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Routes to Reading and Spelling: Testing the Predictions of Dual Route Theory

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Abstract

Dual-route theory, which emphasizes the importance of lexical and nonlexical routes, makes specific predictions about the kinds of strategies that young students might adopt when attempting to correctly read and spell regular and irregular words. The current study tests these predictions by assessing strategy choice on regular, irregular, and nonword items among a group of 55 English-speaking students ages 8–10 years. Performance measures and verbal self-reports were used to classify strategy choice in reading and spelling. The results confirmed that students were able to draw from a wide repertoire of coexisting strategies to support their reading and spelling activities. Hierarchical regression analyses revealed that pure lexical retrieval could best predict reading and spelling accuracy scores on irregular words, whereas both lexical and nonlexical strategies could, to varying degrees, predict scores on the regular items. Unexpectedly, none of the reported reading or spelling strategies could accurately predict students' scores on the nonword items after controlling for age. The theoretical implications for the application of dual-route theory to early reading and spelling, especially in relation to nonword performance, are discussed and outlined.

Keywords: Reading, Spelling, Predictors, Verbal reports, Regular, Irregular, Nonword

Introduction

In their attempts to read and spell, children rarely rely on any single strategy but instead choose from a repertoire of co-existing procedures to assist in the decoding and spelling of novel words (Farrington-Flint, 2015; Rittle-Johnson & Siegler, 1999; Varnhagen, McCallum & Burstow, 1997). There is also a clear indication that young children's reliance on specific strategies, both within the context of reading and spelling, can be largely influenced by the orthographic representations contained within different word items (Share, 1999). However, less is known about the extent to which older children mediate between co-existing strategies as they attempt to read and spell more complex stimuli, including irregular and nonword items. While dual route theory offers clear predictions regarding the formation of lexical and nonlexical routes to reading and spelling, these predictions have not yet been formally assessed in relation to children's explicit strategy choice. The current study was designed to assess changes in 8-to-10 year olds' strategy choice based on their attempts to correctly identify and spell regular, irregular and nonword items and to provide a direct test of the predictions made in dual route theory.

Dual Route Theory

The way in which children progress from slowly sounding out novel words to rapidly recognising them as lexical items has received considerable attention within the literature (Castles & Nation, 2008; Cunningham, Perry, Stanovich, & Share, 2002; Share, 1995, 1999). Several models have been put forward to describe the reading and spelling process, which include (although not exclusively) stage models (Frith, 1985), phase theories (Ehri, 1999; 2000; Siegler, 1996), and connectionist models (Plaut, McClelland, Seidenberg, & Patterson, 1996). Although each of these developmental approaches do provide a clear emphasis on processes involved in acquiring reading and spelling abilities (e.g. phonological,

morphological and orthographic skills), none of these make any specific predictions about how children must flexibly manipulate and apply those skills that are most relevant to optimise success, especially when tackling different word types. Our favoured approach, which does provide quantitative predictions about the application of reading and spelling skills, is dual route theory. Although primarily designed to explain skilled performance, dual route theory offers a clear framework for understanding and independently assessing the specific acquisition of the two main reading processes that children must acquire to become proficient readers. It also makes simple predictions with regard to the differing levels of accuracy which may be expected when identifying or spelling regular and irregular words that can be tested empirically. Furthermore, there has also been a significant rise in the number of dual route models proposed for reading and spelling (Treiman & Kessler, 2014), most of these are seen to be an extension to the original dual route cascaded model of reading acquisition and thinking aloud (Coltheart, Rastle, Perry, Langdon & Zeigler, 2001) which originally emphasised the importance of the orthographic lexicon in guiding reading abilities.

According to dual route theory, reading and spelling is facilitated by a reliance on two, largely independent, routes. The first, termed the lexical route, requires adults and children to derive correct word identifications from print to speech using the mental lexicon and activating word-specific orthographic and phonological memory representations from memory. The second, nonlexical route requires them to decode items using a set of sub-lexical spelling-sound and grapheme-to-phoneme correspondence (GPC) rules. Based on the distinction made within dual route theory, the acquisition of the lexical route is best assessed by irregular reading ability, as irregular words can only be pronounced or spelt correctly if they are already stored in the individual's mental lexicon (including connections to the correct pronunciation). Nonlexical skills, in comparison, are best assessed by nonword

reading ability, as these items will only be correctly pronounced or spelt if the individual is able to successfully apply grapheme-to-phoneme rules as a decoding strategy. In contrast regular words can be read or spelt via either approach, and therefore scores would be expected to be much higher for regular items than for irregular or nonword types (Castles, Bates & Coltheart, 2006; Coltheart, 2006).

Despite some conjecture about the relevance and application of dual route theory to a developmental sample (Snowling, Bryant, & Hulme, 1996), there is evidence that static models of dual route theory can be extended beyond skilled adults to help inform our understanding of reading and spelling acquisition. In their analyses, Castles, Bates and Coltheart (2006) demonstrate how a child's regular word reading score can be accurately predicted by their irregular and nonword reading scores using simple regression modelling. They argue that "regardless of a reader's age, and regardless of whether the person is an intact or impaired reader, a static model of the adult skilled reading system (in these cases, the DRC model) provides an excellent description of their reading performance" (Castles et al., 2006, p.887). Based on this assumption, Castles et al. (2009) developed a revised single word-reading test for children aged 6-11 years that included a selection of regular, irregular and nonword items designed to assess their reading performance based on lexical and nonlexical routes. This data, which provides standardised norms for children aged 5-12 years, provides a valid instrument to fully capture lexical and nonlexical routes to reading acquisition. In using these word lists, studies have identified how some children can be selectively impaired during the reading acquisition process, resulting in the slow acquisition of a lexical route despite showing strengths in developing a nonlexical pathway (see Castles, Bates, & Coltheart, 2006; Jones, Castles, & Kohnen, 2011). Similar normative comparison

data across Grades 1 to 7 can also be found for lexical and nonlexical routes in spelling (Kohnen, Colenbrander, Krajenbrink & Nickels, 2015).

