Spoken Words Activate Cross-Linguistic Orthographic Competitors in the Absence of Phonological Overlap

James Bartolotti (j-bartolotti@u.northwestern.edu)

Natalia L. Daniel (nataliadaniel2012@u.northwestern.edu)

Viorica Marian (v-marian@northwestern.edu)
Northwestern University
Department of Communication Sciences and Disorders
2240 Campus Drive, Evanston, IL 60208 USA

Abstract

Related languages, like English and Spanish, often have similar orthographies but use the same letters to represent different sounds. Learning a second language frequently involves learning additional letter-sound mappings that mismatch those in the native language. In the current study, we investigated whether L2 spoken words activate L2 orthography despite conflict with L1 orthography-to-phonology mappings. Participants first learned an artificial language with letter-sound mappings that mismatched English (e.g., the letter 'G' represented the sound /h/, and the word /ɡufɔ/ was spelled 'hane'). Next, fixations of L1 crosslinguistic orthographic competitors (e.g., 'cane') in response to auditory L2 input (e.g., /ɡufɔ/) were assessed using the visual world paradigm. Results showed that participants fixated L1 competitors that overlapped with L2 targets orthographically (but not phonologically) more than unrelated fillers. We conclude that second language learners can rapidly acquire novel letter-sound mappings, and words based on these mappings are integrated into the existing lexicon where they can activate orthographic competitors in the native language.

Keywords: Language processing; Language learning; Cross-linguistic competition

Introduction

Spoken language processing involves decoding an incoming auditory signal to access words in the mental lexicon. It's not obvious that this process should be affected by orthographic knowledge, because written language is a relatively recent invention, and is learned years after spoken language. Yet, there is evidence that orthography, once acquired, influences performance on phonological tasks (Jakimik, Cole, & Rudnicky, 1985; Johnston, McKague, & Pratt, 2004; Salverda & Tanenhaus, 2010), suggesting tight interconnectivity between orthography and phonology. This interconnectivity may be a source of difficulty during second language acquisition, because the same letters can represent different sounds across languages. For example, the letter 'W' maps onto the phoneme /w/ in English, but /v/ in German (one is a labiovelar approximant, while the other is a voiced labio-dental fricative, which differs on both voicing, place, and manner of articulation). Second language learners thus need to learn and use these novel letter-sound correspondences in the appropriate language context, despite years of experience with a different set of mappings in their native language.

Orthographic knowledge can help or hinder phonological processing, depending on the context. Literate adults perform better than illiterate adults on metaphonological tasks such as adding or deleting sounds at the beginning of non-words (Morais, Cary, Alegria, & Bertelson, 1979), because literate adults can use their orthographic representations as a mental aid. On the other hand, orthography can also distort phonological perception. French speakers are more likely to misperceive the phoneme /p/ as a /b/ in spoken words when the sound is represented by the letter 'B', as in the French word 'absurd,' pronounced /apsyrd/ (Hallé, Chéreau, & Segui, 2000). Furthermore, orthography can affect online processing of speech. Orthographically-related primes improve auditory lexical decision times (Jakimik et al., 1985), but written words can act as competitors during auditory visual world search tasks (Salverda & Tanenhaus, 2010). Based on timecourse analyses from research on event-related potentials (ERPs), these orthographic effects occur early in the speech signal and are time-locked to the source of orthographic effects in the word, suggesting that orthography is activated online during speech processing, and not strictly as a postlexical decision process (Perre & Ziegler, 2008).

The link between orthography and phonology extends to novel words as well. In a recent study (Johnston et al., 2004), monolingual English speakers were taught a series of novel words but only learned the words' phonological forms, and were never presented with orthography. During a subsequent masked priming task, orthographic versions of the trained words showed a significant priming effect, compared to the absence of any effect for completely novel written non-words. This finding suggests that learners automatically generate orthographic forms for novel auditory words, based on the phonotactics of their native language. When these generated forms are accurate, they can accelerate vocabulary learning and improve reading of previously learned auditory words (McKague, Pratt, & Johnston, 2001). During second language learning, though, they are more likely to be inaccurate and impair learning. For example, an English-speaking learner of German may hear the auditory German word /vɛk/ (spelled 'weg') and create an incorrect orthographic representation 'veck' based on their knowledge of English. This incorrect representation may then impair learning to read and write in German, as the learner's internal representations must be inhibited and relearned. Previous work indicates that English speakers are able to learn words and letter-sound mappings in artificial languages with training, even when they include non-English phonemes (Kaushanskaya & Marian, 2009a), graphemes (Bitan & Karni, 2003), or a combination of the two (Kaushanskaya & Marian, 2008). In the current study, we isolated acquisition of novel letter-sound mappings by recombining familiar English letters and sounds. Even when there are no new letters or sounds to be learned, acquiring novel mappings can be difficult – for example, two of the most challenging letters for English learners of Russian to learn are B (pronounced /v/), and Y (pronounced /u/), which are often mispronounced as /b/ and /i/ respectively, representing interference from existing English mappings (Comer & Murphy-Lee, 2004). Full language acquisition requires learners to form new mappings between orthography and phonology that are appropriate for the target language, and to be able to inhibit their native language mappings during L2 processing.

