

Orthography Influences the Perception and Production of Speech

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One intriguing question in language research concerns the extent to which orthographic information impacts on spoken word processing. Previous research has faced a number of methodological difficulties and has not reached a definitive conclusion. Our research addresses these difficulties by capitalizing on recent developments in the area of word learning. Participants were trained to criterion on a set of associations between novel pictures and novel spoken words. Spelling-sound consistent or spelling-sound inconsistent spellings were introduced on the 2nd day, and the influence of these spellings on speech processing was assessed on the 3rd day. Results showed significant orthographic effects on speech perception and speech production in a situation in which spelling-sound consistency was manipulated with perfect experimental control. Results are discussed in terms of a highly interactive language system in which there is a rapid and automatic flow of activation in both directions between orthographic and phonological representations.

Keywords: speech perception, speech production, orthography, word learning, literacy

It is often said that spoken language has primacy over written language. Before acquiring skills in reading and writing, most children have expertise in understanding and producing speech. Indeed, while humans are born with the propensity to use spoken language, reading is a learned form of expertise. It is not surprising, then, that language subsystems that support reading are often characterized as being dependent on those supporting spoken abilities (e.g., Pinker, 1997). In line with this characterization, there is a broad consensus that individuals' experience with the sounds of words (phonology) plays a powerful role in their learning to read (e.g., Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001) and in adult visual word processing (e.g., Rastle & Brysbaert, 2006).

The question that has received less attention is whether individuals' experience with the spellings of words (orthography) comes to influence their spoken abilities. Though inconsistent with the primacy model, an increasing body of literature suggests that speech perception may be shaped by information about the printed forms of words, and there is limited research suggesting that the same could be true of speech production. These data have raised the remarkable possibility that information about the printed forms of words is activated rapidly in spoken language tasks or that phonological representations themselves are altered as a consequence of literacy acquisition (Muneaux & Ziegler, 2004). However, research concerning orthographic influences on speech pro-

cessing has faced a number of substantial methodological difficulties, and as a result has not reached a definitive conclusion.

Orthographic Influences on Speech Perception

The question of whether orthography influences speech perception was addressed initially by Seidenberg and Tannenhaus (1979), who found that participants made faster rhyme judgments for pairs of words that shared their spellings (e.g., toast-roast) as opposed to pairs of words that did not (e.g., toast-ghost). Subsequent studies have corroborated these findings by demonstrating orthographic effects in phoneme monitoring (Dijkstra, Roelofs, & Fieus, 1995), phoneme counting (Treiman & Cassar, 1997), and phoneme deletion (Castles, Holmes, Neath, & Kinoshita, 2003). However, many investigators have argued that these kinds of tasks reflect metalinguistic knowledge, and so it is difficult to conclude that these studies implicate the automatic activation of orthography in speech perception (see Damian & Bowers, 2009b).

Other researchers have approached this issue using priming techniques that measure whether the recognition of an auditory target is speeded by the prior presentation of a phonologically similar prime that overlaps (e.g., message-mess) or does not overlap (e.g., definite-deaf) with the spelling of the target. Jakimik, Cole, and Rudnicky (1985) reported that shared orthography boosted these auditory priming effects, though this study has been criticized for failing to mitigate the possibility of strategic processing. Subsequent research has resulted in some studies showing clear orthographic effects (e.g., Chéreau, Gaskell, & Dumay, 2007) and others producing trends that fail to reach significance over items (e.g., Slowiaczek, Soltano, Wieting, & Bishop, 2003; Taft, Castles, Davis, Lazendic, & Nguyen-Hoan, 2008).

The most compelling evidence for orthographic effects on speech perception comes from studies showing slowed auditory recognition of feedback-inconsistent words (i.e., words that can be spelled in many different ways; e.g., Ziegler & Ferrand, 1998).

