orthography condition and training block.

Data were analysed in a 3 x 2 x 3 ANOVA with group (control vs. SLI vs. ASD) as an independent samples factor and orthography (absent vs. present) and block (1 vs. 2 vs. 3) as repeated samples factors. There were significant main effects of orthography,  $F(1,78) = 70.81$ ,  $p < .001$ ,  $\eta_p^2 = .48$ , and block,  $F(2,156) = 172.65$ ,  $p < .001$ ,  $\eta_p^2 = .69$ , qualified by an orthography x block interaction,  $F(2,156) = 21.01$ ,  $p < .001$ ,  $\eta_p^2 = .21$ . Tests of simple effects (with Bonferroni correction) indicated that for each orthography condition, performance significantly improved between each block (all  $ps < .001$ ). Further, the effect of orthography was highly significant for each block (all  $ps < .001$ ). The main effect of group was not significant, nor did group interact with orthography or block.

As the dependent variable for learning during training is bounded, raw scores were subjected to an angular transformation (as recommended by Kirk, 1968). However, analyses conducted with raw and transformed scores yielded identical patterns of results. Finally, raw and transformed training data did not meet parametric assumptions. Therefore, to support the analyses reported above, a series of nonparametric analyses were conducted, confirming our main findings of an effect of orthography (Wilcoxon Signed Ranks Tests) but no group differences (independent-samples Kruskal-Wallis tests) in each block of training.

**Nonword-picture matching post-test.** The nonword-picture matching task yielded both accuracy and RT data. However, accuracy (proportion correct) was high (orthography absent:  $M = .83$ ,  $SD = .20$ , range = .33 – 1.00; orthography present:  $M = .85$ ,  $SD = .20$ , range = .00 – 1.00), with approximately a third of the children in each group at ceiling (SLI: 9/27, ASD: 8/27, controls: 9/27). In addition, data were far from normally distributed. Therefore, RTs were analysed. RTs for incorrect responses were discarded (all: 16%; SLI: 22%, ASD: 11%, controls: 16%) and RTs were trimmed (4% of RTs for each group) to a maximum of  $2SD$  from each child's mean (one of the methods recommended by Ratcliff, 1993). Mean RTs for each condition were calculated and at this point any missing values (5%) replaced with the mean RT for that condition. A log transformation rendered data that were normally distributed for analyses.

Figure 3 summarises mean RT data (untransformed data are included here to aid interpretation), with mean proportion accuracy within each bar for reference. Transformed RT data were subjected to a 3 x 2 ANOVA with group (control vs. SLI vs. ASD) as an independent sample factor and orthography (present vs. absent) as a related samples factor. This analysis revealed a significant main effect of group,  $F(2,78) = 3.26$ ,  $p = .04$ ,  $\eta_p^2 = .08$ , which, according to tests of simple effects with Bonferroni correction, reflected a trend

for the ASD group to make slower responses than controls ( $p = .06$ ;  $ASD > controls$ ,  $ASD = SLI$ ,  $SLI = controls$ ). The ANOVA also indicated a marginal main effect of orthography,  $F(1,78) = 3.75$ ,  $p = .056$ ,  $\eta_p^2 = .05$ , with faster RTs for items trained with orthography. The interaction between group and orthography was not significant.