Further significance of dual route theory concerns its application to educational and clinical contexts, particularly in the identification of profiles or subgroups based on relative strengths and weaknesses in acquiring the lexical and nonlexical routes. For instance, among clinical samples, both children and adults who experience severe reading difficulties can be accurately classified as showing an impairment of either the lexical or nonlexical pathway (Moore, Porter, Kohnen, & Castles, 2012). Those diagnosed with developmental phonological dyslexia show a specific difficulty in acquiring the nonlexical reading route (sounding out aloud), while those diagnosed with developmental surface dyslexia show a specific difficulty in acquiring the lexical reading route impairing their ability to store and retrieve items from their mental lexicon while leaving the nonlexical route intact (Castles, 2006). By extending these findings to classroom assessment and pedagogy, it is likely that the application of dual route models could help to uncover difficulties in children's early reading and spelling skills and inform the delivery of targeted interventions (McArthur, Castles, Kohnen, Larsen, Jones, Anandakumar & Banales, 2015).

Acquisition of Early Reading and Spelling Strategies

While dual route theory has undergone many revisions, it continues to provide a comprehensive account of the processes involved in reading and spelling among both skilled adult readers (Coltheart, Curtis, Atkins & Haller, 1993; Perry, Ziegler & Zorzi, 2007; 2010) and children (Castles, et al., 2006; Coltheart, 2006). Furthermore, dual route theory can inform our understanding of findings from studies that have examined young children's strategy choice. These studies, which rely on using self-report measures of strategy choice, show in particular how children can carefully navigate between their use of lexical and

nonlexical strategies to achieve success in both the correct identification and spelling of word items (Farrington-Flint, Coyne, Heath & Stiller, 2008a; Farrington-Flint, Stash & Stiller, 2008b; Coyne, Farrington-Flint, Underwood & Stiller, 2012; Lindberg et al., 2011; Rittle-Johnson & Siegler, 1999; Varnhagen, McCallum & Burstow, 1997). For instance, during the initial stages of reading and spelling, almost all children report using a nonlexical approach. This usually involves the identification of perhaps one or two phonemes or graphemes (Stuart & Coltheart, 1988) prior to the segmentation and blending of each individual phoneme or grapheme contained within each word (Ehri, 2014). As children acquire alphabetic knowledge and secure these to memory, they become much more proficient when sounding out using a phonological approach. Although grapheme-to-phoneme (or phoneme-to-grapheme) conversion rules might provide an excellent strategy during the initial stages of learning, it is not the best long-term solution because reading or spelling can be slow, effortful and often laborious. Unless children can secure these spelling-sound patterns to memory then they will struggle in acquiring reading proficiency. Instead children need to move towards a lexical route, one that involves recognising words in terms of their visual spelling forms and storing them to the mental lexicon for automatic processing (Castles et al., 2009; Perry, Ziegler & Zorzi, 2010).

The analysis of children's individual strategy reports has provided us with a clear indication concerning the acquisition of specific reading and spelling skills throughout early literacy development. Farrington-Flint and colleagues (2008a) found, for example, that the use of the nonlexical sounding-out (GPC) strategy was much more common among children in Year 1 than in Year 2, whereas the use of the lexical whole-word retrieval strategy was much more common in Year 2 than in Year 1. In a subsequent study, Farrington-Flint and colleagues (2008b) found a similar developmental pattern in the acquisition of children's

lexical and nonlexical strategies within the context of spelling. An analysis of individual self-reports confirmed that young children are able to adjust their reliance on particular strategies depending on the words already stored within their mental lexicon (see also, Kwong & Varnhagen, 1999; Rittle-Johnson & Siegler, 1999). Furthermore, in using verbal reports to assess strategy choice, past studies have been able to identify different subgroups or profiles based on the children's relative strengths or weaknesses in acquiring lexical or nonlexical routes to reading and spelling (Farrington-Flint, 2015, Coyne et al., 2012) often characterised as either *Phoenician* or *Chinese* readers, respectively (Treiman, 1984; Bowey, 2008).

Performance on regular items is only part of the acquisition process. A central feature in the acquisition of reading and spelling strategies is the acquisition of orthographic knowledge (Bosse, 2015) and the ability to negotiate between subtle changes in word-specific orthographic features (Share, 1995, 1999; Moore et al., 2012). As children begin to explore and refine their use of specific reading or spelling strategies, they tend to move towards recognising larger consolidated word units and begin to make analogies to words stored in their mental lexicon (Goswami, 1993). For both regular and irregular words, children also learn to apply their knowledge of inflectional and derivational morphological rules such as the "-ed" or "-ing" rule (Critten, Connelly, Dockrell & Walter, 2014; Kemper, Verhoeven & Bosman, 2012) alongside a recognition of different grapho-syllabic and morphemic spelling-sound units (e.g., -ump, -tion, -ed, -ing) (Devonshire, Morris, & Fluck, 2013), which helps to facilitate reading and spelling acquisition. Evidence of using these rule-based strategies can be found in many studies that have incorporated self-report data, not just within the context of reading (Farrington-Flint et al., 2008a; Lindberg et al., 2011) but also spelling (Farrington-Flint et al., 2008b; Rittle-Johnson & Siegler, 1999; Sénéchal, Basque & Leclaire, 2006).

In principle, the findings from strategy choice studies appear to support the application of the principles of the dual route theory. However, there has been no specific test of the models' predictions in relation to these explicit strategy reports. In fact, the majority of past studies (Castles, Bates, & Coltheart, 2006; Jones, Castles, & Kohnen, 2011) have tested dual route predictions using normative data or children's performance on standardised tests rather than directly comparing strategy reports based on regular, irregular and nonword items. The current work therefore provides a unique perspective by combining reading and spelling accuracy data alongside children's verbal self-reports to test the predictions of dual route theory in relation to young children's reliance on lexical and nonlexical strategies.