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However, while many studies using this approach have reported robust orthographic effects (e.g., Pattamadilok, Morais, Ventura, & Kolinsky, 2007; Ziegler, Ferrand, & Montant, 2004; Ziegler, Petrova, & Ferrand, 2008), others have reported trends that fail to reach significance over items (e.g., Perre & Ziegler, 2008; Ventura, Kolinsky, Pattamadilok, & Morais, 2008; Ventura, Morais, Pattamadilok, & Kolinsky, 2004), a situation that may result from the fact that this evidence is necessarily derived from a between-items comparison in which the introduction of confounding variables is always a risk. Further, while this result has been generalized to semantic categorization and gender decision (Peereman, Dufour, & Burt, 2009), it is unclear whether it holds for tasks that do not involve an explicit decision component. The few studies that have investigated orthographic effects in shadowing have reported null effects (e.g., Pattamadilok et al., 2007; Ventura et al., 2004; Ziegler et al., 2004), but some of these studies also failed to uncover the lexical effects that are often observed in this task (e.g., Tyler, Voice, & Moss, 2000).

Orthographic Influences on Speech Production

The issue of whether orthography influences speech production was investigated initially by Lupker (1982), who asked participants to name pictures while ignoring superimposed distractor words. Results showed that pictures were named more quickly when distractors overlapped target pictures in sound and spelling (e.g., picture: plane; distractor: cane) than when they overlapped only in sound (e.g., picture: plane; distractor: brain). However, though this result was replicated by Damian and Bowers (2009a), no orthographic influences were observed when distractors were presented in the auditory modality, suggesting that these effects may emerge only when orthography is relevant to the task (and calling into question the claim that orthographic representations are activated in speech *perception*). Similar conclusions could be drawn about related work using the form-preparation paradigm (Meyer, 1990). Damian and Bowers (2003) asked participants to memorize word pairs that occurred in homogeneous blocks in which words overlapped in their initial sound and letter (e.g., coffee–camel), in heterogeneous blocks in which there was no overlap between the words (e.g., gypsy–camel) or in inconsistent blocks in which words overlapped in their initial sound but not letter (e.g., kidney–camel). Participants were then required to produce the second item in each pair when cued by the first. Results showed the typical form preparation advantage of faster recall in homogeneous blocks than in heterogeneous blocks, though this advantage was absent in the inconsistent blocks, suggesting a role for orthography in speech production. However, this result was not replicated in Dutch (Roelofs, 2006) or Chinese (Chen, Chen, & Dell, 2002) and does not arise when participants are required to name blocks of similar-sounding pictures that overlap or do not overlap in their spelling (Alario, Perre, Castel, & Ziegler, 2007).

A New Approach to Investigating Orthographic Influences on Spoken Language

This review demonstrates that methodological difficulties have made it difficult to draw strong conclusions about orthographic influences on speech perception and that there has been insuffi-

cient research to draw any conclusions about orthographic influences on speech production. Our research offers a new approach to this issue by capitalizing on developments in the area of word learning. Recent research has shown that adults can learn novel words in laboratory situations, and that given a period of overnight consolidation (Dumay & Gaskell, 2007), these novel words come to behave like known words in psycholinguistic tasks (Bowers, Davis, & Hanley, 2005; Gaskell & Dumay, 2003; Merkx, Rastle, & Davis, 2011). The beauty of this paradigm for investigating orthographic effects in spoken language lies in the exquisite methodological control that it offers, making it possible to dispense with the between-item designs that have characterized much of the work on speech perception, and instead select a single set of spoken targets whose spelling–sound characteristics can be manipulated across participants.

Participants in our experiment were trained and tested on a set of novel words and pictures over 3 successive days. On the first day, they were trained on the spoken forms of these novel words together with their pictures, until their performance reached criterion. Spelling–sound consistent or spelling–sound inconsistent orthographic representations of the novel words were introduced on the second day, and then on the third day, participants were tested on a range of speeded speech perception and production tasks, including auditory lexical decision, shadowing, and picture naming. It should be noted that none of these tasks involved presentation of an orthographic stimulus. Further, in order to ensure that any null effects of orthography were not due to participants' failure to learn the spellings presented to them on the second day, we conducted a picture spelling test and a forced-choice spelling test at the end of the third day. Our aims were to discover whether the nature of the orthographic code assigned to the novel spoken words would have any impact on the perception and production of those novel spoken words and to ascertain whether this impact was restricted to certain test tasks.