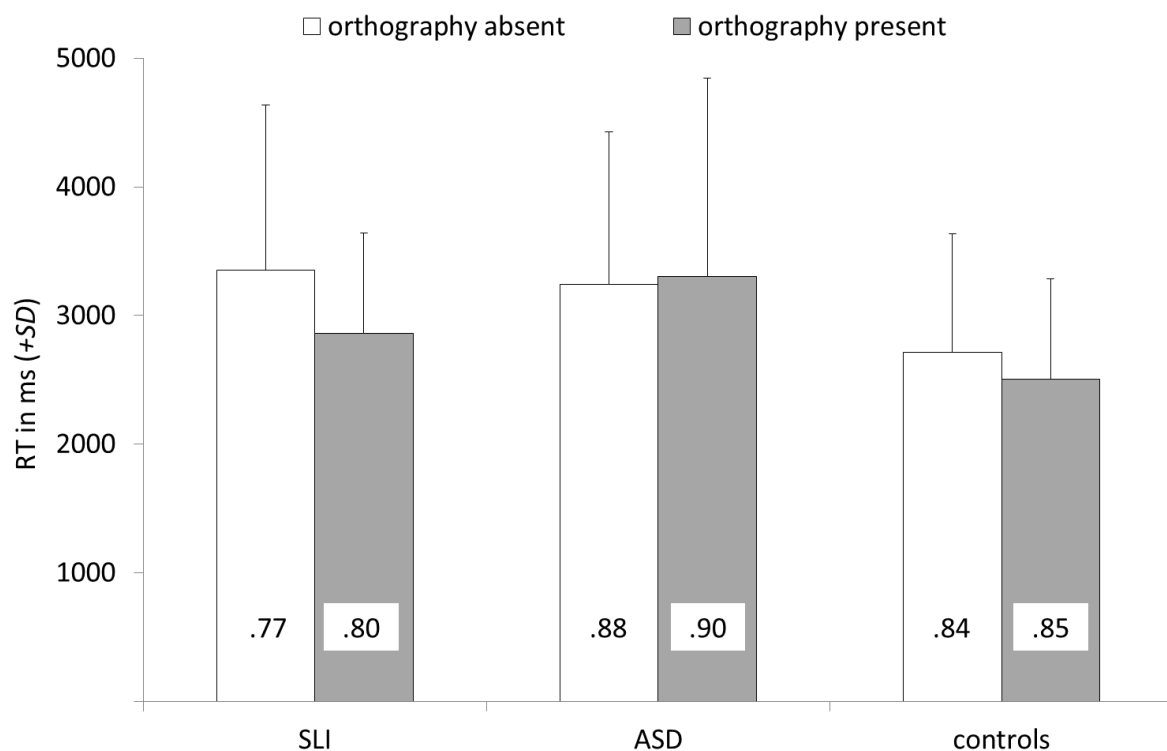


Figure 3. Mean RTs (+SD) for the nonword-picture matching task across control, SLI and ASD groups and orthography conditions. Proportions within bars reflect accuracy.

**Spelling post-test.** Spellings were scored as correct if children produced the target orthographic pattern (see Appendix A). Figure 4 depicts performance on the spelling post-test. As for the training measure, spelling scores were bounded; thus, analyses were conducted for transformed as well as raw scores. An identical pattern of findings was observed across these analyses therefore analyses with raw scores are presented. A 3 x 2 ANOVA with group (control vs. SLI vs. ASD) as an independent sample factor and

orthography (present vs. absent) as a related samples factor revealed main effects of group,  $F(2,78) = 5.05, p < .01, \eta_p^2 = .12$ , and orthography,  $F(1,78) = 243.30, p < .001, \eta_p^2 = .76$ . There was no significant group x orthography interaction. Tests of simple effects (with Bonferroni correction) indicated that the group effect reflected performance in the SLI group that was significantly poorer than performance in the control group ( $p < .01$ ), whilst the ASD group performed at an intermediate level and did not differ from the other two groups. In relation to the presence of orthography, performance was higher in the orthography present (vs. absent) condition. As for training, nonparametric analyses were conducted, confirming the effects of orthography (Wilcoxon Signed Ranks Test) and group reported above (independent-samples Kruskal-Wallis test, followed by Mann-Whitney post hoc tests).