Furthermore, while the dual route theory provides clear predictions regarding the requirements needed to fulfil the lexical and nonlexical routes to reading and spelling, it does not necessarily specify how other skills, such as the contribution of orthographic and morphological strategies, might fit neatly into this classification. We know that within the context of spelling, the application of morphological rules becomes increasingly more important as children are exposed to more morphologically complex word items (Sénéchal, Basque & Leclaire, 2006) especially those that require the identification of prefixed/suffixed derivations, compounds and inflected forms (Deacon, Benere & Pasquarella, 2013; Grainger & Ziegler, 2011). However, whether this approach best describes a lexical or nonlexical route to reading and spelling remains unclear. From a lexical perspective, it is plausible that the detection of letter combinations might correspond to pre-existing phonological and morphological representations already stored in memory. However, as Grainger and Ziegler (2011) advocate, orthographic and morphological approaches might be a function of the sub-lexical route because the chunking of frequently co-occurring letter combinations (that form relevant units for morpho-orthographic processing) might largely facilitate the sublexical

translation of print to sound. On this basis, it also seems plausible to expect that the application of analogies might also be associated with the nonlexical route. However, this whole question of how orthographic, morphological and analogical approaches map onto the two routes specified within dual route theory requires further examination.

Rationale and Research Questions

While dual route theory makes specific predictions about the prominence of lexical and nonlexical routes for reading and spelling, the extent to which these predictions can account for the acquisition of different reading and spelling strategies needs further consideration, particularly in relation to children's performance on regular, irregular and nonword items. Similarly, a closer examination of how morphological and orthographic strategies fit into the original classification of lexical and nonlexical pathways described in dual route models needs to be addressed.

One way to test the direct application of the predictions of the dual route theory is to provide each child a set of nonwords, a set of regular words, and a set of irregular words and ask them to read aloud and to spell each item individually. For each item, children then produce a verbal report corresponding to the strategy they chose to inform how they read or spelt each item. Using these verbal strategy reports, we are then able to assess whether the reliance on a lexical or nonlexical strategy can best predict the child's performance on each of the three word items (regular, irregular and nonwords). In doing so, we can ascertain whether strategy choice is constrained or guided by certain word specific characteristics and provide a direct test of the predictions of dual route theory based on young children's actual application of reading and spelling strategies rather than accuracy data alone.

The current study addressed two research questions. First, do children show similar levels of variability in their choice of lexical and nonlexical strategies based on their reading and

spelling of regular, irregular and nonword items? On the basis of the findings from past studies (Coyne et al, 2012; Farrington-Flint, 2015; Farrington-Flint et al, 2008a; Farrington-Flint et al, 2008b; Lindberg et al., 2011; Rittle-Johnson & Siegler, 1999) it was expected that all children would show flexibility in their strategy choice and show an ability to choose from a wide repertoire of co-existing strategies in their attempt to read and to spell common and uncommon items.

Second, in line with dual route theory, to what extent do the use of lexical and nonlexical strategies predict their children's scores on the regular, irregular and nonword items? That is, can lexical strategies best predict accuracy scores on irregular items while nonlexical strategies best predict their accuracy scores on the nonword items? It is expected, on the basis of dual route theory (Castles et al., 2009; Coltheart et al., 2006) and past research (Castles et al., 2006; Jones, Castles, & Kohnen, 2011), that hierarchical regression analyses would show strong support for the predictions made for following the lexical and nonlexical routes.

Method

Participants

A sample of 55 children (25 male and 30 female) participated in the study. Of these, 26 children were from Year 3 classrooms, comprising 12 males (Mean = 8 years 2 months, SD = 3 months) and 14 females (Mean = 8 years 1 month, SD = 3 months) while 29 children were from Year 4 classrooms, comprising 13 males (Mean = 9 years 2 months, SD = 3 months) and 16 females (Mean = 9 years 2 months, SD = 3 months). (Year groups were selected rather than age groups because we were interested in the effects of schooling on decoding and spelling performance rather than age). Children within the UK are required to begin formal schooling from the age of 5 years which meant that our sample had received at least 3 years

of formal instruction in reading and spelling prior to their participation in the study. All children attended the same state funded primary school and were from lower-to-middle socio-economic suburbs in a British town. The classification of residential neighbourhoods (ACORN) data (CACI, 2013) identified this as a moderate means area with predominant housing in older, rented terraces. Within the sample, 96% of the children were classified as white British descent while the remaining 4% were from Asian origin. All children had English as their first language and no child had a statement of special educational needs or any known difficulties with reading or writing. Prior to commencing the study, all children completed three standardised subtests from the British Ability Scales III (Elliot, Smith & McCulloch, 2011) comprising single-word reading, single word spelling and non-verbal ability (matrices task) as well as a measure of receptive vocabulary using the BPVS III test (see Table 1). As Table 1 shows, the reading, spelling and vocabulary scores for both males and females in Year 3 was slightly higher than the pre-assessment scores in Year 4. In particular, males in Year 4 had lower scores in single word reading, spelling and vocabulary than females in Year 4. However, Multivariate ANOVAs with year group and sex as the IV and pre-assessment scores as the DV confirmed that there was no significant difference among the sample ($p>.05$) on any of these standardised pre-assessment measures suggesting that all children had equivalent levels of reading and spelling ability with no indication of poor language, literacy or non-verbal skills.

Insert Table 1 about here

Instructional Methods

All of the pupils followed the UK National Curriculum guidance comprising a systematically based structured framework of instruction to teach strategies for decoding text and spelling novel word items. This included training in phonics and spelling (including

phoneme and rhyme awareness), knowledge with contextual cues, grammatical knowledge and single word recognition and identification. In their regular classroom instruction, each child had been taught several strategies to read words. Children learnt to recognise words by sight and also received both analytic and synthetic phonics instruction (including letter sounds, consonant clusters, and sight words). Following this, children are taught to sound and blend to read. A sight word approach continued to be used for high-frequency words, which included a high proportion of irregularly spelt words that would be hard to read via taught letter–sound correspondences. Several strategies were also taught for spelling. Phonetically decodable words were taught by children hearing words, breaking them down into phonemes and then writing down the letters to represent the phonemes while irregular words were taught by using the look, cover, write method of instruction (see also McGeown, Johnston & Medford, 2012). As part of classroom instruction, children were taught to explicitly identify their strategy choices aloud in both their reading and spelling activities.

Standardised Measures

All children completed the following standardised assessments.