Method

Participants

Participants were 12 native monolingual Southern British English speakers from an undergraduate population. None reported dyslexia or other language impairment. Participants were paid £30 for their participation.

Stimuli and Apparatus

Training stimuli consisted of 20 novel objects pictured as black-and-white line drawings. Each of these objects was given a novel spoken name whose initial phoneme could be spelled in a regular or irregular manner based on existing English spelling–sound relationships (e.g., /kɪsp/ spelled *kisp* or *chisp*; see Appendix). Length and orthographic *N* were matched across regular and irregular spellings of the spoken words (length: regular $M = 4.35$ letters, irregular: $M = 4.55$ letters; *N*: regular $M = 3.5$ neighbors, irregular $M = 2.6$ neighbors). The assignment of regular or irregular spellings to novel objects was counterbalanced across two versions. The names of the novel objects were recorded by a native speaker of Southern British English.

There were five test tasks implemented over the 3 days of training and testing. The *picture-naming task* used the 20 line drawings learned in training and required a naming response from participants. In the *auditory lexical decision task*, the spoken forms of the 20 new words learned by participants were used for the “yes” response (though these were recorded by a different speaker of Southern British English), and 20 spoken nonwords were used for the “no” response. The items used for the “no” response were matched to learned items on onset, consonant–vowel structure, phonological neighborhood size, and acoustic duration. In the *shadowing task*, all 40 stimuli from the auditory lexical decision task were used plus an additional 20 untrained nonwords matched to the learned items on the same factors described earlier. The *picture-spelling task* used the 20 line drawings learned in training and required a spelling response from participants. Finally, the *forced-choice spelling task* used the regular and irregular spellings of each novel object and required participants to decide which they had learned.

Stimulus presentation and data recording were controlled by DMDX software (Forster & Forster, 2003). Participants gave responses for the five test tasks using a button box (auditory lexical decision, forced-choice spelling), the keyboard (picture spelling), and a Beyerdynamic (Heilbronn, Germany) headset microphone (picture naming, shadowing).

Procedure

Participants were trained and tested over 3 days.

Day 1. Participants were instructed to learn the spoken names of a set of novel objects and told that their performance would be assessed in a picture-naming task. They were told that they had up to 2 hr to achieve a minimum of 80% accuracy and that failure to achieve this result would mean that they could not progress to the following days’ tests and that they would receive only £5. No participants were excluded from the experiment on this basis.

Participants were exposed to the spoken names of the novel objects and their pictures in a series of study and verification blocks. During study blocks, participants were shown a picture of a novel object while listening to its name spoken on headphones, and repeated its name after each trial. During verification blocks, participants chose which of two or three pictures was associated with a particular spoken name and were given feedback consisting of the correct picture–word pairing on each trial. Participants were exposed to the correct picture–word pairings six times during study blocks and a further six times as feedback during verification blocks. Following this fixed training period, participants attempted to name the objects in all 20 pictures. If performance was not 80% accurate at this stage, they were asked to study a chart of the 20 pictured objects, whose spoken names could be accessed on a mouse click. Participants were retested after revision periods of 10 min until they reached 80% accuracy in picture-naming performance.

Day 2. Participants named all 20 pictured objects at the beginning of Day 2. Spellings were then introduced through a series of study and verification blocks that mirrored those used on Day 1. During study blocks, the spelling of the name of each object was presented in conjunction with its picture and spoken name, and participants were required to type the name after each presentation. During verification blocks, participants chose which of two

or three pictures was associated with a particular spelling. Feedback was given on each verification trial that consisted of the picture and its spoken and written name.

Participants named the 20 pictured objects after this orthographic training period. They then completed a surprise spelling test that assessed learning of the written names.

Day 3. Participants were given the five test tasks in the following order: auditory lexical decision, picture naming, shadowing, picture spelling, and forced-choice spelling. In auditory lexical decision, participants decided whether spoken stimuli presented over headphones were words or nonwords; the instructions specified that the term *words* included any that they had recently learned. In picture naming, participants named the novel objects in the pictures learned in training as rapidly as possible. In shadowing, participants repeated trained new words and untrained nonwords as rapidly as possible. In picture spelling, participants wrote the names of the novel objects in the pictures learned in training. Finally, in forced-choice spelling, participants decided as rapidly as possible which of two spellings they had learned in orthographic training.