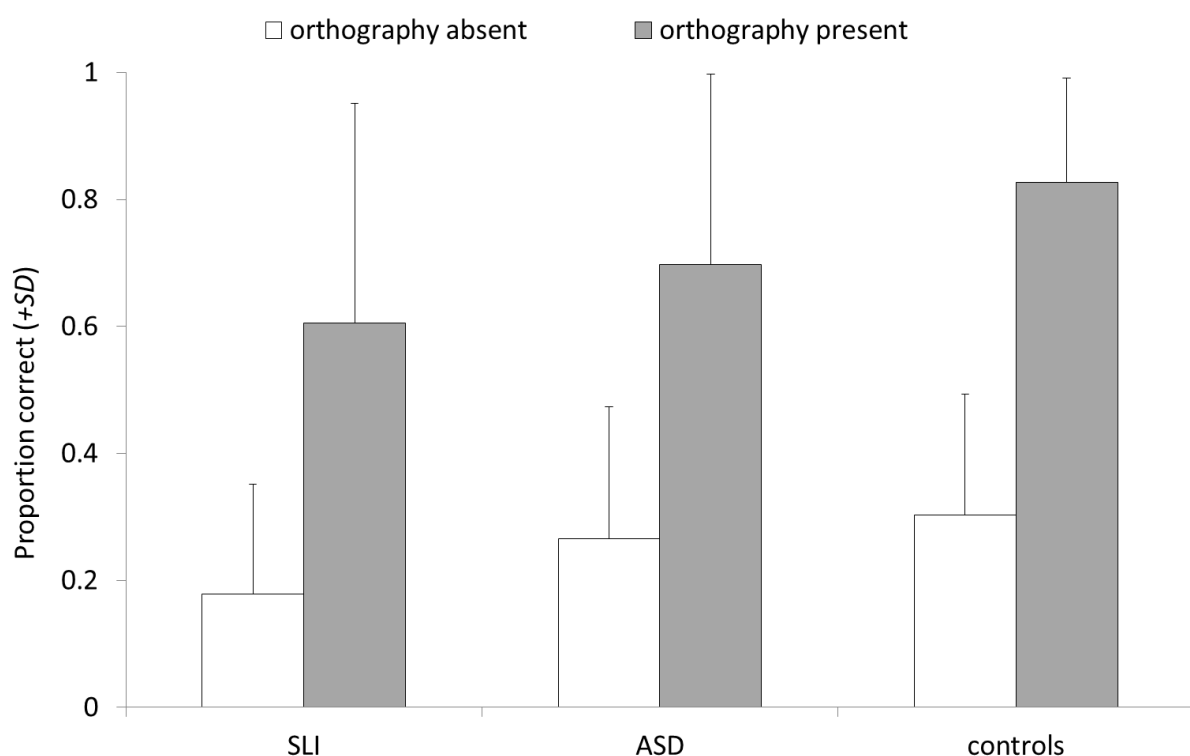


Figure 4. Mean proportion of nonwords (+SD) spelled correctly at post-test across group and orthography condition.

**Supplementary analyses comparing children with SLI and younger typically developing controls matched for nonword reading ability.** Previous studies comparing orthographic facilitation in typically and atypically developing groups (Lucas & Norbury, 2013; Mengoni et al., 2013) have matched their groups on measures of word-level reading to control for access to orthographic cues. We did not take this approach as it would have restricted our sample to those children with age-appropriate word reading abilities, rendering our sample unrepresentative, particularly in relation to the SLI group. At the group level, children with ASD were matched to controls for nonword reading ability (see Table 1) whereas children with SLI were not. Therefore, we matched our children with SLI in pairs to an additional control group of younger typically developing children for nonword reading (max within pair difference = 8 words,  $M = 1.74$ ,  $SD = 2.14$ ). Note that data on these participants has been published in a study where they took part in an identical experiment and completed the same measures of nonword reading, word reading, oral vocabulary and nonverbal reasoning employed here (Ricketts et al., 2009). Also, it was only possible to match 23/27 children with SLI in this way. Younger controls exhibited oral vocabulary and nonverbal reasoning scores in the average range or above ( $T > 40$ ). Details of these groups are summarised in Table 2, which confirms that groups were matched for nonword reading, as well as word reading and nonverbal reasoning. These controls were on average three years younger than the children with SLI.



