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Are Word Representations Abstract or Instance-Based? Effects of Spelling Inconsistency in Orthographic Learning

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In Experiment 1, 62 10-year-old children studied printed pseudowords with semantic information. The items were later represented in a different format for reading, with half of the items spelled in the same way as before and half displayed in a new phonologically equivalent spelling. In a dictation test, the exposure to an alternative spelling substantially increased the number of errors that matched the alternative spelling, especially in good spellers. Orthographic learning predicted word identification when accuracy on orthographic choice for words was controlled. In Experiment 2, the effects on dictation responses of exposure to a misspelling versus the correct spelling, and the interactive effect of spelling ability, were confirmed relative to a no-exposure control in adults. The results support a single-lexicon view of reading and spelling and have implications for abstractionist and instance-based theories of orthographic representations.

Keywords: Orthographic learning, spelling, abstract lexical representations, episodic, instance-based representations

Learning word-specific orthography is vital for fluent and accurate word identification and spelling. Among the variety of theoretical approaches to visual word identification (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Forster, 1994; Plaut, McClelland, Seidenberg, & Patterson, 1996), there is general agreement that word-specific orthography must be stored for proficient litreacy function in English, at the very least to distinguish the many homophones in the language (Frost, 1998). In addition, in the context of dual route models (Coltheart et al., 2001), rules that relate spelling and sound cannot be used successfully to read words with atypical pronunciations or to write words with atypical spellings.

Children are explicitly instructed on the orthography of words at school, but beyond the first few years of litreacy education a great deal of orthographic learning occurs incidentally during reading (Nagy, Herman, & Anderson, 1985). Training studies have provided support for the central claim of the self-teaching model of reading acquisition (Share, 1995); namely, that phonological coding of to-be-learned letter strings facilitates learning in both children (Dixon, Stuart, & Masterson, 2002; Drake & Ehri, 1984; Kyte & Johnson, 2006; Share, 1999) and skilled adult readers (Chalmers & Burt, 2008). Beyond encoding factors, little is known about how learning encounters with words are integrated with prior knowledge of word orthography, phonology, and meaning.

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Organisation and Development of Lexical Knowledge

In the visual word identification litreature it is assumed that word-specific phonology, orthography, and meaning are organised as lexical representations within a store called the mental lexicon (Allport & Funnell, 1981). Traditionally, lexical representations have been conceived within a localist framework in which information about each word is stored separately (Coltheart et al., 2001; Forster, 1994). More recently, connectionist frameworks have modelled word-specific information as a pattern of activation over distributed units used for many words (Plaut et al., 1996). Commonly it is assumed that a single lexical representation serves reading and spelling. The fact that there is a strong item by item association between reading and spelling performance in individual skilled adult readers supports the “single lexicon” assumption with respect to orthography (Burt & Tate, 2002; Holmes & Carruthers, 1998). For example, Burt and Tate (2002) found that skilled adult readers were slower and less accurate in visual word identification of words that they could not spell correctly.

The focus of the present research is the acquisition of orthographic component of the lexical representation. The development of orthographic representations from individual learning encounters with words has received little theoretical attention. In the lexical processing litreature, it is proposed that information that is specific to individual learning encounters with words, such as format (handwriting, letter font), situation, and medium (e.g., street-sign vs. Internet vs. book), is not preserved in the orthographic representation. Such contextual information is assumed to be stored separately in autobiographical (i.e., episodic) memory, perhaps being available to influence performance in lexical tasks (Forster & Davis, 1984).

The above typical view in the lexical processing litreature is termed abstractionist because the key phonological, orthographic, and semantic attributes of a word are abstracted from information that varies over encounters with a word. This abstractionist view of item-specific memories must be distinguished from that used in the implicit learning of artificial grammars in which the term *abstract* typically implies that participants (implicitly) learn the rules necessary for classifying stimulus sequences (Cleeremans & Jiménez, 1998; Pacton, Perruchet, Fayol, & Cleeremans, 2001).

A critical feature of the abstractionist view is that each learning encounter that involves successful word identification updates a single representation of the word (Bowers, 2000). For example, within a connectionist architecture (Seidenberg & McClelland, 1989), the links between the letters and letter clusters of the word and between the orthography and phonology of the word are strengthened when the word is read and pronounced. Thus the presented orthography is integrated with a single representation of the word in lexical memory, even if the presented word is misspelled. In line with the typically observed negatively accelerating trajectory of learning (Kirsner & Speelman, 1996), the effect on the abstract representation of one presentation of a word is assumed to be substantially larger for poorly learned than well-learned words. For a well-learned word reading a misspelling may cause a minimal change of the word's orthographic pattern in memory, whereas for a less well-learned word the orthographic representation will change so that it is more like the misspelling, or perhaps more ambiguous.

An alternative approach to understanding the acquisition of lexical representations comes from the episodic memory litreature. There are a number of instance-based theories of lexical representations that reject the above assumption that key lexical information is integrated in a single representation for each word. Instance-based theories are consistent with the view that the same representations serve reading and spelling, but suppose that multiple representations are stored for each word, corresponding to episodic records of each encounter with a word (Kirsner, Dunn, & Standen, 1987). These representations are thought to include specific information about the encounter, including format (e.g., type font, letter case) and situational information (e.g., semantic context, Tenpenny, 1995). On the simplest application of an instance-based model to orthography, exposure to an incorrect spelling of a word creates a separate record of the incorrect spelling that might be the record that is accessed on a future test, depending on factors such as retrieval cues (Brown, 1988; Jacoby & Hayman, 1987).

A number of other episodic theories suppose that all or many of a word's individual representations are activated in concert when the word is presented (cf. Carr et al., 1994). This idea is fundamental to the Minerva 2 multiple trace model of memory (Hintzman, 1986), which has served as the architecture for extensive theory development in spoken word recognition by Goldinger (1998). The mechanisms of representation and retrieval in Minerva 2 have also been used in reading models (Kwantes & Mewhort, 1999; Reichle & Perfetti, 2003) without any inclusion of specific episodic (e.g., contextual) information. A significant strength of the multiple-trace approach is in the representation of semantic information, much of which must be derived from encounters with words in various contexts (see Jones & Mewhort, 2007).

It is difficult to devise empirical tests that will adjudicate between the key assumptions of abstractionist and episodic approaches. A body of research has investigated the extent to which word repetition effects in reading tasks are sensitive to variation in perceptual or contextual information from the first to the second presentation. On the basis of the inconsistent evidence that has emerged, one review concluded in favour of the episodic view that contextual information is preserved in the lexical knowledge that supports reading (Tenpenny, 1995) and another in favour of the abstractionist view that contextual information is not preserved (Bowers, 2000).

Lexical researchers conducting training studies with novel letter strings generally endorse the idea of that unitary, abstract representations are formed from memory episodes, and typically assume that this process may take many exposures. A recent pressing concern has been to find tests which show lexicalisation, by which is meant the formation of an abstract representation in the lexical memory system. However, the idea that tests can be found that are sensitive to lexicalisation but not episodic memory has been problematic. Bowers, Davis, & Hanley (2005) inferred lexicalisation from competition with similar already known words and showed that *banana* was more slowly classified semantically after training on *banara* (cf. Gaskell & Dumay, 2003). Others have used the masked priming of newly trained items by orthographically similar nonwords to show lexicalisation (Johnston, McKague, & Pratt, 2004) or have shown effects of newly trained items on picture naming (Clay, Bowers, Davis, & Hanley, 2007). It is by no means clear that these tests show nonepisodic effects. For example, Qiao, Forster, Witzel (2009) found no evidence for lexical competition of *banara* with *banana* and suggested an episodic basis to the Bowers, Davis, & Hanley (2005) result. Interference in picture naming can easily be explained by episodic retrieval cued by the presentation of a similar letter string. Furthermore, there is evidence that at least some masked priming effects are influenced by episodic memory variables (Bodner & Masson, 2001; Forster, 1985).

The empirical approach in the present studies differed from previous research in priming effects by examining memory in a recall task, as suggested by Jamieson and Mewhort (2005). Participants' early learning of orthography was tested in spelling to dictation. Inconsistency of training orthography was used to probe what memories were producing test performance. A secondary aim was to examine the correlations among reading and spelling skills and orthographic learning to provide information on the skills involved in orthographic learning and its relationship with visual word identification.