Results

Reaction times (RTs) for spoken responses in picture naming and shadowing were derived manually via visual inspection of the speech waveform using CheckVocal software (Protopapas, 2007).

Picture Naming

Picture naming was assessed at four time points during the experiment, once at the end of Day 1 when 80% accuracy had been achieved, twice on Day 2 (before and after orthographic training), and once on Day 3. We analyzed RTs by participants and by items using three-factor analyses of variance (ANOVAs). In the participant analysis, we treated time of testing (four levels) and spelling regularity (two levels) as repeated factors and version (two levels) as an unrepeated factor. In the items analysis, we treated time of testing and regularity as repeated factors and version as an unrepeated factor. RT and error data by participants are shown in Table 1.

The latency analysis revealed a significant interaction between time and regularity, $F_1(3, 30) = 5.11, p < .01, F_2(3, 54) = 4.65, p < .001$. This interaction reflected the fact that spelling regularity influenced picture-naming latency at both time points after orthographic training—Day 2 post-orthography training: $t_1(11) = 4.06, p = .002, t_2(19) = 5.60, p = .001$; Day 3 testing: $t_1(11) = 2.44, p = .04, t_2(19) = 2.71, p = .014$ —but not prior to the introduction of orthography—Day 1: $t_1(11) = -0.23, ns, t_2(19) = 0.65, ns$; Day 2 pre-orthography training: $t_1(11) = 0.00, ns, t_2(19) = 0.35, ns$. In the presence of this interaction, main effects on the latency data are not reported. The accuracy analysis revealed a main effect of time of testing since participants’ performance improved with increasing exposure to the stimuli, $F_1(3, 30) = 10.79, p < .001, F_2(3, 54) = 8.02, p < .001$. There were no other main effects or interactions that reached significance both by participants and by items.

Auditory Lexical Decision

We analyzed RT data for “yes” responses using two-factor ANOVAs. The analysis by participants treated target type (regular

Table 1
Reaction Time (in Milliseconds) and Percentage Error as a Function of Time of Testing and Spelling Regularity of Trained Written Names

Time of testing	Regular condition		Irregular condition		Difference (ms)
	ms	%	ms	%	
Day 1	1,235	9.2	1,255	6.7	20 ^{ns}
Day 2 Pre-orthographic training	1,361	13.3	1,361	15.8	0 ^{ns}
Day 2 Post-orthographic training	1,052	2.5	1,270	5.0	218*
Day 3	1,071	2.5	1,239	5.0	168**

Note. *ns* = not significant ($p > .05$). Data for Day 1 and Day 2 pre-orthographic training reflect picture-naming times for groups of items that were later assigned to the irregular and regular conditions.

* $p < .05$. ** $p < .005$.

or irregular) as a repeated factor and version as an unrepeatable factor, while the analysis by items treated both variables as unrepeatable. The latency analysis revealed a main effect of regularity (regular $M = 1,068$ ms; irregular $M = 1,174$ ms), $F_1(1, 10) = 10.60$, $p < .01$, $F_2(1, 18) = 5.03$, $p < .05$. There were no effects that reached significance in the accuracy analysis (regular error $M = 5.0\%$, irregular error $M = 4.2\%$; all $ps > 0.5$).

Shadowing

We analyzed RT data using two-factor ANOVAs that treated target type (regular, irregular, untrained) as a repeated factor by participants and as an unrepeatable factor by items, and that treated version as an unrepeatable factor both by participants and by items. The latency analysis revealed a main effect of target type, $F_1(1, 10) = 4.77$, $p < .05$, $F_2(2, 79) = 4.96$, $p < .05$. Follow-up t tests showed that learned words were produced more quickly than untrained items (learned $M = 916$ ms, untrained $M = 952$ ms), $t_1(11) = 2.67$, $p < .05$, $t_2(78) = 3.17$, $p < .01$, whereas there was no difference in shadowing latency for regular and irregular items (regular $M = 914$ ms, irregular $M = 918$ ms), $t_1(11) = 0.25$, *ns*, $t_2(19) = 0.23$, *ns*. Error rates were extremely low (<1% for all conditions), and there were no effects that reached significance (all $ps > 0.5$).