Table 2. *Participant characteristics for supplementary group comparison*

Measure	SLI ( <i>n</i> = 23)			Younger controls ( <i>n</i> = 23)			<i>F</i>	<i>p</i>	$\eta_p^2$
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range			
Age <sup>1</sup>	11.38	1.71	8.53-13.47	8.19	.23	7.83-8.75	78.19	<.001	.64
Nonverbal reasoning <sup>2</sup>	52.39	7.04	41-65	54.39	5.76	41-65	1.11	.30	.03
Nonword reading <sup>3</sup>	25.74	13.93	3-57	25.13	12.69	2-50	.02	.88	.00
Word reading <sup>3</sup>	58.91	13.64	25-83	53.09	14.33	25-73	2.00	.17	.04
Oral vocabulary <sup>2</sup>	29.57	7.61	20-46	51.52	7.72	41-66	94.35	<.001	.68

Notes. <sup>1</sup>in years; <sup>2</sup>*T*-score (*M* = 50, *SD* = 10); <sup>3</sup>Raw score (nonword reading max = 63; word reading max = 104)

In the pre-training phase of the experiment, there was no significant difference between children with SLI (*M* = .79, *SD* = .14) and younger controls (*M* = .76, *SD* = .11),  $F(1,44) = .60$ ,  $p = .44$ ,  $\eta_p^2 = .01$ . Performance of children with SLI and younger controls on other experimental measures is summarised in Table 3. Training data were subjected to a 2 x 2 x 3 ANOVA with group (SLI vs. younger control) as an independent sample factor and orthography (present vs. absent) and block (1 vs. 2 vs. 3) as repeated samples factors. This analysis revealed significant main effects of orthography,  $F(1,44) = 36.98$ ,  $p < .001$ ,  $\eta_p^2 = .46$ , and block,  $F(2,88) = 62.28$ ,  $p < .001$ ,  $\eta_p^2 = .59$ , qualified by an orthography x block interaction,  $F(2,88) = 9.21$ ,  $p < .001$ ,  $\eta_p^2 = .17$ . Tests of simple effects (with Bonferroni

correction) indicated that for each orthography condition, performance significantly improved between each block (all  $ps < .02$ ). The effect of orthography was significant for blocks 2 and 3 (all  $ps < .001$ ) but not for block 1. The main effect of group was not significant, nor did group interact with orthography or block. Transformed RTs on the nonword picture matching task were analysed in a 2 (group) x 2 (orthography) ANOVA; there were no significant main effects or interactions. Spelling data were analysed in a 2 (group) x 2 (orthography) ANOVA, revealing a main effect of orthography,  $F(1,44) = 91.03$ ,  $p < .001$ ,  $\eta_p^2 = .67$ , but no significant main effect of group or orthography x group interaction. In sum, children with SLI showed equivalent learning to younger typically developing children matched for word reading, during training and in nonword-picture matching and spelling post-tests. Further, groups showed equivalent benefit from orthography.

Table 3. *Supplementary group comparison on experimental measures*

Measure	SLI ( $n = 23$ )				Younger controls ( $n = 23$ )			
	Orthography absent		Orthography present		Orthography absent		Orthography present	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Training 1 <sup>1</sup>	.06	.10	.08	.10	.07	.10	.10	.11
Training 2 <sup>1</sup>	.12	.18	.30	.25	.17	.19	.30	.20
Training 3 <sup>1</sup>	.27	.28	.43	.30	.26	.19	.42	.21
Nonword-picture matching <sup>2</sup>	3395	1306	2857	757	3078	838	2933	779
Spelling <sup>1</sup>	.18	.17	.59	.36	.28	.18	.61	.30

Notes. <sup>1</sup>proportion correct; <sup>2</sup>RT (untransformed) to correct responses

## Discussion

Children with SLI, children with ASD and typically developing children are more likely to learn novel oral vocabulary items when they were taught in the presence of orthography, replicating previous findings from typically developing children (Ricketts et al., 2009; Rosenthal & Ehri, 2008) and children with ASD (Lucas & Norbury, 2013). This effect was demonstrated for the first time in children with SLI, who showed equivalent orthographic facilitation compared to same age controls (main analyses) and younger controls matched for nonword reading (supplementary analyses).