The critical theoretical distinction addressed in the present experiments was whether the representations serving reading and spelling are abstract and unitary in the sense that each new encoding is integrated with previous learning, or whether separate episodic representations of alternative orthography are preserved in memory. To test the episodic view, learners were required to use contextual information to effect retrieval of a particular record of a spelling (Brown, 1988; Jacoby & Hollingshead, 1990) or differential activation of a representation that best matched the retrieval cues (Hintzman, 1986). Finally, the studies aimed to provide some information on a difference between instance-based and abstractionist accounts that is especially relevant to orthographic learning. In abstractionist accounts the integration of prior with new learning provides a mechanism whereby past learning can support the encoding of current presentations of an item. Instance-based models have not been developed to address the acquisition of records of words, and each encoding is effectively independent of other encodings.

Previous research with moderately familiar words shows that university students who perform spelling-related tasks on misspelled words exhibit a subsequent impairment in spelling accuracy for the words (Brown, 1988). In Grade 5 children Bradley and King (1992) found that multiple exposures to correct and incorrect spellings in sentences in a proof-reading task affected spelling accuracy for the words. It has been found with adults that reading a misspelling produces a deficit in accuracy on a subsequent dictation test (Dixon & Kaminska, 1997; Jacoby & Hollingshead, 1990). However, the effect is small. Furthermore, only Dixon and Kaminska were able to show a specific effect of the misspelling seen in the exposure phase; that is, a significant increment in the number of dictation responses that matched the exposed misspelling.

The idea that separate records of encounters with words are accessed was the basis of explanations of the misspelling exposure effect by both Jacoby and Hollingshead (1990) and Brown (1988). By contrast, Dixon and Kaminska (1997) favoured an abstractionist account because their misspelling exposure effect persisted over a retention interval of one week. An important assumption made by Jacoby and Hollingshead (1990) and by Brown (1988) was that a single encounter allowed a misspelling to be sufficiently well encoded that it could be produced at test. This is a plausible assumption to make about the encoding of familiar words but perhaps does not apply to the learning of new letter strings.

In the present studies participants were trained briefly on pseudowords and then had a reading exposure of some pseudowords in their correct or alternative spellings. The training and reading-exposure phases were separated contextually by means of intervening tasks and changes in textual context, format, and tasks. This separation provided participants with some episodic cues at test to support explicit retrieval of the correct spelling. Participants' ability to use episodic information to produce the correct spelling would favour an instance-based account in which the correct spelling was retrieved singly at test, or preferentially activated in multiple traces. The abstractionist account predicts a strong influence of the recent misspelling, a result that might also be observed within the episodic framework if episodic cues were ineffective.

The misspelling exposure paradigm may indicate how well orthography can be encoded on a single trial and whether the influence of spelling inconsistency depends on the quality of learning of the correct spelling. Only the instance-based views assume adequate encoding of alternative spellings, with episodic cues being the main determinant of what spellings are most strongly activated at test. Experiment 2 tested the opposing abstractionist prediction that the vulnerability to misspelling exposure depends upon the quality of prior learning of the correct spelling. Finally, individual differences in learning may be revealing about the nature of orthographic representations, as outlined below.

Individual Differences in Orthographic Learning

The developmental and adult litreature on spelling ability is consistent with an effect of reading and spelling ability on the efficiency of learning the orthography of unfamiliar words (Bailey, Manis, Pedersen, & Seidenberg, 2004). For example, in training studies Reitsma (1989) found that dyslexic children fell behind their peers in the development of orthographic representations. A number of authors have suggested that differences in orthographic processing underlie differences in orthographic learning during reading. Frith (1980) argued that poor spellers may identify words on partial information and fail to process orthographic detail during reading. In the lexical-decision task in skilled adult readers, poor spellers are more likely than good spellers to mis-classify a nonword formed by transposing two internal letters of a word (Holmes & Ng, 1993).

The presumed differences in orthographic learning ability between good and poor spellers may interact with our training conditions to shed light on the nature of orthographic representations. Specifically, on an instance-based view, good spellers might achieve a better memory for individual encounters with a letter string, with records that differentiate the alternative spellings seen. Poor spellers may fail to encode the differences between the spellings. Additionally, the efficient encoding of letter strings by good spellers may free up time or cognitive resources for studying the item context (Miller & Keenan, 2009). Consistent with this idea, there is some evidence that proficient learners of new letter strings have better episodic memories of training encounters (Perfetti, Wlotko, & Hart, 2005) and that successful university students have strong episodic memories of encounters with material in lectures (Conway, Gardiner, Perfect, Anderson, & Cohen, 1997). Thus good spellers may be better able than poor spellers to use contextual information to select the spelling that is sought. Consequently, on an episodic theory good spellers should be less vulnerable to producing the misspelling at test.

Alternatively, on an abstractionist view of orthographic representations, if good spellers are more likely to acquire orthography incidentally during reading, then they should also be more likely to acquire orthography when an item's orthography is changed in such a way that its phonology, meaning, and syntactic roles are preserved. Thus the abstractionist account predicts a larger misspelling exposure effect for good than poor spellers. Dixon and Kaminska (1997) tested this prediction and failed to find support for it. One difficulty was that good spellers would have been confident about more of the spellings than poor spellers, and within the abstractionist framework, a misspelling will have a more substantial updating effect on representations of words about which a writer is unsure. This difficulty does not apply to the present study in which experience with items was equated for good and poor spellers via the use of novel letter strings.

Experiment 1

Grade 5 (10-year-old) children participated in an orthographic learning experiment described below, as well as completing tests of spelling recognition and production, phonological coding (nonword pronunciation), word reading, and passage comprehension. The spelling production test was used to identify good and poor spellers for an evaluation of spelling ability interactions with reading exposure. The relationship between orthographic learning and individual skills was of interest given the recent focus on orthographic processing skill (OPS). Measures of this skill, defined as the ability to form, store, and access orthographic representations (Stanovich & West, 1989), typically predict word identification when phonological skills and print exposure are controlled (Olson, Forsberg, Wise, & Rack, 1994; Stanovich, West, & Cunningham, 1991). Usually OPS is assessed by the orthographic choice test, a spelling test in which participants decide which of two phonologically identical letter strings is a word (e.g., *brane* vs. *brain*). In the present study a three-choice spelling recognition test provided an orthographic choice test of OPS.

Children's ability to learn novel word-like letter strings promises to provide a more direct and accurate measure of the core components of OPS, given that children's existing representations of words may be affected substantially by differences in reading experience. Experiment 1 assessed the association between learning of novel orthography and the traditional measure of OPS, orthographic choice (spelling recognition). In addition, we assessed the associations with orthographic learning of phonological coding skill, word identification skill, comprehension, and spelling production. It was expected that orthographic learning would be strongly associated with word identification and spelling, and in line with the self-teaching hypothesis (Share, 1995), that phonological coding skill would predict orthographic learning.

In the orthographic learning session, children spelled newly learned pseudowords to dictation after an intervening reading exposure to the items, in which half of the items were in their original (target) spellings and half were in an altered spelling that preserved the item phonology. Variation of format, accompanying text, and task over the learning and reading phases allowed a partial contextual separation of the two encounters, and children were asked to use this episodic information to retrieve the correct spelling. It was expected that reading a pseudoword that was misspelled (hereafter termed a foil) would increase the probability of the foil spelling on a later spelling production test. Specifically, foil spellings were expected to be more frequent in the foil than the target exposure condition and vice versa for target spellings. It was predicted that good spellers would be more likely to learn the orthography of items that were read, and thus would be more accurate overall than poor spellers. Also, if the abstractionist view of orthographic representations is correct, good spellers should be more likely than poor spellers to reproduce the foil spelling after a reading exposure to it.

Method

Participants. The participants were 62 children in Grade 5 from five socioeconomically diverse schools within the Catholic education system in Brisbane. There were 22 boys and 40 girls, and the mean age was 10 years and 1 month. Scores on the standard spelling production test were unavailable for two children. Two speller groups were selected from the best and poorest in the spelling production test, with the constraint that item counterbalance sets for the orthographic learning task were equally represented. There were 20 in each of the spelling ability groups, with good spellers having at least 45 correct of 70 and poor spellers having no more than 37 of 70.

Materials and design. The South Australian Spelling Test (Westwood, 1979) was administered in the standard dictation format and was also modified for administration as a three-alternative orthographic choice test. The Cronbach reliabilities of the South Australian spelling tests on the present data sets were $\alpha = .92$ for spelling production and $\alpha = .81$ for recognition. The initial 19 words were simple or frequent words of two to four letters, and they were omitted from the recognition test. For the remaining 51 words (three to 13 letters in length), two distractors were devised by the second author by adding, deleting, and/or replacing one to two letters to make a misspelling that in most cases (88%), and for at least one of the distractors, preserved the phonology of the word.