The British Ability Scales III Word Reading Test (Elliott, Smith, & McCulloch, 2011) was administered as a test of context free single word recognition consisting of ninety word items. Children are asked to read aloud a series of words of increasing difficulty and after eight errors in a block of ten items, testing is stopped. Elliott and Smith report internal reliability (Cronbach's α) at .99.

The British Ability Scales III Spelling Test (Elliott et al., 2011) was administered as a test of single word spelling ability consisting of seventy-five items. The word to be spelt is read

out loud, the word is then embedded within a sentence and finally read out loud again. Internal reliability (Cronbach's α) is reported at .96.

The British Ability Scales III Matrices Test (Elliott et al., 2011) was administered as a measure of non-verbal ability. Each child is asked to identify the correct image to complete the pattern. After five errors within six consecutive items, testing is stopped. Internal reliability (Cronbach's α) is reported at .82.

The British Picture Vocabulary Scale III (Dunn, Dunn, Styles & Sewell, 2009) was administered as a measure of receptive vocabulary. For each item, the researcher says a word, and the child has to point to the picture (from four options) that best illustrates the word's meaning. The questions broadly sample knowledge of words from a variety of areas such as actions, animals, toys and emotions, and parts of speech such as nouns, verbs or attributes. After more than eight errors within any block, testing is stopped. No internal reliability scores are provided because these are built into the confidence bands.

Experimental Reading and Spelling Tests

An experimental reading and spelling test was devised to elicit strategy reports based on regular and irregular word items. Items were carefully selected from the revised version of the Castles and Coltheart Reading Test 2 (CC2) (Castles, Coltheart, Larsen, Jones, Saunders & McArthur, 2009) comprising sixty items using age-appropriate norms from Castles et al 2009 (see, Appendix 1). The stimuli were chosen because of the standardised norms; the careful matching between regular and irregular items and their relevance to the dual route model of reading aloud. The stimuli were taken from the Macquarie On-line Test Interface (MOTIF: http://www.maccs.mq.edu.au/research/resources) and the instructions given to each child followed the same guidelines as provided by Castles and colleagues (2009). The same

sixty items were used in the reading and spelling trials and comprised 20 regular items (e.g. *middle, luck*), 20 irregular items (e.g. *island, bowl*) and 20 nonword items (e.g. *delk, pite*). For the word reading trials, each word appeared individually on a printed card and the child was asked to identify this word as accurately as possible. The word remained in sight until the child had provided a response with no time limit imposed.

For the spelling trials, each child was presented with the same stimuli as the reading trials to allow for comparisons in strategy performance across the two tasks (Farrington-Flint, 2015). The order in which the items were presented was randomised for each child to remove order effects. Rather than being presented on card, each item was spoken twice by the experimenter both aloud in isolation and then within a contextual appropriate sentence. The child was then asked to write out the correct spelling of the word on the response sheet as accurately as possible. There were no time limits imposed.

The original instructions for collecting verbal self-reports were consistent with past studies (Farrington-Flint, 2015; Coyne et al., 2012; Rittle-Johnson & Siegler, 1999) in which after each attempt, children were asked "How did you read/spell this word?" When a child remained quiet or replied with "I don't know", they were asked "Did you just know how to read it? Or did you recognise a part of the word? Or did you do something else?" Prompts were given in the same order each time and no other additional prompts or feedback was provided. (These additional prompts were required on no more than 2% of all trials). All individual self-reports were audio recorded for subsequent analysis.

Coding Reading and Spelling Strategy Reports

Although past research has used a range of methods to study strategy choice, including the analysis of keystroke latencies (Kwong & Varnhagen, 2005) and error analyses (Chiappe & Siegel, 1999; McGeown, Medford & Moxon, 2013), we chose to use retrospective verbal

self-reports because they have been found to be a consistent and reliable measures of strategy choice (Edwards, Weinstein, Goetz & Alexander, 2014; Siegler, 1996) and consistent findings have been reported in past studies with children of the same age (Farrington-Flint, 2015; Coyne et al., 2012; Lindberg et al., 2011; Rittle-Johnson & Siegler, 1999). Two independent coders, naïve to the aims of the study, classified each child's verbal self-reported strategy for each individual word item. There was an overall agreement in 90% of cases showing strong reliability.

Rather than coding each verbal self-report corresponding to either a lexical or nonlexical route, we extended our scheme to build on past studies (Farrington-Flint, 2015; Lindberg et al., 2011; Rittle-Johnson & Siegler, 1999), and code orthographic and morphological strategies as a separate category (elaborate nonlexical, see below). Each self-report was coded as one of the following four categories: pure lexical retrieval (immediate retrieval from the mental lexicon, "I knew it"), elaborate nonlexical strategy (which includes partial retrieval, "I was combining 's' and 't' together makes the sound 'st'"); moderate nonlexical strategy (purely phonological attempts without any retrieval "I blended the letters together to make the sound") and a non-specific strategy ("I don't know" or no audible response). The non-specific category was used on very few trials suggesting that children were confident in reporting their strategy choice (see Appendix B).

Procedure

All data was collected from each child individually by the third author across two separate testing sessions each lasting approximately 45 minutes. In Session 1, children completed the BAS III spelling test, and BPVS III receptive vocabulary test before completing the experimental reading test. In Session 2, the children completed the BAS III reading test and the BAS III matrices test before completing the experimental spelling test.

However, to counterbalance the order of presentation, half of the sample began with Session 1 and the remaining half began with Session 2. The time between each testing session was between 5 and 7 days apart.

Results

To address each research question, the results are summarised in two sections. First, we begin by considering the distribution of all strategy reports, in relation to the frequency and accuracy, corresponding to each of the three word items (regular, irregular and nonword). In the second section, we test the claims of dual route theory by including hierarchical regression models to test the extent to which lexical and nonlexical strategies could accurately predict scores on the regular, irregular and nonword items.

Do Children show Variability in their Choice of Lexical and Nonlexical Strategies?