### Orthographic facilitation for vocabulary acquisition

Oral vocabulary acquisition was approximated by teaching children nonword-referent mappings and learning indexed during training (production trials) and at post-test (RTs in the nonword-picture matching task). During training, there was clear evidence for greater learning of oral vocabulary items that had been trained with orthography across SLI, ASD and control groups (main analysis:  $\eta_p^2 = .48$ ; supplementary analysis:  $\eta_p^2 = .46$ ). Further, the absence of an interaction between orthography and group indicated equivalent orthographic facilitation across groups. Here our findings diverge somewhat from those of Lucas and Norbury (2013) found that children with ASD showed more influence of orthography than typically developing children in some (but not all) analyses. These contrasting findings may warrant further investigation. Despite a large effect of orthography during training, this main effect was smaller in the post-test (main analysis:  $\eta_p^2 = .05$ ; supplementary analysis:  $\eta_p^2 = .06$ ).

The spelling post-test was included to ensure that children were attending to the orthographic forms when they were present. The large main effect of orthography on spelling (main analysis:  $\eta_p^2 = .76$ ; supplementary analysis:  $\eta_p^2 = .67$ ) indicates that children

were sensitive to orthographic cues and showed substantial learning of orthographic forms as a result of seeing them during the training phase. This finding resonates with research showing that opportunities to view orthographic forms are sufficient for orthographic learning to occur (e.g., Bowey & Miller, 2007; Ricketts, Bishop, Pimperton, & Nation, 2011; Share, 1999). To investigate individual differences in orthographic processing more directly, future studies could incorporate eye tracking into the experimental paradigm, in line with Lucas and Norbury (2013).

Previous studies have shown that the presence of orthography is more beneficial for children with greater existing orthographic knowledge, as indexed by word recognition ability (Ricketts et al., 2009; Rosenthal & Ehri, 2008). In our main analyses, individual differences in word reading (SLI = ASD < controls) and the acquisition of orthographic forms (SLI < ASD = controls), did not align with the degree of benefit from orthography. This finding was particularly surprising for the children with SLI, who showed equivalent orthographic facilitation to same-age peers despite substantially poorer orthographic knowledge (on average  $>1SD$ , see Table 1). In supplementary analyses, children with SLI and younger controls were matched for nonword and word reading but again showed equivalent orthographic facilitation. Why was poorer word reading not associated with reduced orthographic facilitation in our study? One possibility is that for our sample, the monosyllabic orthographic forms were simple enough to serve as reliable orthographic cues. In previous studies where a link between word reading and orthographic facilitation has been observed, children were on average younger and/or stimuli more complex (Ricketts et al., 2009; Rosenthal & Ehri, 2008).<sup>2</sup> In sum, the presence of orthography appears to support oral vocabulary acquisition across children with SLI, children with ASD and typically

developing children, despite markedly different profiles of existing orthographic and oral vocabulary knowledge.