The Word Attack, Word Identification, and Comprehension subtests of the Woodcock Reading Mastery Tests (Woodcock, 1987) assessed phonological coding (nonword pronunciation) and word reading. The test manual lists a split-half reliability for these subtests of $r = .89$, $r = .91$, and $r = .73$, respectively. In analyses the scores were expressed as equal-interval (Rasch-scaled) W scores (Woodcock, 1987).

For pseudoword training, 16 orthographically legal letter strings were devised that did not closely resemble any single English word (except for the accidental inclusion of the word *curtelage*; see Appendix). They ranged in length from six to 10 letters (mean 7.6) and they had from one to three syllables. For each item we devised an orthographically legal alternative spelling that preserved the pronunciation of the item, a brief definition, and a sentence (e.g., *dreakot: dreekot; a small pink flower; Can you see the dreakot growing over there?*). The definition was presented with the item in the training phase, and the sentence was presented in the reading exposure phase. In case the initial items had more plausible spellings than the alternative spellings subsequently generated for them, the initial items were targets in the first half of the item set and the alternative spellings were designated targets in the second half of the item set. The target spelling was designated the correct spelling and was the spelling used in training. The alternative spellings were the misspelled foils for the reading exposure phase. For the reading exposure two counterbalanced item sets A and B were produced such that set A had the first half of the items correct for reading and the second half incorrect for reading, and vice versa for set B. Thirty-one children received set A, and the remainder received set B. Thus exposure (target vs. foil spelling) was varied within-participants such that eight trained items were exposed in the original (target) spelling and eight items were exposed in the incorrect, foil spelling. A different random order of items was used for training, reading, and test.

Procedure. For the tests of individual differences each child was tested individually except that the orthographic choice version of the South Australian spelling test was administered in small groups and the dictation version of this test was administered in class by each child's teacher. The order of administration of the spelling tests was counterbalanced, and no child received the two tests on a single day.

The children spent approximately 20 minutes completing the Word Identification, Word Attack (phonological coding), and Passage Comprehension subtests of the Woodcock test (1987). These tests were administered after the pseudoword training phase and before the reading exposure phase of the pseudoword tasks.

The pseudoword tasks were administered in a single session lasting approximately 40 minutes. The pseudoword training on target pseudowords was given first. Children were told that they were to learn how to spell some made-up words. The second author produced a yellow sheet of paper and showed an item and its definition (e.g., *a small pink flower*) to the child, pronounced the pseudoword, read the meaning aloud, pronounced the pseudoword again, and then asked the child to read the pseudoword aloud. After she had finished the 16-item list she showed the list to the child and asked him or her to write out the list without the meanings.

After the intervening word and nonword identification and comprehension tests, the reading exposure phase of the pseudoword task was conducted. The pseudowords appeared on a white sheet of paper, one per line in their sentences, with half of the items correctly spelled (target exposure condition) and half in their alternative, incorrect spelling (foil exposure condition). No specific information was given about spelling changes before the reading task.

The children asked to read the sentences silently (e.g., *Can you see the dreakot growing over there?*). When they had finished they were asked to read the made-up words aloud. The dictation test of the pseudowords was administered next. The children were asked to write the items exactly as they had seen them first, on the yellow paper, which was visible face-down on the table.

Results

Orthographic learning: Effects of exposure to a misspelling. Responses on the dictation test of trained pseudowords were scored as correct spellings (the spelling of the first-presented, target, item), spellings matching the foil, and other spellings. The last category hereafter is referred to as "null" spellings. These scores are shown in Table 1. The two counterbalance groups did not differ on the number correct in the target exposure condition, $F < 1$, confirming that we were successful in matching the item subsets on spelling difficulty. Data were collapsed over counterbalance sets for subsequent analyses. *MSE*s are reported for the major analyses in the total sample.

The percentages of correct and foil spellings were analysed in a Response type (correct vs. foil misspelling) × Exposure condition (target vs. misspelled foil) within-participants/items ANOVAs by participants (*F1*) and items (*F2*).[1] There were more correct (target) than incorrect (foil) spellings, yielding a significant main effect of response type, $F1(1,61) = 20.53$, $MSE = 535$, $p < .001$, $F2(1,15) = 9.37$, $MSE = 29$, $p = .008$. The main effect of exposure was not significant, indicating that the combined number of correct and foil spellings, and thus the proportion of null spellings, did not differ over exposure conditions. Of most interest was a reversal of the direction of effects of target versus foil exposure on the correct versus foil responses, with a disordinal Response type × Exposure interaction, $F1(1,61) = 88.84$, $MSE = 494$, $p < .001$, $F2(1,15) = 76.69$, $MSE = 14$, $p < .001$. Simple effects analyses were conducted over exposure condition within each response category. Correct responses were more frequent in the target exposure than the foil exposure condition, $F1(1,61) = 76.56$, $p < .001$, $F2(1,15) = 86.27$, $p < .001$, whereas foil spellings were substantially more frequent in the foil exposure condition than in the target exposure condition, $F1(1,61) = 73.44$, $F2(1,15) = 51.30$, $p < .001$, indicating that the likelihood of producing foil spellings was increased by exposure to the foils. The number of target spellings that children produced in the target exposure condition was positively correlated with the number of their foil spellings in the foil exposure condition, $r(62) = .39$, $p = .002$.

The data for the dictation test of orthographic learning for the speller subgroups were subjected to a Spelling ability × Exposure × Response type (correct vs. foil misspelling) ANOVA (see Figure 1). Good spellers showed greater conformity with the presented spellings, producing more target and foil spellings combined (and correspondingly fewer null spellings) than poor spellers, confirmed by a main effect of group, $F1(1,38) = 62.51$, $F2(1,15) = 57.32$, $p < .001$. The interaction of exposure and response was significant, as in the analysis for the total sample. Figure 1 shows that spelling ability substantially affected the pattern of results, with a large advantage for the correct over foil spellings for good spellers in the target exposure condition, relative to poor spellers overall and relative to the foil condition. Good spellers achieved 78% accuracy on consistently trained items, whereas poor spellers achieved only 23% on these items. The two-way interactions with spelling ability were significant, for Exposure × Spelling ability, $F1(1,38) = 7.40$, $p = .009$, $F2(1,15) = 4.58$, $p = .049$, and Response type × Spelling ability, $F1(1,38) = 24.97$, $F2(1,15) = 25.12$, $p < .001$. These interactions were qualified by a three-way interaction of exposure, response type, and spelling ability, $F1(1,38) = 34.20$, $F2(1,15) = 35.37$, $p < .001$. Spelling ability × Exposure simple interaction tests were conducted for each response type separately. Relative to poor spellers, good spellers showed a larger increment in correct responses going from foil to target exposure, $F1(1, 38) = 43.47$; $F2(1, 15) = 39.19$, $ps < .001$, and a larger increment in foil responses going from target to foil exposure, $F1(1, 38) = 15.25$, $p < .001$; $F2(1, 15) = 13.99$, $p = .002$. A follow-up comparison confirmed that the percentage of target spellings in the target exposure condition was larger for good than poor spellers, $F1(1, 38) = 104.50$, $F2(1, 15) = 90.75$, $ps < .001$. An additional comparison confirmed that the percentage of foil spellings in the foil exposure condition was larger for good than poor spellers, $F1(1, 38) = 8.43$; $F2(1, 15) = 10.32$, $ps = .006$. Thus the results supported the abstractionist predictions that good spellers would be more accurate for consistently trained items and also more likely than poor spellers to reproduce a foil misspelling that they had read.

Orthographic learning and individual skills. The mean percent correct for spelling production was 59% ($SD = 9.71$), and for orthographic choice the mean percent correct (of 51) was 66% ($SD = 17.72$). The age-normed standard scores for the Word

Table 1
Experiment 1: Mean Percent Target, Foil, and Other ("Null") Spellings by 10-Year-Old Children for Trained Pseudowords as a Function of Exposure Condition in the Second Phase of the Orthographic Learning Task

	Spelling produced on dictation test		
Exposure	Target	Foil	Null
Target (correct)	47 (28.73)	8 (10.24)	45 (26.62)
Foil (alternative)	19 (17.05)	33 (20.80)	48 (23.25)

Note. Standard deviations are shown in parentheses.

[1] In view of the ipsative nature of the response type variable the null responses were removed from the analyses. The fact that the levels of the response type factor are not independent of each other does not violate the assumptions of repeated measures ANOVA (Hays, 1963, p. 455).