Overall, children's accuracy on the reading trials ranged from 15 to 100% on regular items (M = 89%, SD = 18%) and 5 to 90% on irregular items (M = 56%, SD = 19%) and 5 to 100% on the nonword items (M = 77%, SD = 23%). On the spelling trials, accuracy ranged from 0 to 100% (M = 64%, SD = 22%) on the regular items, from 0 to 80% on the irregular items (M = 36%, SD = 20%) and 0 to 80% (M = 47%, SD = 20%) on the nonword items (Table 2). To explore these results further, a repeated measure (mixed) ANOVA was carried out with 2 (task) x 3 (word type) as the within-groups factor and year group as the between group factor. While there was no main effect for year group, $F(1,53) = 2.63$, $p = .111$, $eta^2 = .047$; a significant main effect was found for both task, $F(1,53) = 334.96$, $p = .00$, $eta^2 = .863$, and word type, $F(2,106) = 179.50$, $p = .00$, $eta^2 = .772$. These effects were qualified by a significant two-way interaction between task and word type, $F(2,106) = 11.93$, $p = .00$, $eta^2 = .184$ and between word type and year group, $F(2,106) = 179.50$, $p = .00$, $eta^2 = .772$. The

three-way interaction between task, year group and word type failed to reach significance ($p>.01$). To further explore the children's strategy choice in more detail, the frequency and accuracy of all verbal self-reports for each reading and spelling trial was analysed according to word type (regular, irregular and nonword items).

Insert Table 2 about here

In relation to the reading trials, pure lexical retrieval was the most common approach for the identifying the regular word items in Years 3 and 4 (55% and 64%) resulting in high levels of word identification. However, elaborate strategies such as drawing analogies to known words, were also common suggesting that many of the children were retrieving word-subunits rather than just using the phonological information of the displayed graphemes to guide their word identification of regular items. Performance on the irregular items, for both year groups, showed a reliance on using a wider repertoire of co-existing strategies including pure lexical retrieval (39% and 49%), elaborated strategies (26% and 33%) and moderate strategies (31% and 15%) but, the greatest gains in irregular word reading accuracy related solely to pure lexical retrieval and moderate strategies. For nonword items, while there was a reliance on using both elaborated and moderate strategies across Years 3 and 4, there was no definitive strategy associated with accuracy. Instead there was an equal spread of accuracy scores across all types of strategies ranging from 53% to 79% (Table 3).

In relation to children's spelling, a similar pattern of results emerged. Across both year groups, children relied primarily on pure lexical retrieval in their attempts to spell regular word items (54% and 60%), which resulted in the highest levels of accuracy. For irregular items, the predominant strategy was pure lexical retrieval for Years 3 and 4 (42% and 53%) followed by moderate and elaborated approaches. For nonword items, elaborated strategies were most common (44% and 58%) followed by pure lexical retrieval (21% and 18%) and

moderate strategies (23% and 17%), although the accuracy with which each these strategies were used did vary across year group. For Year 3, the highest accuracy related to pure lexical retrieval (65%), which was surprising given that they were nonword items, but the accuracy scores for Year 4 remained the highest for an elaborated strategy (52%). (Table 4)

Insert Tables 3 & 4 about here

To what Extent Do Lexical and Nonlexical Strategies Predict Regular, Irregular and Nonword Scores?

Having explored the distribution of strategy reports for reading and spelling across the regular, irregular and nonword items, the next step was to provide a direct test the predictions of dual route theory (Coltheart et al., 2001; Grainger & Ziegler, 2011). Six separate hierarchical multiple regression analyses were carried out to examine the extent to which lexical and nonlexical strategy reports (pure lexical, moderate and elaborated reports) could accurately predict the children's reading and spelling scores on the regular, irregular and nonword items. Collinearity statistics were run and the variance inflation factor and tolerance statistics confirmed that multicollinearity was not an issue. The order of entry of each variable is detailed in Tables 5 to 7.

The first two regression analyses explored predictions for children's regular word items for reading and spelling, respectively (Table 5). Strategy reports were treated as the IV and regular word accuracy as the DV. In both models, age was entered first to partial out the effects age on children's ability to read and spell regular items. Age accounted for 14.9% of the variance of regular word reading and just over 8% for regular word spelling. In Step 2 the three predominant strategy types based on regular items were entered into the model.

After controlling for the effects associated with age, strategy reports accounted for an additional 53.5% of the overall variance in the model. A significant amount of the variance was accounted for by pure lexical retrieval use (B = 1.06, p <.01) and elaborated strategy use (B = .858, p <.05) supporting our initial prediction. However, in relation to children's spelling, once age was partialled out, strategy reports accounted for an additional 44.8% of the variance with only pure lexical retrieval as a significant predictor (B = .994 p <.01) only partially supporting our prediction.

Insert Table 5 about here

The next two regression analyses repeated the same order of entry to assess predictors of irregular reading and spelling performance, respectively (Table 6). For irregular word reading, age could account for just over 9% when entered into Step 1, and strategy reports could account for an additional 35.6% of the variance in Step 2. When entered into Step 2 of the model, pure lexical retrieval and elaborated strategy use were significant predictors of irregular reading (B = 1.038 and B = .705, respectively). For spelling, age accounted for over 8% of the variance on irregular items although only pure lexical retrieval (B = .863) could account for an additional 29.5% of the variance.

The final two sets of hierarchical regressions analyses, unexpectedly, found that neither age when entered into Step 1 of the model, nor any of the strategy reports could account for any significant variance in predicting nonword reading or spelling (Table 7).

Insert Tables 6 & 7 about here

Discussion

In the current study, we set out to test the predictions of dual route theory by exploring the extent to which children's reported strategy usage could accurately predict their reading

and spelling scores on regular, irregular and nonword items. Although children were able to choose flexibly and adaptively from a repertoire of co-existing approaches, the regression models provided support for the application of dual route theory to reading and spelling among our developmental sample of 8-to-10 year olds. In support of the predictions, while lexical retrieval strategies and nonlexical strategies could predict regular word reading and spelling, lexical retrieval could accurately predict performance on the irregular items. Unexpectedly, none of the strategy reports could accurately predict children's performance on the nonword items. The implications of these findings are discussed.