Picture Spelling

Knowledge of the spellings of the novel words was highly accurate on Day 2 (regular $M = 98.3\%$, irregular $M = 97.5\%$) and remained so at the end of Day 3 (regular $M = 95.8\%$, irregular $M = 91.7\%$). There were no significant effects of regularity, $F_1(1, 10) = 2.6$, *ns*, $F_2(1, 18) = 9.78$, $p = .01$, or day of testing on picture spelling, $F_1(1, 10) = 2.57$, *ns*, $F_2(1, 18) = 3.24$, *ns*, and there was no interaction between these factors, $F_1(1, 10) = 1.29$, *ns*, $F_2(1, 18) = 1.39$, *ns*.

Forced-Choice Spelling

One participant was removed from this analysis because he was unable to reach a decision within 6 s, and three additional data points greater than 3,000 ms were removed. Results revealed no effect of regularity on forced-choice spelling RT (regular $M = 1,086$ ms, irregular $M = 1,108$ ms), $t_1(10) = 0.38$, *ns*, $t_2(19) =$

0.99, *ns*, or accuracy (regular error $M = 7.3\%$, irregular error $M = 6.4\%$), $t_1(11) = 0.29$, *ns*, $t_2(19) = 0.55$, *ns*.

Discussion

One important question in language processing research concerns the effect of literacy on speech processing. Despite the fact that reading is a learned form of expertise that is dependent on our inborn capacity for speech, substantial evidence indicates that speech perception may be critically influenced by orthographic representations once literacy is acquired, and there is emerging evidence to this effect in respect of speech production. However, much of this evidence has not been statistically robust, and some of the findings have proven difficult to replicate. Further, it remains unknown the extent to which these findings reflect properties of the tasks used to measure speech processing as opposed to reflecting properties of the speech processing system itself.

Our approach to this issue was to train and test participants on a novel spoken vocabulary over 3 successive days. On the first day, participants were trained to criterion on a set of associations between novel pictures and novel spoken words. Spelling-sound consistent or spelling-sound inconsistent spellings were introduced on the second day in a fully counterbalanced manner, and we assessed the influence of these spellings on the third day in a series of speech-processing tasks, none of which involved orthography. With respect to speech perception, results showed a significant orthographic effect on auditory lexical decision but not on shadowing, thus replicating previous findings with real words (e.g., Pattamadilok et al., 2007; Ziegler et al., 2004). With respect to speech production, results showed for the first time an effect of orthography on simple picture naming that emerged immediately following the introduction of the spellings of words on the second day and that persisted in testing on the third day. These results demonstrate orthographic involvement in speech processing tasks that do not require orthographic processing and in a situation in which spelling-sound consistency can be manipulated with perfect experimental control.

How might orthography have influenced these speech processing tasks? One relatively uninteresting possibility is that participants simply did not have the resources to learn items in the irregular condition fully, perhaps due to the additional attentional or working memory requirements of learning an unusual spelling-

sound mapping. This is unlikely given that (a) participants had already learned the phonology of the novel words to a high criterion prior to the introduction of the orthography; (b) participants learned the regular and irregular spellings equally well; (c) participants showed an equal benefit for stimuli with regular and irregular spellings in shadowing relative to untrained stimuli; and (d) picture-naming performance for items with irregular spellings actually improved following the introduction of orthography. More likely is that the effects observed arose because orthographic representations are activated automatically during speech processing. For example, if a picture of a /kIsp/ activates the orthography CHISP, then this orthography may lead to activation of the regular pronunciation /tSIsp/, thus slowing picture naming by virtue of phonological competition between /tS/ and /k/. Similarly, the activation of the orthography CHISP (and subsequent activation of /tSIsp/) on presentation of the auditory stimulus /kIsp/ may interfere with participants' decisions about whether this was a learned item in the auditory lexical decision task.