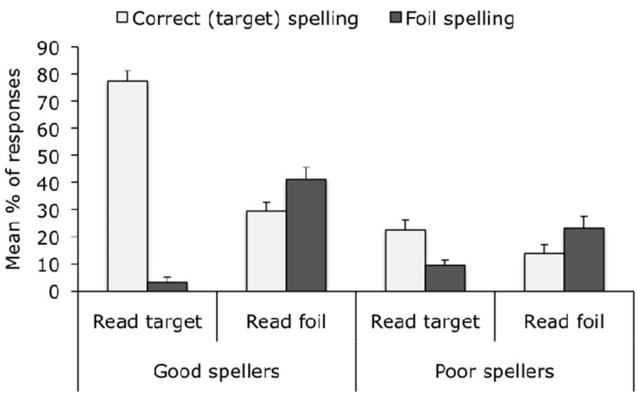

Figure 1. Experiment 1: Mean percentage (and standard errors) of total spelling responses of good and poor speller groups in the orthographic learning task that were correct (matching the target) versus matching the foil, as a function of exposure (target vs. foil).

Attack test of phonological coding, Word Identification, and Comprehension are shown in Table 2.

Orthographic learning was assessed via the number correct on the dictation test in the target exposure condition (i.e., for consistently spelled items). Bivariate correlations among orthographic learning and the five reading and spelling measures were positive and at least moderately high, as shown in Table 3. Spelling production and orthographic choice had only a moderately high correlation despite the fact that the items for the latter test consisted of 51 of the 70 words from the spelling production test. Nevertheless, there was strong concordance in item-by-item accuracy for the words common to the two tasks; $r(51) = .87, p < .001$, for the item-based correlation between tasks. To assess the contribution of the reading measures to orthographic learning we conducted a simultaneous regression of orthographic learning on phonological coding, word identification, and passage comprehension. The regression equation accounted for 59% of the variance in orthographic learning, $R^2 = .77, F(3, 58) = 28.11, p < .001$, with word identification the only significant predictor, $\beta = .62, t(58) = 3.33, p = .002$.

The predictive utility of the orthographic learning score and orthographic choice as predictors of word identification was assessed in hierarchical multiple regression analyses with phonological coding controlled by entry at the first step. Both orthographic predictors were significant in the full equation, for orthographic choice $\beta = .18$, $t(58) = 2.32$, $p = .03$, and for

Table 2
Experiment 1: Standard Scores Against Age Norms (M = 100, SD = 15) on the Woodcock Word Identification, Phonological Coding, and Passage Comprehension Tests for the Total Sample and Good and Poor Spellers

Group	Word identification	Phonological coding	Comprehension
Total sample	97	97	100
Good spellers	108	106	112
Poor spellers	91	89	95

Table 3
Experiment 1: Matrix of Correlations for Number of Pseudowords (PW) Correctly Spelled in the Target Exposure Condition and the Measures of Individual Skills

Test	2	3	4	5	6
1. PW dictation	.62**	.76**	.80**	.65**	.64**
2. Word attack	—	.83**	.67**	.47**	.56**
3. Word identification		—	.81**	.63**	.75**
4. Spelling production			—	.62**	.74**
5. Spelling recognition				—	.52**
6. Comprehension					—

** $p < .001$.

orthographic learning, $\beta = .30$, $t(58) = 3.52$, $p = .001$. Most importantly, the increment in variance was .04 for orthographic learning and only .02 for orthographic choice, indicating that orthographic learning was the superior predictor of word identification. The contributions to word identification in hierarchical regression analyses without phonological coding were 3% for orthographic choice and 22% for orthographic learning.

Discussion

Orthographic learning: Effects of a misspelling exposure on dictation. There was a marked superiority of the consistent over the inconsistent exposure condition, which presumably reflects the combined effects of learning for the consistently trained items and interference for inconsistently trained items. An effect of an exposure to a misspelling was supported by the increased probability of matches between the foil and a child's spelling in the foil compared with the target exposure conditions. The greater susceptibility of good spellers to foil exposures is consistent with the abstractionist account. However, a full assessment of the effects of learning and interference on spelling accuracy requires an additional baseline condition in which there is no reading exposure. This was the purpose of Experiment 2, which was conducted with adults. The results for the exposure manipulation are discussed for the two experiments together in the General Discussion.

Correlates of orthographic learning. The Grade 5 children varied markedly in their ability to learn pseudowords after brief training, but good spellers had a high success rate (78%) in learning the orthography of twice-presented (i.e., consistently trained) items. Learning may have been supported by the presentation of distinctive meanings for the items (but see Nation, Angell, & Castles, 2007), ensuring that children gave an appropriate pronunciation of the items on the two exposures. It is likely also that good spellers have a substantial amount of knowledge about typical English spelling and pronunciation patterns which supported their learning. Consistent with this possibility, the highest rate of null spellings in good spellers was observed for the orthographically atypical item *bevrel*, and the lowest rate was found for *muttled* and *stoiker*. The mean accuracy in the present sample of 47% is notably less than the spelling accuracy of nearly 70% achieved by Grade 5 children in an orthographic training study (Bailey et al., 2004). There were more training trials (six) in the Bailey et al. study, and their items were monosyllables.

The reading and spelling measures had moderate to strong positive associations with orthographic learning, in line with previous findings (Cunningham, Perry, Stanovich, & Share, 2002). The association between phonological coding and orthographic learning supports the results of a training study by Kyte and Johnson (2006) and is consistent with the self teaching hypothesis (Share, 1995). Only word identification was a significant predictor in multiple regression analysis on the standard tests of reading, reflecting the high correlation of word identification with the other predictors and the learning score. The importance of individual phonological skills may have been underestimated because we provided the phonology of the pseudowords. Recent findings suggest that providing item phonology produces a benefit similar to that produced by having learners engage in a phonological encoding task during training (Chalmers & Burt, 2008).

Consistent with the importance of orthographic learning for reading and writing, and in line with previous research, the orthographic learning score was strongly associated with the word identification and spelling production tests. The association of learning with orthographic choice validates the use of the commonly used orthographic choice test as a measure of orthographic processing skill, but the correlation between orthographic learning and orthographic choice was far from perfect (r = .65). Thus orthographic choice tests with known words are not necessarily a good indicator of a child's ability to acquire new orthographic representations. More than 20% of the total variance in word identification was shared with orthographic learning when orthographic choice was partialed out, indicating a utility of the learning measure that is remarkable given that it was assessed for only eight items.

Experiment 2

The purpose of Experiment 2 was twofold. First, the experiment was designed to replicate the effects of reading a misspelling on newly learned pseudowords and extend the findings to an adult sample. There is good reason to suppose that the use of episodic retrieval cues is similar in 10-year-old children and adults (Ceci & Howe, 1978). However, it was important to show that the children's difficulty in isolating the relevant encounter with the item reflects the organisation of lexical knowledge rather than difficulty experienced by children with episodic retrieval strategies. The second aim was to assess the misspelling exposure effect with an important no-exposure baseline condition to allow separate assessments of the effects of target and foil exposure.

University students were trained and tested on a largely new (more difficult) item set in conditions similar to those of Experiment 1. They were also tested on spelling ability in a dictation test and on a phonological choice test of phonological coding skill. The phonological coding test and a lexical-decision task for another experiment were interpolated between the orthographic training and test phases to make the training-to-test interval comparable with that used in Experiment 1.

The university students were expected to show a smaller range of performance in orthographic learning and the other tests and smaller correlations than the children among phonological coding, spelling, and orthographic learning. Otherwise the results were expected to be similar to those of Experiment 1. In particular, not only spelling but also phonological coding skill was expected to be associated with orthographic learning, as predicted by the self teaching hypothesis (Share, 1995). With respect to the effects of the exposure manipulations on orthographic learning, it was assumed that adults and Grade 5 children would have a similar ability to use memory retrieval strategies (Ceci & Howe, 1978). Thus the university students were expected to show a comparable susceptibility to the influence of the misspelled foil. In other words, as in Experiment 1, the exposure to a misspelled foil was expected to increase misspellings that matched the foil, especially among good spellers.