### **Interpreting the orthographic facilitation effect**

Findings that words are more likely to be learned when they are taught in the incidental presence of orthography have been interpreted as reflecting a benefit from orthography when learning novel phonological forms, such that the orthographic forms bond with the phonological forms in memory, resulting in more robust lexical representations (Ricketts et al., 2009; Rosenthal & Ehri, 2008). This is our favoured interpretation. Indeed the spelling post-test indicated that children were aware of the orthographic forms, showing substantial incidental learning of orthography. Nonetheless, alternative interpretations are possible. In the orthography absent condition, two sources of information were available, one verbal and one visual (phonological form, picture of novel object) whereas in the orthography present condition, there was a third source of visual information (orthographic form). Thus, improved performance in the latter condition may reflect the availability of additional visual information rather than orthography per se (see Ricketts et al., 2009; Sadoski, 2005). To test this possibility, Mengoni and colleagues compared their orthography present condition with a control condition in which the orthographic form was substituted for an 'alien spelling' (Greek or Cyrillic letters). Their finding of greater learning in the orthography present condition adds weight to the argument that it is orthography, rather than an additional visual cue, that supports learning. This control condition was not included in our study, or in other previous studies (Lucas & Norbury, 2013; Ricketts et al., 2009; Rosenthal & Ehri, 2008), with Lucas and Norbury (2013) arguing that it is not clear that having an additional visual cue (that is not orthographic) should improve learning. Indeed, presenting children with meaningless strings of letter-like

symbols could be confusing. Nonetheless, given the close similarities between our paradigm and that of Mengoni and colleagues, it seems reasonable to extrapolate their findings, interpreting improved learning in our study as reflecting an orthographic facilitation effect.

### **Comparing learning across groups**

At post-test, children showed substantial learning of nonword-referent mappings, with accuracy close to ceiling. Thus, the three blocks of training were enough to support reliable recognition of the objects in response to their labels. Given high accuracy on this task, RTs were used to probe group differences, showing a trend for children with ASD to select referents more slowly than controls. As indexed by the production measure during training however, performance was lower. Arguably, by involving phonological production, this task is more demanding than the recognition task employed at post-test. During training, groups did not differ. Given that impaired phonological processing is characteristic of SLI (e.g., Williams et al., 2008), and enhanced phonological learning and performance has been reported in ASD (e.g., Lucas & Norbury, 2013), this finding may seem unexpected. Note though, that we pre-exposed children to phonological forms, and didn't proceed with training until they could accurately pronounce each nonword correctly. This may have compensated for phonological weaknesses in our SLI group. Indeed, the SLI group showed marginally poorer novel word repetition at the beginning of the pre-training phase in the main (but not supplementary) analyses. By pre-training phonology, we hoped to capture at training the ability to develop links between phonology and semantics (the object), above and beyond the ability to store, process or produce phonological strings. In this paradigm, it appears that children with SLI, children with ASD and typically developing children were able to learn phonology-semantic mappings to an equivalent extent (accuracy during training

and post-test), although children with ASD may take slightly longer than controls to access these representations (RTs during post-test).

In addition to measuring learning experimentally, we used a standardised task to indicate oral vocabulary knowledge. On this task, children with SLI showed weaker existing oral vocabulary knowledge than children with ASD and controls (both same age and younger). Therefore, as found in previous studies (Lucas & Norbury, 2013; Mengoni et al., 2013), there was a discrepancy between oral vocabulary learning and longer term learning and retention of oral vocabulary knowledge, with group differences being less evident in the experimental paradigm. It is worth noting that five children in the same age control group obtained oral vocabulary scores that were below the average range ( $34 < T < 40$ ). As suggested by an anonymous reviewer, this may have masked any group differences in vocabulary learning. However, conducting experimental analyses without the five triplets that contained a control child with low vocabulary (resulting  $n = 66$ ) did not change the group effects observed.

While learning phonology-referent mappings is an important aspect of vocabulary development, particularly for young children, our task exposed participants to limited semantic information. In contrast, success on the standardised vocabulary task required children to provide verbal definitions, drawing on relatively complex semantic knowledge. Further, learning occurred in a single session on one day, whereas naturalistic oral vocabulary development is incremental, with information being learned across different contexts, and over time. An important question for future research will be whether differences between children with SLI, children with ASD and typically developing children would emerge in a task in which children are exposed to richer semantic representations, and where information is taught over time and contexts, and retention explored. Indeed, in

studies that adopt paradigms more akin to intervention sessions, children with SLI do show poorer learning than their peers (e.g., Steele et al., 2013).