One aspect of our results that needs to be explained is why orthographic effects do not appear to be found in shadowing (whether in our experiment or in the previous literature). Two kinds of explanation have been proposed previously. One states that orthographic representations might be activated only in spoken tasks that involve a decision component (Ventura et al., 2004). However, the fact that strong orthographic effects were observed in a simple picture-naming task in our experiment allows us to discount this explanation. The other explanation that has been proposed is that orthographic representations are activated only when spoken stimuli are represented lexically, and shadowing does not activate lexical representations (Ventura et al., 2004). The problem for this explanation is that the shadowing data in our study showed a strong effect of learning, suggesting that lexical representations of the trained words had been activated. Thus, neither of these accounts appears to offer a satisfactory explanation of the different patterns of effects observed in shadowing as opposed to picture naming and auditory lexical decision.

A third type of explanation that we propose stresses the importance of the relative time course of orthographic and phonological information. When the stimulus is a spoken word or nonword, phonological activation has a head start over orthographic activation. Thus, when participants hear the new word /kIsp/, they activate their corresponding phonological lexical representation earlier than the orthographic lexical representation (e.g., CHISP). When the task is simply to repeat the spoken stimulus, this phonological activation can drive the process of speech production before there is much opportunity for orthographic feedback to exert an influence, thus explaining the lack of spelling–sound consistency effects in the shadowing task. When the task requires additional processing stages as in auditory lexical decision, the extra time required to perform the task provides greater opportunity for inconsistent orthographic feedback to activate conflicting phonological representations, thus slowing response times (or for consistent orthographic feedback, to reinforce the correct phonological representation, thus speeding response times). Finally, when the task is picture naming, the stimulus simultaneously activates orthographic and phonological representations, so that phonological activation does not have any head start over orthographic activation. In this situation, there is considerable opportunity for orthographic feedback to influence speech production, thus

explaining the strong spelling–sound consistency effects we observed. Although this account emphasizes the importance of the relative time course of orthographic and phonological information, it should be noted that the current data do not allow us to rule out a related account, in which task difficulty, rather than time course, is the critical factor. Adjudicating between these two possibilities will be one goal for future research.

Two final points are worthy of consideration. Previous research on the regularity effect in reading aloud has established that this effect interacts with word frequency (e.g., Seidenberg, Waters, Barnes, & Tanenhaus, 1984) and position of irregularity (e.g., Rastle & Coltheart, 1999). That is, the regularity effect is smaller for higher frequency words and for words in which the irregularity occurs later in the word. On the basis of the regularity by frequency interaction, we might reasonably expect that the regularity effect that we observed would get smaller if participants were given additional training on the new words. It is more difficult to make predictions regarding the effect of position of irregularity, given that both the speech stream and the putative phonological recoding process involve a serial component. Further research will therefore be required to establish whether our result generalizes to the situation in which the irregularity occurs in the coda.

In conclusion, our results provide the clearest evidence to date of orthographic involvement in speech processing. These orthographic effects can best be understood as reflecting massive interactivity in language processing, in which previously learned spelling–sound associations give rise to a rapid and automatic flow of activation in both directions between orthographic and phonological representations. Our results may also provide some clues as to the relative time course of orthographic and phonological information as a function of the nature of the input stimulus and the task; this aspect of language processing will be an important one for further investigations. Finally, this study provides a further illustration of the methodological advantages offered by novel word training paradigms in psycholinguistics (e.g., Bowers et al., 2005; Gaskell & Dumay, 2003; Merks et al., 2011).

References





















- Alario, F. X., Perre, L., Castel, C., & Ziegler, J. C. (2007). The role of orthography in speech production revisited. *Cognition*, *102*, 464–475. doi:10.1016/j.cognition.2006.02.002
- Bowers, J. S., Davis, C. J., & Hanley, D. A. (2005). Interfering neighbours: The impact of novel word learning on the identification of visually similar words. *Cognition*, *97*, B45–B54. doi:10.1016/j.cognition.2005.02.002
- Castles, A., Holmes, V. M., Neath, J., & Kinoshita, S. (2003). How does orthographic knowledge influence performance on phonological awareness tasks? *Quarterly Journal of Experimental Psychology, Section A: Human Experimental Psychology*, *56*, 445–467.
- Chen, J. Y., Chen, T. M., & Dell, G. S. (2002). Word-form encoding in Mandarin Chinese as assessed by the implicit priming task. *Journal of Memory and Language*, *46*, 751–781. doi:10.1006/jmla.2001.2825
- Chéreau, C., Gaskell, M. G., & Dumay, N. (2007). Reading spoken words: Orthographic effects in auditory priming. *Cognition*, *102*, 341–360. doi:10.1016/j.cognition.2006.01.001
- Damian, M. F., & Bowers, J. S. (2003). Effects of orthography on speech production in a form preparation paradigm. *Journal of Memory and Language*, *49*, 119–132.
- Damian, M. F., & Bowers, J. S. (2009a). Assessing the role of orthography in speech perception and production: Evidence from picture–word in-