Of particular interest in Experiment 2 was the information provided by the no-exposure condition. First, comparison with the target exposure condition provided an estimate of the learning produced by the second reading of the items, while comparison with the foil exposure condition provided a well-controlled assessment of the effect of the foil. In addition, the no-exposure condition allowed us to ask whether the increase in foil spellings was accompanied by a decrease in the probability of the correct spelling. To address this issue we attempted to make the items of Experiment 2 sufficiently difficult to produce a rate of null spellings that was sizable and similar to the rate of Experiment 1. In this situation the effect of a foil exposure may be exhibited largely as a reduction in the proportion of correct responses, largely as a reduction in the proportion of null responses, or a mix of these effects.

Thus the results for the no-exposure condition should provide some evidence concerning which items were most vulnerable to the influence of foils. Specifically, a similar probability of correct spellings in the foil and no-exposure conditions would suggest an effect of foils on null spellings, that is, on items learned inaccurately and perhaps with little confidence, whereas a lower probability correct in the foil than the no-exposure condition would suggest that correctly learned items were affected by the foils. Larger effects of foils on poorly learned items (null spellings) is most consistent with an abstractionist theory in which a single representation is updated on each exposure to a word, because items whose learning is well below asymptote have a greater capacity for new learning (Plaut et al., 1996). By contrast, the instance-based approach would most readily accommodate a lack of association between the quality of prior learning and the effect of a foil exposure. The reason is that the probability of a foil spelling is affected by episodic factors affecting the probability of contacting the record of the foil spelling, or the amount of its activation, and not by the accuracy of the first record of the item.

Method

Participants. Thirty-nine introductory psychology students from the University of Queensland participated for course credit. There were 10 males and 29 females, and the mean age was 19 years and 7 months (range 17–36 years). Good and poor speller groups were selected such that they were equally distributed over counterbalancing sets. There were 12 participants in each group, with good spellers exceeding the mean on the spelling test by at least .5 *SD*s and all but one of the poor spellers falling below the mean by at least .5 *SD*s.

Materials and design. An assessment of spelling ability was obtained by administering 34 words of the dictation test of the Wide Range Achievement Test (Snelbaker, Wilkinson, Robertson,

& Glutting, 2001), excluding simple monosyllabic words, and the 20 words of the level 2B category of the Experimental Spelling Test (Fischer, Shankweiler, & Liberman, 1985). The word sets were randomly intermixed, and computer sound recordings and brief definitions were produced for each item.

Phonological coding was assessed by a phonological choice test, in which participants were required to decide which of a pair of visually displayed nonwords is pronounced like an English word (e.g., *thord* vs. *thurd*). There were 40 nonword pairs. Items were four to six letters long (mean 4.8) and had one or two syllables.

For pseudoword learning, 21 new orthographically legal letter strings were devised as described in Experiment 1. Six items derived from the set of Experiment 1 were added to make a total of 27 (see Appendix). The complete set ranged in length from six to 11 letters (mean 8.3), and they had from one to four syllables. An additional item was used for practice on the first training trial. Alternative spellings, definitions, and sentences were devised as in Experiment 1; for example, *lomestary: lomistary; a vagabond or wanderer; The life of a lomestary in rural Australia has become more difficult with drought and financial hardship*. A computer recording of each pseudoword pronunciation was made by the first author.

Exposure (original vs. alternative spelling vs. no exposure) was varied within-participants, with 13 participants allocated to each of three lists counterbalanced and prepared as in Experiment 1.

Procedure

Participants were tested individually on a computer with tasks controlled by Eprime (Schneider, Eschman, & Zuccolutto, 2002). The training phase was followed by the phonological choice test, and after intervening 132-trial lexical-decision task for an unrelated experiment, students completed the exposure phase, a brief distractor activity and then the dictation test of the pseudowords followed by the words of the spelling ability test. All letter strings were displayed in 18- or 20-point courier font.

Before the training phase participants were instructed that they were to learn some made up words and their meanings. Throughout training the screen was bright blue, and with the exception of the pseudoword, which was yellow, text was displayed in white letters. Each trial began with a ready signal (+++) for 350 ms, and then the pronunciation was presented during a 1500-ms interval. Next the pseudoword was displayed in the centre of the screen in yellow letters and participants named it aloud. The display was terminated by the vocal response, and after a 250-ms pause, the pseudoword reappeared for 1500 ms with its definition displayed below, and participants were given 2000 ms during which the screen was blank to think about the item and its meaning. The definition reappeared for 1000 ms without the pseudoword, and then the definition reappeared with the yellow pseudoword below it and a black filled rectangle at the bottom of the screen. Participants typed in the pseudoword, which appeared in yellow inside the black box. There was a 2000-ms pause before the next trial. The first trial was a practice trial with an additional pseudoword.

During the phonological choice test the screen was black and lettering was white. On each trial a ready signal (+++) was displayed for 500 ms and then the two nonwords were displayed side by side in the centre of the screen. Participants rested their index fingers on the two buttons of a response box and pressed the right or left button to indicate which nonword was homophonic with an English word. There were four practice trials at the beginning of the list. The correct response occurred equally often on the left and right. Participants were instructed to respond as quickly and accurately as possible.

After completing the intervening (unrelated) lexical-decision task, participants completed the exposure phase with a black screen and white lettering. They read an intermixed sequence of nine sentences containing a pseudoword target and nine containing the misspelled foil. They were instructed that some of the letter strings might be the same as or similar to the items they had studied previously. On each trial after a 500-ms ready signal (++) the sentence was displayed in the centre of the screen and participants were asked to read it silently and think about its meaning. They pressed a button on the response box when they had finished, and the pseudoword or foil from the preceding sentence was displayed for naming in the centre of the screen underneath the prompt “Read aloud:”. The display was terminated by the microphone response, which initiated a 2000-ms interval before the next trial.

After the last sentence a white screen appeared and participants were instructed in black letters to type in at least six words that can be made from the word *conversation* and to terminate their list by pressing the ENTER key. The purpose was to ensure that the final trials of the exposure phase were displaced from working memory.

The final dictation test of pseudoword learning was conducted with black lettering on a white screen. Participants were instructed that they should type in the pseudowords as they were spelled in the first phase, which was described to them. On each trial a ready signal was displayed as before, the definition of the pseudoword was presented in the centre of the screen for 800 ms, and then while the definition remained in review the pronunciation of the item was played during a 1500-ms interval. Participants then typed their response, using the backspace key to make corrections. After terminating their response with the ENTER key they were prompted to press the space bar for the next trial. After the pseudoword dictation block was completed, participants proceeded similarly through two blocks of dictation with the words from the spelling ability tests and their brief definitions. Each block was separated by a brief rest break. Participants were then debriefed about the purpose of the experiment.

Results

Orthographic learning and misspelling exposure. Naming latencies recorded during the exposure phase were examined in case participants showed any disruption on misspelled foils. Latencies more than 3500 ms were removed, and from the remaining data, latencies in excess of three standard deviations from each participant’s mean were discarded. A total of 1.4% of trials were removed. The mean naming latency was 847 ms, with latencies for misspellings nonsignificantly faster for foils than targets (Fs $<$ 1.3).

For the dictation test of orthographic learning, responses were scored as correct, foil, or null, as previously described (see Table 4). The percent correct in the no-exposure condition did not vary over counterbalance sets ($F1 < 1$), but there were some differences among sets in the percent correct for the correct exposure condition, $F1(1, 36) = 3.97$, $p = .028$. Counterbalance set

Table 4
Experiment 2: Mean Percent Target, Foil, and Other ("Null") Spellings by Adults for Trained Pseudowords as a Function of Exposure Condition in the Second Phase of the Orthographic Learning Task

	Spelling produced on dictation test		
Exposure	Target	Foil	Null
Target (correct)	46 (19.28)	7 (7.08)	47 (20.70)
Foil (alternative)	25 (13.95)	31 (17.19)	44 (19.74)
None	29 (16.62)	10 (10.13)	61 (19.22)

Note. Standard deviations are shown in parentheses.

was included as a factor in the ANOVAs. The percentages of correct and foil spellings were analysed in Response type (correct vs. foil misspelling) × Exposure condition (target vs. misspelled foil vs. no exposure) × Counterbalance set mixed design ANOVAs by participants (*F1*) and items (*F*2), with counterbalance set the only between-participants factor. Replicating Experiment 1, there was a preponderance of correct, target responses over foil misspellings, reflected in a main effect of response type, $F1(1, 36) = 78.09$, $MSE = 236$, $p < .001$; $F2(1, 24) = 15.00$, $MSE = 851$, $p = .001$. There was a smaller percentage of correct plus foil spellings (& hence a larger percentage of null spellings) in the no-exposure condition than the other conditions, resulting in a main effect of exposure, $F1(2, 72) = 22.23$, $MSE = 68$; $F2(2, 48) = 12.79$, $MSE = 113$, *p*s < .001. A follow-up comparison by participants revealed that as in Experiment 1, there was no difference in null spellings between the target and foil exposure conditions, $F1(1, 38) = 1.70$, $p = .20$.