There was a significant effect of group on the spelling post-test in our main analysis ( $\eta_p^2 = .12$ ), reflecting poorer performance in the SLI group compared to same age controls, which is consistent with poor spelling in SLI more generally (e.g., Dockrell et al., 2014). In the supplementary analyses, children with SLI and younger controls did not differ in spelling performance. Thus, learning of novel orthographic forms aligned with nonword reading, resonating with findings that the ability to decode from print is a strong predictor of orthographic learning in typically developing children (e.g., Bowey & Miller, 2007; Ricketts et al., 2011; Share, 1999). To our knowledge previous research has not investigated orthographic learning in children with SLI.

Experimental studies of SLI and ASD typically exclude children with low nonverbal ability (e.g., Hsu & Bishop, 2014; Lucas & Norbury, 2013), and approach that we also adopted (note that one triplet had scores just below the average range i.e.  $T = 39$ ) as we were concerned that children with low nonverbal ability would not be able to access our experimental paradigm. Our sample is therefore unlikely to be representative of language impairment and ASD more generally (see Baird et al., 2006; Catts, Fey, Tomblin, & Zhang, 2002); additional group differences might emerge if more heterogeneous samples were employed, or other subgroups included.

### **Spelling-sound consistency**

We taught nonwords in this study, rather than real words, which would arguably be more naturalistic. Using nonwords minimised the influence of any pre-existing knowledge on learning and afforded us control over the characteristics of our stimuli. Importantly, it meant that we could introduce an element of spelling-sound inconsistency within our



stimuli, which is a key characteristic of the English orthographic system. Notably, our short training session and within-subjects design meant that only two items with each consistency pattern were learned within each orthography condition. Given this, and that our aim was to investigate orthographic facilitation for vocabulary acquisition across our three groups, rather than exploring the items for which the effect might be more or less prominent, we collapsed across consistency in our analyses. Nonetheless, Appendix A indicates that the orthographic facilitation effect was clear for 11 of the 12 nonword stimuli. It is worth noting that even ‘inconsistent’ or irregular words include a large degree of consistency – in our ‘inconsistent’ stimuli all mappings except one were consistent, similar to many inconsistent monosyllabic English words (e.g., pint, knock). Further, whether the spelling pattern of a word is inconsistent to the reader will depend on the reader’s experience, i.e. the corpus of words that they hold within their orthographic lexicon.<sup>2</sup> Indeed, the degree to which items such as pimb and baip would be inconsistent for our participants is questionable, given that many highly frequent words in the English language include the ‘inconsistent’ spelling-sound mappings that we employed (e.g., mb climb/comb, ai in train/wait).

Ehri and others (Ehri, 2014; Ricketts et al., 2009; Rosenthal & Ehri, 2008) have argued that the benefit of orthography for oral vocabulary acquisition is mediated orthography boosting learning for novel phonological forms. This assertion could lead to a prediction of an orthography x consistency interaction, with a more pronounced orthographic effect for stimuli with consistent orthography-phonology mappings. We did not seek to investigate this hypothesis here but initial studies have yielded mixed findings, with some studies observing an interaction while others do not (Jubenville et al., 2014; Rastle, McCormick, Bayliss, & Davis, 2011; Ricketts et al., 2009). Future research could build on the present study by employing a larger number of items. Further, cross-linguistic studies could

investigate whether orthographic facilitation is more pronounced in transparent languages where mappings between spelling and sound are consistent.

### **Conclusions**

The present study extends previous research by showing that presenting orthography in an incidental manner is not only beneficial for children with ASD and typically developing children, children for whom oral vocabulary and orthographic knowledge may be relatively well developed, but also for children with SLI, where oral vocabulary and word reading are areas of particular weakness. Practically, this suggests that incidentally presenting the spelling of a word while it is being taught will promote learning. Importantly, this strategy can be readily incorporated into a range of instructional approaches (class teaching, individual interventions etc.) with very little cost in terms of time and resources. In our own observations of these SLI and ASD participants in class, we noted that while words were frequently written on the board whilst being described, this practice was by no means universal, occurring in approximately half of the classes.