- terference tasks. *European Journal of Cognitive Psychology*, 21, 581–598. doi:10.1080/09541440801896007
- Damian, M. F., & Bowers, J. S. (2009b). Orthographic effects in rhyme monitoring: Are they automatic? *European Journal of Cognitive Psychology*, 22, 1–11.
- Dijkstra, T., Roelofs, A., & Fieus, S. (1995). Orthographic effects on phoneme monitoring. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, 49, 264–271. doi:10.1037/1196-1961.49.2.264
- Dumay, N., & Gaskell, M. G. (2007). Sleep-associated changes in the mental representation of spoken words. *Psychological Science*, 18, 35–39. doi:10.1111/j.1467-9280.2007.01845.x
- Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers*, 35, 116–124. doi:10.3758/BF03195503
- Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition*, 89, 105–132. doi:10.1016/S0010-0277(03)00070-2
- Jakimik, J., Cole, R. A., & Rudnicky, A. I. (1985). Sound and spelling in spoken word recognition. *Journal of Memory and Language*, 24, 165–178. doi:10.1016/0749-596X(85)90022-1
- Lupker, S. J. (1982). The role of phonetic and orthographic similarity in picture–word interference. *Canadian Journal of Psychology/Revue canadienne de psychologie*, 36, 349–367. doi:10.1037/h0080652
- Merkx, M., Rastle, K., & Davis, M. H. (2011). The acquisition of morphological knowledge investigated through artificial language learning. *Quarterly Journal of Experimental Psychology*, 64, 1200–1220. doi:10.1080/17470218.2010.538211
- Meyer, A. S. (1990). The time course of phonological encoding in language production: The encoding of successive syllables. *Journal of Memory and Language*, 29, 524–545. doi:10.1016/0749-596X(90)90050-A
- Muneaux, M., & Ziegler, J. C. (2004). Locus of orthographic effects in spoken word recognition: Novel insights from the neighbour generation task. *Language and Cognitive Processes*, 19, 641–660. doi:10.1080/01690960444000052
- Pattamadilok, C., Morais, J., Ventura, P., & Kolinsky, R. (2007). The locus of the orthographic consistency effect in auditory word recognition: Further evidence from French. *Language and Cognitive Processes*, 22, 700–726. doi:10.1080/01690960601049628
- Peereman, R., Dufour, S., & Burt, J. S. (2009). Orthographic influences in spoken word recognition: The consistency effect in semantic and gender categorization tasks. *Psychonomic Bulletin & Review*, 16, 363–368. doi:10.3758/PBR.16.2.363
- Perre, L., & Ziegler, J. C. (2008). On-line activation of orthography in spoken word recognition. *Brain Research*, 1188, 132–138. doi:10.1016/j.brainres.2007.10.084
- Pinker, S. (1997). Preface. In D. McGuinness (Ed.), *Why our children can't read and what we can do about it*. New York, NY: Simon & Schuster.
- Protopapas, A. (2007). CheckVocal: A program to facilitate checking the accuracy and response time of vocal responses from DMDX. *Behavior Research Methods*, 39, 859–862. doi:10.3758/BF03192979
- Rastle, K., & Brysbaert, M. (2006). Masked phonological priming effects in English: Are they real? Do they matter? *Cognitive Psychology*, 53, 97–145. doi:10.1016/j.cogpsych.2006.01.002
- Rastle, K., & Coltheart, M. (1999). Serial and strategic effects in reading aloud. *Journal of Experimental Psychology: Human Perception & Performance*, 25, 482–503. doi:10.1037/0096-1523.25.2.482
- Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest*, 2, 31–74. doi:10.1111/1529-1006.00004
- Roelofs, A. (2006). The influence of spelling on phonological encoding in word reading, object naming, and word generation. *Psychonomic Bulletin & Review*, 13, 33–37. doi:10.3758/BF03193809
- Seidenberg, M. S., & Tanenhaus, M. K. (1979). Orthographic effects on rhyme monitoring. *Journal of Experimental Psychology: Human Learning and Memory*, 5, 546–554. doi:10.1037/0278-7393.5.6.546
- Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning & Verbal Behavior*, 23, 383–404. doi:10.1016/S0022-5371(84)90270-6
- Slowiaczek, L. M., Soltano, E. G., Wieting, S. J., & Bishop, K. L. (2003). An investigation of phonology and orthography in spoken-word recognition. *Quarterly Journal of Experimental Psychology, Section A: Human Experimental Psychology*, 56, 233–262.
- Taft, M., Castles, A., Davis, C., Lazendic, G., & Nguyen-Hoan, M. (2008). Automatic activation of orthography in spoken word recognition: Pseudohomograph priming. *Journal of Memory and Language*, 58, 366–379. doi:10.1016/j.jml.2007.11.002
- Treiman, R., & Cassar, M. (1997). Can children and adults focus on sound as opposed to spelling in a phoneme counting task. *Developmental Psychology*, 33, 771–780. doi:10.1037/0012-1649.33.5.771
- Tyler, L. K., Voice, J. K., & Moss, H. E. (2000). The interaction of meaning and sound in spoken word recognition. *Psychonomic Bulletin & Review*, 7, 320–326. doi:10.3758/BF03212988
- Ventura, P., Kolinsky, R., Pattamadilok, C., & Morais, J. (2008). The developmental turnpoint of orthographic consistency effects in speech recognition. *Journal of Experimental Child Psychology*, 100, 135–145. doi:10.1016/j.jecp.2008.01.003
- Ventura, P., Morais, J., Pattamadilok, C., & Kolinsky, R. (2004). The locus of the orthographic consistency effect in auditory word recognition. *Language and Cognitive Processes*, 19, 57–95. doi:10.1080/01690960344000134
- Ziegler, J. C., & Ferrand, L. (1998). Orthography shapes the perception of speech: The consistency effect in auditory word recognition. *Psychonomic Bulletin & Review*, 5, 683–689. doi:10.3758/BF03208845
- Ziegler, J. C., Ferrand, L., & Montant, M. (2004). Visual phonology: The effects of orthographic consistency on different auditory word recognition tasks. *Memory & Cognition*, 32, 732–741. doi:10.3758/BF03195863
- Ziegler, J. C., Petrova, A., & Ferrand, L. (2008). Feedback consistency effects in visual and auditory word recognition: Where do we stand after more than a decade? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34, 643–661. doi:10.1037/0278-7393.34.3.643

(Appendix follows)

Appendix

Test Pictures, Written Names, And Spoken Names

Picture	Irregular Spelling	Regular Spelling	I.P.A.
	THIMP	TIMP	/tɪmp/
	SURP	SHURP	/ʃɜp/
	CERK	CHERK	/tʃɛk/
	WHOFF	HOFF	/hɒf/
	CHONT	KONT	/kɒnt/
	THESH	TESH	/tɛʃ/
	SULF	SHULF	/ʃʌlf/
	CESK	CHESK	/tʃɛsk/
	WHOAT	HOAT	/həʊt/
	CHISP	KISP	/kɪsp/
	THIST	TIST	/tɪst/
	SUST	SHUST	/ʃʌst/
	CEFT	CHEFT	/tʃɛft/
	WHOBE	HOBE	/həʊb/
	CHIRM	KIRM	/kɜm/
	THUSP	TUSP	/tʌsp/
	SUME	SHUME	/ʃʊm/
	CELP	CHELP	/tʃɛlp/
	WHOSK	HOSK	/hɒsk/
	CHIBE	KIBE	/kaɪb/