As in Experiment 1, target exposure increased target spellings and foil exposure increased foil spellings, resulting in a significant Response type × Exposure interaction, $F1(2, 72) = 42.15$, $MSE = 245$; $F2(2, 48) = 22.02$, $MSE = 113$, *p*s < .001. Analyses of the simple effects of exposure condition within each response category confirmed an effect of exposure on the percentage of correct responses, $F1(2, 76) = 25.07$; $F2(2, 52) = 13.36$, *p*s < .001, and foil responses, $F1(2, 76) = 45.09$; $F2(2, 52) = 31.06$, *p*s < .001. Follow-up comparisons against the no-exposure baseline condition showed that more correct responses were made after a second exposure of the target, $F1(1, 38) = 38.23$; $F2(1, 26) = 19.12$, *p*s < .001, and more foil responses were made after an exposure to the foil, $F1(1, 38) = 41.09$; $F2(1, 26) = 44.38$, *ps* < .001. The main effect of counterbalance set was not significant. The interaction of counterbalance set with exposure was significant by participants and marginally so by items, $F1(4, 72) = 10.43$, $MSE = 236$, $p < .001$; $F2(4, 48) = 2.56$, $MSE = 289$, $p = .072$, largely reflecting a greater reduction in null spellings by a second target exposure for one of the counterbalance sets compared with the other two. As in Experiment 1, the number of correct spellings that students produced in the target exposure condition was positively correlated with the number of their foil spellings in the foil exposure condition, $r(39) = .60$, $p < .001$.

The data of good and poor spellers groups are shown in Figure 2. Speller group × Response type × Exposure × Counterbalance set ANOVAs on the percentage of correct and foil spellings replicated the effects found for the total sample. In addition, there was a main effect of spelling ability, reflecting more correct plus foil responses (i.e., fewer null responses) by good than poor spellers, $F1(1, 18) = 17.26$, $p = .001$; $F2(1, 24) = 19.67$, $p = .006$.

To allow comparison of the results with those of Experiment 1, we compared good and poor spellers on the percentage of target spellings in the target exposure condition and the percentage of foil responses in the foil exposure condition. Good spellers were more accurate than poor spellers in the target exposure condition, $F1(1, 22) = 11.06$, $p = .003$; $F2(1, 26) = 7.97$, $p = .009$, and more likely to produce a foil spelling than poor spellers in the foil exposure condition, $F1(1, 22) = 9.36$, $p = .006$, $F2(1, 26) = 9.35$, $p = .005$. Figure 2 shows that although good spellers were more likely to produce the correct (target) spelling, relative to poor spellers they showed a markedly greater increase in foil spellings in the foil exposure condition, resulting in a Speller group × Response type × Exposure interaction, $F1(2, 36) = 3.52$, $p = .040$; $F2(2, 48) = 4.25$, $p = .02$. The interaction was decomposed by examining the Speller group × Exposure interactions for each response type. For correct responses the Speller group × Exposure interaction was not significant, *F*s < 1.5. By contrast, the Speller group × Exposure interaction was significant for foil responses, $F1(2, 36) = 7.08$, $p = .003$; $F2(2, 48)$, $= 6.05$, $p = .005$, reflecting a larger effect of exposure on the probability of foil responses in good than poor spellers. Analyses of the exposure effect on foil responses within each speller group showed a significant increment attributable to foil exposure for both good spellers, $F1(2, 18) = 31.99$, $p < .001$; $F2(2, 48) = 30.12$, $p < .001$, and poor spellers, $F1(2, 18) = 22.46$, $p < .001$, $F2(2, 48) = 8.06$, $p = .002$.

In relation to the locus of the effect of foil exposure, the data for the total sample and the speller groups indicated that relative to the no-exposure condition, the increase in foil responses produced by foil exposure did not come at the cost of a substantial decrement in the probability of a correct response (see Table 4 & Figure 2). A comparison of correct response percentages in the foil and no-exposure conditions in the total sample confirmed that there was no significant difference, $F1(1, 38) = 1.69$, $p = .201$; $F2(1, 24) = 1.03$, $p = .319$.

Individual differences. On the Fischer, Shankweiler, & Liberman (1985) level 2b and WRAT-3 spelling items the mean

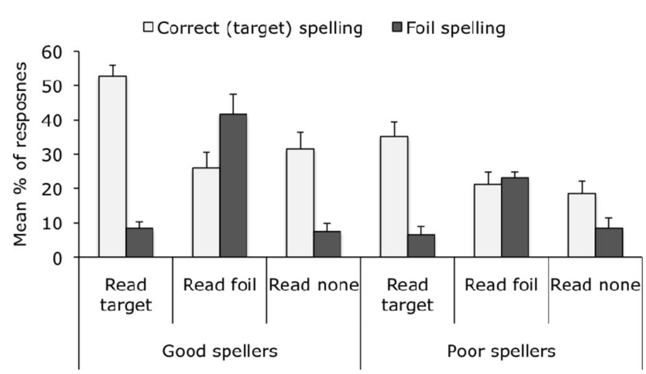

Figure 2. Experiment 2: Mean percentage (and standard errors) of total spelling responses of good and poor speller groups that were correct (matching the target) versus matching the foil, as a function of exposure (target vs. foil vs. none).

percent correct was 68% (SD = 11.64). The mean accuracy on the phonological choice test was 83% (SD = 6.53), and after removal of latencies longer than 5000 ms, the mean correct response latency was 720 ms (SD = 177.30). Phonological choice accuracy and latency were significantly correlated with the standard test of spelling ability, $r(39) = .42$, $p = .008$; and $r(39) = -.53$, $p = .001$, respectively. In addition, spelling ability and phonological choice accuracy (but not latency) predicted the percent correct in the dictation test of orthographic learning in the target exposure condition, $r = .36$. $p = .023$; and $r = .38$, $p = .017$, respectively.

Discussion

The largely new item set proved to be as difficult for adults as were the Experiment 1 items for children, with the percentage of null spellings in the pooled target and foil exposure conditions being 46% in Experiment 2 and 47% in Experiment 1. Consequently, the experiments provided approximately the same opportunities for spellings to be shifted by target and foil exposure during the sentence reading phase. There were some differences in the magnitude of effects over counterbalance sets, but only for the effect of a target exposure in the whole sample, and there were no differences in the direction of effects over sets. The results were clear-cut: overall the data pattern for the target and foil exposure conditions mirrored that observed with children. In the university students a reading of a misspelled foil substantially increased its probability as a response in the dictation test of newly learned pseudowords. As was observed with 10-year-old children, the foil exposure effect was larger in good than poor spellers. This result suggests, in line with the abstractionist view, that good spellers incorporate the misspelling into the memory representation formed during training, and that this updating process normally supports the formation of orthographic representations of consistently spelled unfamiliar words encountered during reading. Good spellers did not show the superior contextual separation of the target and foil spellings that might be expected on an instance-based account of orthographic representations.

The only notable difference between the experiments was that, as expected, the differences in spelling performance between good and poor spellers appeared to be more marked in the child sample than in the university student sample. This effect was mainly evident in the probability of correct responses and was confirmed in an Experiment × Speller ability × Exposure ANOVA by participants on correct responses, which revealed a significant Experiment × Ability interaction, $F1(1, 60) = 16.31$, $p < .001$. In addition, there was a significant three-way interaction, $F1(1, 60) = 6.87$, $p = .011$, reflecting a larger effect of exposure on good spellers in Experiment 1 than 2 and a smaller effect of exposure on poor spellers in Experiment 1 than 2.

Significant new information was provided by the no-exposure condition of Experiment 2. First, a second exposure to the pseudoword target in the reading phase produced a substantial increment in correct spellings. Given the similarity of the results for the two experiments, this result suggests that the difference between exposure conditions in Experiment 1 partly reflected a learning benefit for targets. Second, relative to the no exposure condition, exposure to a foil substantially increased the probability of misspellings that matched the foil. This outcome supports the conclusion drawn in Experiment 1 about the effect of foil exposure.