In sum, there is a tight interconnectivity between orthography and phonology, but letter-sound mappings often conflict across languages, which may lead to second language learning difficulties. The current study was designed to investigate how learners manage these difficulties. The first goal of the study was to assess how well learners are able to acquire vocabulary in a novel language with letter-sound correspondences that mismatch English. The second goal was to determine whether auditory words in the L2 will activate L2 orthography, based on spreading activation from the L2 to words that resemble the L2 orthographic form. These questions are addressed by teaching participants a L2 vocabulary with letter-sound correspondences completely distinct from English. If participants are able to learn the novel ortho-phono mappings, then presentation of the auditory form of the word will lead to activation of the corresponding orthographic form. In a connectionist model of language processing, activation should then spread to similarly spelled words in the lexicon.

Because the novel language and English have different letter-sound mappings, auditory targets in the new language do not overlap phonologically with their English orthographic competitors (e.g., the novel word /ɡufɔ/, spelled ‘hane’, overlaps orthographically but not phonologically with the English word ‘cane’). If participants look at crosslinguistic orthographic competitors upon hearing L2 words, they must have activated the target’s L2 orthographic form, which then spread activation to orthographically related items, including the crosslinguistic competitor. The current study thus allows us to simultaneously assess the effects of novel ortho-phono mappings and cross-linguistic interference on speech processing in a newly learned language.

Methods

Participants

Twenty monolingual English speakers (16 females, 4 males) participated. Eyetracking data was unavailable for one participant due to equipment error. All participants reported current English use at 99% of the time or more, and a proficiency of three or less on a scale of 1 (no knowledge) to 10 (perfect) in a second language (LEAP-Q, Marian, Blumenfeld, & Kaushanskaya, 2007).

Materials

A miniature artificial language named Colbertian[1] was created using a novel alphabetic system. Thirteen English graphemes (four vowels and nine consonants) were paired with thirteen English phonemes so that the English and Colbertian sounds for each letter differed maximally in voice, place, and manner for consonants, or height, backness, and rounding for vowels (Table 1). Reusing English phonemes ensured that participants needed only to learn the novel letter-sound correspondences, but not any new phonetic categories.

Table 1: Colbertian Alphabet

Grapheme	English Phoneme	Colbertian Phoneme
a	/eɪ/ /æ/	/u/
e	/i/ /ɛ/	/ɔ/
i	/aɪ/ /ɪ/	/æ/
o	/oʊ/ /ɔ/	/i/
b	/b/	/s/
d	/d/	/tʃ/
h	/h/	/ɡ/
k	/k/	/w/
n	/n/	/f/
p	/p/	/z/
r	/ɹ/	/h/
t	/t/	/dʒ/
v	/v/	/t/

Twenty-four words were then created using the Colbertian alphabet (Table 2). Each word was recorded by a female speaker of Standard American English, and was associated with an easily-nameable black and white line drawing (naming consistency higher than 80% from the International Picture Naming Project database, Bates et al., 2003, or norming with Amazon’s Mechanical Turk). Each of the novel words was designed to overlap orthographically, but not phonologically, with an English competitor word in order to isolate the effect of English orthographic knowledge on Colbertian auditory word processing. Target words, competitor words, and filler words were matched on the following variables: phonological neighborhood size (IPhOD; Vaden, Halpin, & Hickok, 2009), orthographic neighborhood size (N-Watch; Davis, 2005), English lexical frequency (SUBTLEX-US; Brysbaert & New, 2009), concreteness, imageability, or familiarity (MRC Psycholinguistic Database; Coltheart, 1981), all p’s > 0.05.

[1]The language was named after comedy show wordsmith and Northwestern University alumnus Stephen Colbert to engage participants in the learning task.