Lexical and Non-Lexical Routes to Reading and Spelling

Although past studies have often focussed solely on analysing accuracy scores and normative data to test specifically the predictions of dual route theory (Castles, Bates, & Coltheart, 2006; Jones, Castles, & Kohnen, 2011; Kohnen, Colenbrander, Krajenbrink & Nickels, 2015), a novel feature of our current work was to test these predictions using measures of actual strategy reports so as to provide a better understanding of the application of dual route model in relation to children's classroom-based strategy performance. In doing so, we have found evidence for the application of dual route theory in relation to young children's reading and spelling performance.

Based on the regular word items, children were able to draw on a range of different co-existing strategies to help inform their reading and spelling scores. Despite using a range of strategies, however, the distribution of strategy reports for regular items did suggest that pure lexical retrieval and elaborate strategies were among the most common and most accurate approaches overall. These strategy reports differ from those found among younger children (see, Farrington-Flint et al., 2008a; Farrington-Flint et al., 2008b; Kwong & Varnhagen, 2005; Rittle-Johnson & Siegler, 1999). We have shown that among an older sample of 8-to-

10 year olds', there is a stronger reliance on using orthographic and morphological rules than on pure phonological attempts at decoding. The fact that the elaborated strategy, which comprised of three different elements (e.g., phonological chunking/clustering, analogy and morphology) showed a high frequency across regular word items strengthens Grainger and Ziegler's (2011) claims that orthography and morphology, as well as phonology, should be included within the sub-lexical pathway of dual route models. It is likely that orthographic and morphological approaches best reflect the sub-lexical route because the chunking of frequently co-occurring letter combinations might largely facilitate the sublexical translation of print to sound. Finally, in support of dual route predictions, not only did children use a combination of both lexical and nonlexical strategies, the data from the regression models revealed that pure lexical retrieval was a unique predictor of children's reading and spelling scores for the regular words items.

In terms of children's scores on the irregular items, we also supported the predictions of dual route theory. In relation to spelling, we found that only pure lexical strategies could accurately predict irregular spelling accuracy, accounting for 29% of the overall variance in the regression model, suggesting that words had been processed via the orthographic lexicon/semantic system. For word reading, pure lexical retrieval was also the strongest predictor of irregular scores followed by a small contribution offered by nonlexical strategies. This suggests that for both reading and spelling, the children's item-specific vocabulary knowledge may have increased the number of orthographic representations stored within the mental lexicon to enable a more accurate identification of these complex irregular items (Johnston, McGeown & Moxon, 2014; Share, 1999; Wang, Nickels, Nation & Castles, 2013).

While strategy reports largely support the dual route predictions for performance on regular and irregular items, there was no evidence that these predictions could be extended to

children's nonword performance. We would expect, on the basis of dual route theory, that nonlexical strategies would provide a unique prediction for the correct identification and spelling of nonword units. We found that lexical retrieval and elaborate strategies were among the most frequent strategies and despite the fact that lexical strategy was used least often, it translated to relatively high levels of accuracy in both reading and spelling (see Tables 3 & 4). Furthermore, the regression analyses confirmed that no individual strategy could uniquely predict performance on the nonword items, after partialling out the effects of age. This is a challenging finding requiring careful consideration. One possible explanation concerns the high degree of orthographic similarity between our nonword items with real word equivalents perhaps accounting for why children thought they were recalling from memory and therefore reported as such. For example, it is likely that children might have attempted to decode or spell particular nonword items (e.g. seldent) by segmenting these graphemes into easily accessible subunits (e.g. sel and dent) in which there is a high degree of orthographic consistency with real words (e.g. selfish, seldom) as well as recognising real words contained within the nonword items (e.g. dent). It is also likely that the children may have drawn analogies to pre-existing words thereby reducing demands on the nonlexical pathway (Coltheart & Leahy, 1996).

An alternative interpretation is that children may have an implicit understanding of nonword units, and therefore were unable to verbally explain their procedure during spelling production. We know from past research that the properties of pseudowords and nonwords can affect lexical classification and that children's spelling can be influenced by subtle sublexical patterns, such as number of phonological neighbours (Kemp, Treiman, Blackley, Svoboda & Kessler, 2015). Young spellers, for example, are able to accept nonword items as being 'legal' in English when containing final doublets (e.g. *baff*) while rejecting other

possibilities including initial doublets (e.g. *bbff*) because they are aware that, in general, English words tend not begin with two consonant letters (see, Cassar & Treiman, 1997). Furthermore, research has shown that spelling production can be constrained by relatively poor levels of implicit knowledge when measured on spelling recognition tasks (Coyne et al., 2012). The fact that implicit levels of spelling knowledge may not have translated into explicit forms of spelling production could account for inconsistency in nonword scores.

In uncovering this complexity of strategy choice, particularly in relation to scores on the regular and irregular items, the current study has made an important contribution to supporting the application of dual-route theory to children's' reading and spelling acquisition. That is, predictions have been largely supported in the developing skills of regular and irregular word reading and spelling and suggests that this static model of skilled reading can be extended from adults to children (see also Castles, Bates & Coltheart, 2006). A further contribution of this work has been the extension of the dual route theoretical framework to further incorporate variability and adaptive choice among children's reading and spelling skills (Farrington-Flint, 2015; Siegler, 1996). In doing so, there is strong indication that the orthographic and morphological approaches, often found during early reading and spelling production, might best be accounted for by the nonlexical route to development. It is likely that children's past formal schooling experience and their instruction in using analytic and synthetic phonics did influence the children's strategy selection, particularly on the regular items, and suggests that strategy choice might be a 'learned' rather than 'unrehearsed' response to the stimuli.

Limitations and Future Directions

Given the limited support for the dual route model in relation to nonword performance, one limitation of the present study might be the inclusion of existing nonword item sets from

Castles and colleagues (2009) rather than devising our own items that stringently controlled for orthographic consistency, word frequency and consonant clusters (see Moore et al., 2012). The fact that many of these nonword items equated to real word equivalents could account for the inconsistency in strategy reports in the current work. This is likely because we know that while nonword reading and spelling is considered to be the optimal measure of phonological decoding/nonlexical reading skills, not all nonword items provide an accurate measure of nonlexical reading skills (Moore et al., 2012) and that a number of subtle characteristics of nonword items can influence how easily they are read or spelt (see, Colenbrander, Nickels, & Kohnen, 2011). It is possible that our choice of nonword stimuli, might have restricted or influenced children's strategy choice unduly. Future work, might further consider the relationship between the acquisition of reading and spelling strategies by incorporating sets of stimuli that are more and/or less nonword like, and manipulating the frequency of each orthographic unit in a more systematic manner, which should help to gain a more accurate depiction of the role of nonlexical strategies to children's success on reading and spelling nonword items (Castles et al., 2006).