Finally, the probability of a correct response (target spelling) was similar in the foil- and no-exposure conditions. It appears that participants offered foil spellings for items that otherwise would have been null spellings, whereas items that participants could spell correctly at the end of training were less vulnerable to the misspelling exposure. Thus, in line with the prediction of the abstractionist account, the locus of the effect of exposure to the foils primarily is on the spellings of items that were most poorly learned at the end of training. An effect primarily on items that are less well learned is consistent with the very modest effect of exposure to misspellings reported in previous studies with words (e.g., Jacoby & Hollingshead, 1990). Indeed, in the present experiment, a comparison of the percent correct in no-exposure and foil exposure conditions would indicate no effect of reading the foil on the subsequent dictation test. This inference is contradicted by the large effect of foil exposure on the probability that misspellings matched the foil.

As expected, the associations among spelling ability, phonological choice, and orthographic learning were of moderate size and positive, and the pattern was consistent with the results of Experiment 1. These results are discussed briefly in the general discussion.

General Discussion

Language and litreacy skills and orthographic learning. In Grade 5 children and university students, spelling production and phonological coding skill were associated with orthographic learning as assessed by dictation. Consistent with the self-teaching hypothesis (Share, 1995), phonological coding skill was associated with both preexisting spelling knowledge and new orthographic learning. As suggested previously, it is possible that the correlation between phonological coding and orthographic learning was attenuated by our presentation of item phonology during training, which has been shown to reduce the importance of phonological encoding at study, presumably also reducing the importance of individual differences in phonological encoding skill (Chalmers & Burt, 2008). In Experiment 1 the three standard tests of reading, word identification, phonological coding, and comprehension, had significant associations with orthographic learning, but only word identification was a significant predictor in a simultaneous regression analysis.

In Experiment 1 orthographic learning had a moderately strong association with the orthographic choice test of spelling recognition. It was proposed that a test of orthographic learning of novel stimuli is a superior to tests of prior learning such as orthographic choice as an indicator of orthographic processing skill. This hypothesis was supported by the finding that orthographic learning was a better predictor of word identification than orthographic choice, even when phonological coding was controlled.

Effects of reading an alternative spelling and the role of spelling ability. In both experiments exposure to the misspelled foil increased the probability that misspellings in the dictation test matched the foil, providing clear evidence of the effect of the reading exposure. In the absence of a no-exposure baseline in Experiment 1, it might be argued that the result reflects a high probability of the foil spelling after only one learning trial. This explanation is unlikely, given (a) the much lower probability of the foil spelling after a single additional reading exposure to the correct spelling, and (b) the high preponderance of null spellings, with 66% and 63% of the spellings of the child and adult poor spellers, respectively matching neither of the presented spellings of an item. Furthermore, Experiment 2 closely replicated Experiment 1 in an adult sample and showed that relative to a no-exposure baseline, reading exposures of both the correct spelling and the foil spelling had an effect on the spellings offered in the dictation test. Therefore it is concluded that in both experiments the exposure manipulation had the expected effect. The similarity of the results with children and adults suggests a continuity in orthographic learning and memory in the adult and child groups, supporting arguments for adult-like memory function by the age of 10 years (Ceci & Howe, 1978).

In line with the common view that a single store of word orthographies serves visual word identification and spelling (Burt & Tate, 2002; Holmes & Carruthers, 1998), reading a misspelling affected the spellings given in a subsequent spelling test. Although the misspelling exposure effect appears to be well established in the existing litreature, Jacoby and Hollingshead (1990) noted that in most studies exposure to a misspelling has involved a spelling attempt rather than reading alone. Also, typically spelling accuracy has been assessed without regard to whether a participant's misspelling corresponded to the exposed misspelling. The present experiments confirmed the findings of Dixon and Kaminska that reading a misspelling increases the probability of spelling responses that match the misspelling that was seen. The misspelling exposure effect observed here was substantially larger than in studies with familiar words, presumably because of the fragility of new learning and the recency of the reading exposure.

Notably, we found support for a prediction that was not supported in the Dixon and Kaminska study. Specifically, the authors hypothesised that the errors of good spellers would be more likely to match the exposed error than the errors of poor spellers. In the present experiments involving children and skilled adult readers, with prior experience with the items equated for good and poor spellers, exposure to a misspelling produced a larger increase in good than poor spellers in the percentage of dictation responses that matched the exposed misspelling. In addition, on consistently trained items, good spellers were more accurate than poor spellers in both experiments. These results are consistent with claims that good readers and spellers process orthography fully during reading, whereas poor readers and spellers are more likely to use a "partial cue strategy" for word decoding (Burt, 2006; Frith, 1980; Holmes & Ng, 1993). As discussed below, the differential effect of foil exposure on good spellers is most consistent with the abstractionist theory.

Examination of the item data for the two experiments suggests that items with moderate to high spelling predictability, that is, few plausible spellings, were more likely to show an increase in foil matches than were more orthographically unusual items. It is likely that the relative typicality of the foil and correct spellings also played a role. For example, in the foil exposure conditions, good child spellers produced most foil spellings for *stanchible* (foil *stanchable*) and good adult spellers produced most foil spellings for *fambel* (foil *famble*) and *tranuce* (foil *tranoose*). The greater typicality of the foil spellings *stanchable* and *famble* would favour these spellings.

A critical finding of Experiment 2 was that relative to the no-exposure baseline, foil exposure substantially decreased the percentage of null spellings but did not significantly affect the proportion of correct responses. As predicted from the abstractionist account, it appears that foils were offered mainly for items that were not adequately learned. The implications of this finding for the nature of orthographic representations are discussed in more detail below.

Orthographic representations: Abstractionist and instance-based accounts. As discussed earlier, reading researchers typically assume a single, acontextual, orthographic representation for each word that is updated during reading (Forster, 1994). On this view a detrimental effect of an exposure to a misspelling of a word indicates that the word's orthographic representation has been updated by the misspelling, with the consequence of rendering the representation more like the misspelling or more ambiguous. An additional exposure to the correct spelling increases the accuracy and accessibility of the single representation. Thus a strong differentiation of the effects of foil and target spelling exposures was expected on the abstractionist view.

On alternative, instance-based theories of word processing (Goldinger, 1998; Jacoby & Hollingshead, 1990; Kwantes & Mewhort, 1999), an exposure to a misspelling establishes a separate record in which the spelling is incorrect. The incorrect representation may be accessed separately in a future spelling test (single-retrieval accounts), or it may be highly activated in a set of retrieved records (multiple-trace models). This outcome can be expected if participants were unable to use episodic cues to ensure preferential activation of the spelling that was demanded at test. The probability of access of a prior record, or the strength of its activation, is assumed to depend upon factors such as recency (Mulhall, 1915) and contextual matches at study and test. In the target exposure condition a second record of the correct spelling is created which may increase the probability of the correct spelling, either through effects on the probability of access of a correct record, or on the activation of the correct spelling in the retrieved records.

On instance-based accounts the effective use of episodic cues should produce similarly high accuracy over no-exposure and target exposure conditions, with perhaps a modest increase in foil spellings in the foil exposure condition as a result of occasional retrieval of the foil spelling (single-retrieval theories) or partial activation of the foil spelling (multiple-trace theories). By contrast, ineffective use of episodic cues (together with recency) can be expected to produce the exposure effects actually observed and predicted from the abstractionist account.

Although the present pattern of results can be reconciled with episodic approaches if it is assumed that episodic cues were ineffective, detailed examination of the results in the present experiments indicates some problems for instance-based accounts. First, within the multiple-trace account, which arguably is the most influential and plausible episodic account of lexical representations, it is not obvious in the foil exposure condition that the combined activation of the target and foil would produce a substantial increment in foil spellings rather than increasing null spellings.

Second, as noted, the greater vulnerability to foil exposure effects of items spelled incorrectly in the no-exposure condition indicates that exposure effects are greater for poorly learned than well-learned items. Additionally, with respect to target exposures, inspection of item means for Experiment 2 revealed that the benefit in dictation depended on the amount of item learning achieved during training. Specially, the three items that had zero accuracy in the no-exposure condition benefited substantially from target reading-exposure (by 31 to 62 percentage points), whereas the five easiest items (most accurately spelled in the no-exposure condition) had small target exposure benefits ranging from −8 to 15 percentage points. This latter result is unlikely to reflect ceiling compression, given that the accuracy in the no-exposure condition was only 54% for three of the five items. These results suggest, beyond the scope of instance-based accounts, that for moderately difficult items the second encoding of an item is more likely to be accurate than the first, and thus each encoding is not independent or prior encodings.