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### Footnotes

<sup>1</sup>The picture of the object (and spelling for orthography present trials) remained on the screen until the experimenter initiated the next trial. Thus, inspection time varied ( $M = 1919$ ,  $SD = 1558$ ). Note that as in Ricketts et al. (2009), the picture was present for longer in the orthography absent than present condition (2059 vs. 1779;  $F(1,80) = 22.91$ ,  $p < .001$ ,  $\eta_p^2 = .22$ ). Thus, it was not the case that children had longer with the stimuli when orthography was present (driving superior performance in the orthography present condition).

<sup>2</sup>We would like to thank an anonymous reviewer for raising these points

### **Acknowledgments**

We would like to acknowledge the support of all the students, their families and schools. We are also grateful to Olympia Palikara and Mia Travlos for assistance with data collection. This research was funded by the UK Department for Education as part of the Better Communication Research Programme:

<https://www.gov.uk/government/organisations/department-for-education/series/better-communication-research-programme> (accessed 29.01.2015).

Appendix A. *Experimental stimuli with item-level performance*

Consistency	Phonology	Orthography	Training <sup>1</sup>						Nonword- picture matching <sup>2</sup>		Spelling <sup>1</sup>	
			Block 1		Block 2		Block 3		O-	O+	O-	O+
			O-	O+	O-	O+	O-	O+				
Items with consistently spelled phonemes:												
	/bɪlp/	bilp	0.05	0.13	0.05	0.43	0.22	0.38	3450	3242	0.63	0.80
	/gɑl/	garl	0.10	0.02	0.13	0.29	0.18	0.44	3598	2996	0.45	0.80
	/jɔɪg/	joig	0.03	0.02	0.13	0.15	0.23	0.44	3223	3577	0.20	0.66
	/lʌs/	luss	0.20	0.45	0.49	0.78	0.66	0.85	1863	1887	0.32	0.88
Items with one inconsistent consonant:												
	/gʌtʃ/	gutch	0.00	0.18	0.10	0.38	0.10	0.53	2789	2848	0.61	0.68
	/nɑb/	knarb	0.05	0.18	0.10	0.40	0.27	0.50	3901	3076	0.02	0.53
	/pɪm/	pimb	0.15	0.07	0.40	0.29	0.63	0.41	2644	2925	0.08	0.73
	/rɔɪd/	wroid	0.08	0.15	0.23	0.41	0.40	0.68	3288	2705	0.03	0.54

Consistency	Phonology	Orthography	Training <sup>1</sup>						Nonword- picture matching <sup>2</sup>		Spelling <sup>1</sup>	
			Block 1		Block 2		Block 3		O-	O+	O-	O+
			O-	O+	O-	O+	O-	O+				
Items with one inconsistent vowel:												
	/beɪp/	baip	0.05	0.08	0.17	0.23	0.34	0.45	3006	3023	0.07	0.55
	/daʊf/	dowf	0.00	0.05	0.07	0.25	0.17	0.53	3498	2577	0.15	0.63
	/jit/	jeet	0.08	0.05	0.18	0.41	0.30	0.63	2584	2578	0.25	0.83
	/lʊg/	loog	0.03	0.12	0.10	0.27	0.15	0.61	2901	2944	0.18	0.90

Notes. O- = orthography absent; O+ = orthography present; <sup>1</sup>Proportion of participants producing an accurate response; <sup>2</sup>Mean RT (ms) to produce correct response

Appendix B. *Example of nonword-referent pairing in orthography absent and present conditions*

Orthography absent

Orthography present

Hear:

/daʊf/

/daʊf/

See:



### Highlights

- Children were more likely to learn words when they were taught with orthography
- Equivalent benefit from orthography was observed across SLI, ASD and control groups
- Approaches to teaching new words should emphasise orthography