A further limitation might also concern word characteristics contained within the regular and irregular items. Many of these items were mono- and bi-syllabic which did not allow for any detailed assessment of children's application of morphological rules. One way to extend the findings might be to consider the inclusion of additional items that contain derivation and inflection of morphemes rather than just highly regular orthographic units (Deacon, Benere, & Castles, 2012; Deacon, Benere & Pasquarella, 2013). Items that include grapho-syllabic and different morphemic spelling-sound units (e.g., -ump, -tion, -ed, -ing) would capture children's morphological knowledge of spelling in greater detail (Devonshire, Morris, & Fluck, 2013) in addition to incorporating item analysis as well as participant analysis (see,

Wang, Nickels, Nation & Castles, 2013) to fully explore the way in which nonword items might influence reading and spelling strategy performance fully.

While the current data adds to burgeoning evidence to support the benefits of using verbal self-report data to capture the range of co-existing strategies that children use in reading and spelling (Farrington-Flint, 2015; Lindberg et al., 2011; Kwong & Varnhagen, 2005; Rittle-Johnson & Siegler, 1999) and allows us to consider research questions that could not be satisfied by quantitative accuracy data alone, a final limitation concerns our reliance solely on retrospective verbal reports as a measure of strategy choice. Despite positive comments regarding the reliability of verbal reports (Edwards, Weinstein, Goetz & Alexander, 2014; Siegler, 1996), there is some concern that introspective reflections from young children could be problematic in that young children may be unreliable in clearly articulating their approach to strategy selection (Ericsson & Simon, 1980). To address these concerns and limitations, future work could include other assessment methods, including response time (Farrington-Flint et al., 2008a; 2008b) keystroke latencies (Kwong & Varnhagen, 2005) or behavioural observations (Rittle-Johnson & Siegler, 1999) as well as using qualitative analyses based on spelling errors (Chiappe & Siegel, 1999; McGeown, et al., 2013).

Implications for Teaching and Learning

In supporting the predictions of dual route theory, our current findings may have important implications for learning and instruction. The assessment of young children's performance on regular, irregular and nonword items, for example, might help to provide a more detailed understanding of the progress that children make in acquiring lexical and nonlexical routes to reading/spelling. Furthermore, it is possible to use calculations based on children's irregular and nonword scores to establish their regular reading and spelling abilities (Castles Bates & Coltheart, 2006) and to identify different profiles or subgroups

based who might experience early difficulties in acquiring either lexical or nonlexical skills (Farrington-Flint, 2015). This may, in turn, help to further inform learning and instruction by identifying specific groups of children who might require further targeted literacy instruction, depending on their irregular and nonword reading and spelling abilities. Finally, and from a broader perspective, increasing fluency in decoding and transcriptive skills frees up cognitive resources for text-level reading comprehension and writing processes.

Conclusion

The findings from our current study provide further support for the application of dual route theory in relation to children's acquisition of reading and spelling skills. We have shown that children often rely on a range of co-existing strategies to inform their identification and spelling of words and how the static model of dual theory can be applied not only to skilled adult readers and those with dyslexia (Coltheart, Curtis, Atkins & Haller, 1993; Perry, Ziegler & Zorzi, 2007; 2010) but also to typically developing children. While the predictions of dual route theory did not fully support reading or spelling performance on the nonword items, we have provided recommendations for future research to help elucidate the precise skills involved in nonword abilities more closely. The application of dual route theory within the classroom context might also provide teachers with a model with which they can fully assess children's acquisition of lexical and nonlexical routes to literacy.

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Appendix A

Stimuli used in the Experimental Reading and Spelling Test

Regular words	Irregular words	Nonwords
Middle	Island	Delk
Luck	Bowl	Farl
Chicken	Couple	Pite
Tail	Soul	Framp
Market	Sure	Brinth
Cord	Iron	Borp
Pump	Lose	Trobe
Wedding	Cough	Gurve
Marsh	Choir	Beft
Chance	Ceiling	Pofe
Check	Deaf	Jeaph
Navy	Brooch	Pleech
Flannel	Yacht	Salpy
Stench	Tomb	Grenty
Nerve	Routine	Stendle
Curb	Gauge	Tapple
Context	Meringue	Seldent
Brandy	colonel	Brennet
Weasel	Bouquet	Bormil
Sleek	Shove	Bleaner

Appendix B

Strategy Explanations and Coding Examples

Strategy	Examples of self-reports	Example
Pure lexical retrieval	This involves retrieving words from memory and is automatic and quick.	I just knew it I remembered it from before We learnt it in class
Elaborated non-lexical Strategy	Children will use rules or refer to morphemes (e.g. double‘s’, ‘ed rule – ing). Any kind of chunking or clustering (e.g. ‘st’) will also fall under this strategy including the use of analogy.	It’s the same as ‘duck’ I know that combining ‘s’ and ‘t’ together makes the sound ‘st’. It’s like record but without the ‘re’ sound.
Moderate non-lexical strategy	This involves letter-by-letter decoding or sounding out individual items contained within the word. Explicit phonological attempts including partial or complete identification of phonemes.	I used the sounds I used the some of the letters phonemes
Non-specific strategy	The child may not give any response or provide an incomplete or irrelevant response, including guessing.	I do not know I guessed

Table 1

Means (& Standard Deviations) for Scores on the Pre-Assessment Standardised Tests According to Year Group and Sex