A final and related point is that the results are not entirely consistent with the most obvious explanation of the misspelling exposure effect by instance-based theories, namely, that the effect reflects a lack of strong episodic information differentiating the alternative spellings. Specifically, the data for the foil exposure condition do not suggest that participants encoded target and foil spellings and produced the foil because they forgot (or did not encode) which context was associated with which spelling. Critically, a failure of episodic memory is a viable explanation of the effect of foil exposure only if participants normally formed accurate records of the foil and the target spellings. The present studies clearly show that for many participants an individual record is unlikely to be an accurate record of a letter string. There was a large proportion of null spellings by adults in Experiment 2 and for the average and below-average child spellers of Experiment 1. Furthermore, because more poorly learned items appear to be most vulnerable to the effect of a misspelling exposure, a simple failure of contextual memory is an unlikely cause of the misspelling exposure effect.

An alternative possibility is that episodically targeted retrieval failed because the to-be-retrieved item itself was inadequately encoded. Consistent with this possibility, participants have difficulty using episodic information to discriminate among prior occurrences of highly unfamiliar words in an episodic recognition test (Chalmers & Humphreys, 1998). However, the present good spellers should have been in the best position to use contextual information to select the target spelling. The fact that they were not very successful in this task is not encouraging for episodic approaches, particularly those relying on the idea of retrieval of a single record (Jacoby & Hollingshead, 1990). Within multiple-trace models (Reichle & Perfetti, 2003), the similarity of the concurrently activated alternative spellings might serve as a basis for explaining the failure of episodic differentiation even in good spellers.

It is clear that if an instance-based theory is to provide a successful account of lexical processing it must be modified to account for the fact that the complete orthography is unlikely to be stored on a single encounter with a letter string. The idea that items are imperfectly coded may be easier to accommodate within multiple-trace episodic theories because the combined activation of multiple and imperfectly accurate traces can be expected to produce a more coherent and perhaps more accurate representation of orthography. However, other problems arise if incorrect encodings are assumed to be common within a multiple-trace model. For example, difficult words would have a large number of incorrect encodings so that increases in the number of learning trials would not necessarily benefit difficult words more than easy words.

In sum, orthographic training is somewhat beyond the scope of instance-based approaches. In particular, it would be advisable to incorporate mechanisms by which prior encounters with letter-strings enhance readers' ability to encode orthographically accurate records of encounters with them. Perhaps retrieval of past encounters with the item and similar letter strings at the time of encoding could influence encoding. In addition it would be useful to incorporate effects of regularities in sublexical letter sequences (e.g., that *famble* is more typical than *fambel*) into an instance-based approach. Within developmental abstractionist approaches these regularities directly participate in the learning process (Plaut et al., 1996) or may be applied as a separate set of sound-spelling rules (Houghton & Zorzi, 2003).

In a number of respects the present results fit naturally with abstractionist theories of word representations. Notably, the marked susceptibility of participants to foil exposures, and the higher susceptibility of good spellers to them, are most consistent with a view that updating of a single abstract orthographic representation for each item was the controlling factor in performance on the dictation test. Also, the reading exposure to the correct spelling in Experiment 2 produced an increment in spelling accuracy (relative to no exposure) in almost all items. Additionally, the inference that, relative to no-exposure baseline, the effect of an exposure to the foil in Experiment 2 was mainly evident for poorly learned items, also has a natural interpretation in terms of updating of a single abstract orthographic representation for each word. The simplest assumption of an abstractionist theory is that a representation is more or less automatically updated by a misspelling, provided that the misspelled word is recognised (cf. Wheeldon & Monsell, 1992). As implemented in connectionist models of word identification (Plaut et al., 1996), the learning produced by a single learning trial is a function of the discrepancy between what is to be learned and what has already been learned.

However, the abstractionist theory is limited in terms of accounting for the influence of episodic information in lexical tasks. In the present experiments it is likely that participants also made some use of episodic information to discriminate target and foil spellings. For example, given that good spellers reproduced many target and foils spellings successfully, they may have remembered both spellings occasionally and used episodic information to decide which was correct. Also, encoding and rehearsal strategies during the exposure phase may have affected the dictation test. For example, perhaps when participants recognised that the spelling of the foil was different from what was learned they made an effort to rehearse the original spelling and encode the new one as changed. However, if they were unable to recall the original spelling, or failed to notice the spelling change, they may have been inclined to accept the new spelling as the original spelling, particularly if it was a typical representation of the item's phonology. It is clear that learning encounters produce episodic effects whose interplay with lexical representations has not been addressed by the abstractionist approach.

A second issue that abstractionist accounts must address is the concurrent availability in memory of two spellings of a word, for example that *occassionally* is a common student misspelling of *occasionally,* and that *artifact* and *artefact* are alternative acceptable spellings. It is unclear whether these should be considered as separate representations of an item. Third, episodic information about encounters with relatively familiar words may sometimes play a role in spelling; for example, in acquiring the variations in spelling for British and American English, and learning the correct form of orthographically related words (e.g., *principle* vs. *principal*; *dependent* vs. *dependant*). Consequently, although the present results are more consistent with the abstractionist than the instance-based theories, neither approach provides a comprehensive account of what is known about orthographic representations.

Conclusion

The present experiments extend recent research on orthographic learning by examining the effects of training inconsistency, examining the learning of multisyllabic items, and confirming the relationships between spelling skills, phonological coding skills, and orthographic learning. The findings were most easily accommodated within the abstractionist view that reading words updates a single representation of a word that serve both reading and spelling. However, abstractionist accounts have yet to directly address the role of episodic memory in orthographic learning, whereas episodic theories have not addressed learning over encounters in the encoding of item-specific orthography. Exposing readers to word misspellings has the potential to provide valuable information for theory development on the interplay between episodic and acontextual information in word learning and in learning more generally.

Résumé

Dans l'Expérience 1, 62 enfants âgés de 10 ans ont étudié des pseudo-mots imprimés avec des informations sémantiques. Les items ont été présentés à nouveau ultérieurement dans un format de lecture différent, avec la moitié des items épelés de la même façon qu'auparavant et la moitié épelés d'une nouvelle façon, phonologiquement équivalente. Dans un test de dictée, l'exposition à une épellation alternative a fait augmenter le nombre d'erreurs de façon importante, en association avec l'épellation alternative, particulièrement chez les participants qui étaient bons en orthographe. L'apprentissage orthographique prédisait l'identification des mots lorsque la précision des choix orthographiques était contrôlée. Dans l'Expérience 2, les effets sur les réponses à la tâche de dictée de l'exposition à une épellation correcte vs incorrecte et l'effet interactif de l'habileté en orthographe ont été confirmés par rapport à un groupe contrôle d'adultes non exposés. Les résultats appuient une vision de la lecture et de l'épellation à simple lexique, et ont des répercussions sur les théories abstractionnistes et fondées sur l'exemple des représentations orthographiques.

Mots-clés : Apprentissage orthographique, épellation, représentations lexicales abstraites, épisodique, représentations par l'exemple

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Appendix

Pseudowords

Targets and Misspelled Foils for Experiments 1 and 2, With Response Percentages in the Foil Exposure Condition

Experiment 1				Experiment 2			
Target	%	Foil	%	Target	%	Foil	%
frellidip	16	frelidip	48	rhyphumbent	31	rhyphumbant	15
gleard	19	gleerd	48	reglessent	31	reglescent	23
imithore	26	imithoar	6	lomestary	23	lomistary	8
pladent	23	plaident	23	sootum	62	sootem	31
stanchible	6	stanchable	55	rickin	31	ricken	69
temorang	23	temerang	39	pladent	23	plaident	62
tranuce	6	tranoose	42	frusative	38	fruzative	23
vawdle	6	vordle	42	brertular	8	brurtular	31
bevrel	10	beverel	10	tranuce	15	tranoose	62
curtelage	6	kurtleage	10	loubix	46	loobix	0
dreakot	13	dreekot	48	improshany	23	improshony	15
glessence	32	glessanse	6	vawdle	15	vordle	31
laydette	16	laidette	23	lurpature	31	lirpature	8
muttled	48	mutled	29	derriator	8	derreator	15
stoiker	32	stoyker	39	mavardion	0	mavardian	31
woadale	23	wodale	52	dreakot	23	dreekot	46
				flomen	8	flomin	46
				recuscident	0	recussident	62
				dysplesive	23	dysplisive	0
				stevoneer	23	stevuneer	0
				mounce	85	mounse	15
				bectrilogy	62	bectrylogy	8
				frellidip	8	frelidip	15
				syllation	15	sillation	15
				temorang	15	temerang	77
				gleerdion	31	gleardion	31
				fambel	8	famble	92

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