	Year 3		Year 4	
	Male	Female	Male	Female
BAS II reading	108.83 (20.09)	108.07 (20.85)	102.15 (10.35)	104.62 (7.69)
BAS II spelling	110.33 (20.35)	113.71 (30.49)	99.08 (10.63)	106.06 (8.41)
BPVS II vocabulary	98.58 (13.83)	96.57 (15.90)	83.15 (11.40)	89.50 (11.12)
BAS II Matrices*	55.25 (18.91)	59.29 (18.74)	48.92 (16.10)	51.63 (18.63)

Note. * represents T scores

Table 2

Means (& Standard Deviations) for Percent Reading and Spelling Accuracy Scores as a Function of Regular, Irregular and Non Word Type

	Year 3			Year 4		
	Regular	Irregular	Nonword	Regular	Irregular	Nonword
Reading test	84 (22)	51 (23)	75 (27)	94 (11)	61 (14)	80 (19)
Spelling test	60 (26)	30 (23)	47 (23)	69 (17)	42 (16)	48 (18)

Table 3

Means (& Standard Deviations) for Percent Frequency and Percent Accuracy of Individual Strategies on the Reading Test

	Frequency			Accuracy		
	Regular	Irregular	Nonword	Regular	Irregular	Nonword
Year 3						
Pure Lexical Retrieval	55 (25)	39 (22)	16 (16)	93 (14)	77 (30)	71 (34)
Elaborated strategy	27 (21)	26 (18)	45 (28)	90 (17)	44 (30)	79 (29)
Moderate strategy	14 (23)	31 (20)	30 (32)	56 (35)	21 (24)	64 (38)
Non-specific strategy	4 (6)	5 (7)	9 (10)	55 (44)	23 (35)	53 (45)
Year 4						
Pure Lexical Retrieval	64 (26)	49 (23)	20 (26)	97 (8)	84 (14)	77 (37)
Elaborated strategy	31 (26)	33 (23)	57 (27)	93 (17)	43 (33)	77 (28)
Moderate strategy	3 (7)	15 (15)	13 (20)	72 (43)	17 (24)	64 (39)
Non-specific strategy	2 (4)	3 (5)	9 (15)	80 (44)	28 (42)	72 (40)

Table 4

Means (& Standard Deviations) for Percent Frequency and Percent Accuracy of Individual Strategies on the Spelling Test

	Frequency			Accuracy		
	Regular	Irregular	Nonword	Regular	Irregular	Nonword
Year 3						
Pure Lexical Retrieval	54 (30)	42 (31)	21 (29)	66 (27)	46 (28)	65 (31)
Elaborated strategy	27 (24)	29 (27)	44 (30)	66 (26)	17 (24)	54 (28)
Moderate strategy	16 (28)	23 (30)	23 (32)	32 (42)	15 (27)	44 (35)
Non-specific strategy	3 (5)	7 (8)	9 (11)	25 (38)	0 (0)	35 (38)
Year 4						
Pure Lexical Retrieval	60 (24)	53 (26)	18 (25)	72 (19)	57 (25)	44 (34)
Elaborated strategy	33 (23)	36 (26)	58 (22)	67 (23)	30 (26)	52 (22)
Moderate strategy	5 (8)	7 (9)	17 (22)	71 (40)	10 (29)	38 (27)
Non-specific strategy	3 (8)	4 (11)	7 (17)	50 (48)	0 (0)	35 (39)

Table 5

Predictors of Regular Word Reading and Spelling

	B	SEB	β	R^2 change
Reading ability				
Step 1				
Chronological age	2.26	.74	.386*	.149**
Step 2				
Chronological age	3.18	6.09	.054	
Pure Lexical Retrieval	.729	.274	1.060*	
Elaborated strategy	.645	.279	.858*	
Moderate strategy	-.037	.296	-.036	.535**
Spelling ability				
Step 1				
Chronological age	2.164	.966	.294	.087*
Step 2				
Chronological age	.932	.746	1.27	
Pure Lexical Retrieval	.830	.311	.994*	
Elaborated strategy	.607	.321	.633	
Moderate strategy	.114	.331	.108	.448**

Note. For reading ability: Step 1 R^2 = .149. Step 2 R^2 = .683. * p < .05 ** p < .01.
For spelling ability: Step 1 R^2 = .087. Step 2 R^2 = .534. * p < .05 ** p < .01
SEB = standard error for the regression coefficient

Table 6

Predictors of Irregular Word Reading and Word Spelling

	B	SEB	β	R^2 change
Reading ability				
Step 1				
Chronological age	1.963	.845	.304*	.092*
Step 2				
Chronological age	.025	.776	.004	
Pure Lexical Retrieval	.885	.275	1.038**	
Elaborated strategy	.662	.299	.705*	
Moderate strategy	.196	.281	.194	.356**
Spelling ability				
Step 1				
Chronological age	1.931	.894	.284*	.081*
Step 2				
Chronological age	.955	.803	.141	
Pure Lexical Retrieval	.619	.229	.863**	
Elaborated strategy	.415	.240	.538	
Moderate strategy	.160	.258	.178	.295**

Note. For reading ability: Step 1 R^2 = .092. Step 2 R^2 = .448. * p < .05 ** p < .01.
For spelling ability: Step 1 R^2 = .081. Step 2 R^2 = .376. * p < .05 ** p < .01
SEB = standard error for the regression coefficient

Table 7

Predictors of Non-Word Reading and Non-Word Spelling

	B	SEB	β	R^2 change
Reading ability				
Step 1				
Chronological age	1.339	1.047	.173	.030
Step 2				
Chronological age	.268	1.038	.035	
Pure Lexical Retrieval	.249	.245	.232	
Elaborated strategy	.184	.264	.218	
Moderate strategy	-.183	.248	-.211	.169
Spelling ability				
Step 1				
Chronological age	.304	.919	.045	.002
Step 2				
Chronological age	-.061	.836	-.009	
Pure Lexical Retrieval	.394	.165	.520*	
Elaborated strategy	.290	.173	.426	
Moderate strategy	-.005	.175	-.007	.256

Note. For reading ability: Step 1 R^2 = .030. Step 2 R^2 = .199. * p < .05 ** p < .01.
For spelling ability: Step 1 R^2 = .002. Step 2 R^2 = .258. * p < .05 ** p < .01
SEB = standard error for the regression coefficient