Table 2: Colbertian Vocabulary

Colbertian Orthography	Colbertian Phonology	English Translation	English Competitor
vite	/tædʒɔ/	wig	kite
tave	/dʒutɔ/	pan	cave
eron	/ɔhif/	tent	iron
dipe	/tʃæzɔ/	snake	pipe
vope	/tizɔ/	mouse	rope
vate	/tudʒɔ/	ear	gate
kire	/wæhɔ/	gun	fire
dibe	/tʃæsɔ/	hose	dice
rako	/huwi/	grapes	rake
dova	/tʃitu/	ax	dove
rike	/hæwɔ/	shark	rice
nove	/fitɔ/	sun	nose
rone	/hifɔ/	swan	cone
hane	/gufɔ/	ruler	cane
bave	/sutɔ/	purse	wave
nake	/fuwɔ/	bird	cake
bine	/sæfɔ/	pants	wine
robi	/hisæ/	bench	robe
tavo	/dʒuti/	raft	taco
vabe	/tusɔ/	owl	vase
bika	/sæwu/	plate	bike
bona	/sifu/	cow	bone
roke	/hiwɔ/	lock	rose
tapi	/dʒuzæ/	cat	tape

Procedure

Participants learned Colbertian in a single experimental session in four steps. In the first step, participants were exposed to each of the Colbertian words' spellings and pronunciations. A single written word appeared in the center of a computer screen, and the auditory form of the word was pronounced over headphones. The participant repeated the word aloud and clicked the mouse to advance to the next word. Each word was presented once, for a total of 24 exposures. In the second step, participants practiced associating the words and their pronunciations until they reached a 90% learning criterion. In a single trial, four Colbertian words were shown on the screen, and the auditory form of the target word was played over headphones. After selecting one of the four words, participants received feedback: the target word turned green, the three foils disappeared, and the word was replayed over headphones. This ensured that participants had an opportunity to relearn the words they answered incorrectly. After 24 trials, with each word as a target once, the participant was shown their accuracy for the block. Each participant repeated blocks of 24 trials until they reached 90% accuracy on two consecutive blocks.

In the third step, participants were familarized with the meanings of the words they had just learned. Four pictures appeared on the screen, and after 1500 ms, a Colbertian word appeared on the center of the screen and was played over headphones, and the picture it represented was outlined with a red box (nontarget pictures remained visible)[2]. In the fourth step, participants practiced associating Colbertian words with their pictures until achieving the 90% learning criterion. In each trial, four pictures were displayed on the screen, and the target word was simultaneously presented in written and auditory forms. After selecting a picture, feedback was provided: the target picture was outlined in a red box (nontarget pictures remained visible) and the target word was replayed over headphones. Each trial, including response time and feedback, lasted exactly six seconds to equate picture viewing times across trials. After 24 trials, with each word as a target once, the participant was shown their accuracy for the block. Participants continued doing training blocks until they reached 90% accuracy on two consecutive blocks, at which point they were finished learning Colbertian.

After learning Colbertian, participants immediately began a visual world eyetracking task to assess the effect of English orthographic knowledge on Colbertian spoken word processing. Each trial began with a 1000 ms fixation cross to orient participants' gaze. Next, the cross disappeared and four pictures appeared in the corners of the screen. After a 500 ms delay, a Colbertian word indicating the target picture was played over headphones (the orthographic form of the target was never shown). The participant's task was to click on the target picture as quickly and accurately as possible. No feedback was provided. Trial presentation was controlled by the experimental software (MATLAB with Psychophysics toolbox), and monocular eye gaze was recorded with an SR Eyelink 1000 eyetracker at 1000 Hz in order to assess changes in activation of pictured referents over time. In 24 Experimental trials, the English name of one of the three filler pictures overlapped orthographically (but not phonologically) with the orthographic form of the Colbertian target word in three out of four letters (Targets and Competitors are shown in Table 2). Twenty-four Filler trials, in which none of the pictures overlapped orthographically or phonologically with the Colbertian target, were included to mask the experimental manipulation.

Finally, participants' knowledge of Colbertian's letter-sound correspondences was assessed with a novel word generalization task. In each of 48 trials, four novel Colbertian words, one target and three foils, were presented in the four corners of the screen, and the novel auditory form of the target was played over headphones. The participant selected a word and the next trial began after an inter-trial interval of 1500 ms. Accuracy and response time were recorded, but no feedback was provided. Twenty-four of the trials constituted the Simple Discrimination condition, in which none of the foils used any of the target word's letters in the same position (e.g., Target /suzɔ/ spelled 'bape' and Foils 'kovi', 'vedo', 'rina').

[2]To control for picture familiarity, targets, competitors, and fillers from the visual world task were viewed equally during training. Competitors never appeared with the overlapping Colbertian targets.

As such, knowing only one of the letters in Colbertian was sufficient to identify the target. The other 24 trials constituted the Hard Discrimination condition, where one foil overlapped the target in the first consonant, another overlapped in the second consonant, and the third overlapped in both vowels (e.g., Target /wɔtʃæ/ spelled 'kedi', with C1 Foil '**k**ova', C2 Foil 'na**d**o', Vowel Foil 'b**e**r**i**'). Thus, a correct response required additional knowledge of the target beyond a single letter-sound mapping. Simple and Hard Discrimination trials were presented in an intermixed fashion.

Results

Learning

Participants reached the 90% criterion for whole word learning after M = 10.10 blocks (SD = 7.40, Range [2, 31]). For learning the semantic meaning of the words, participants reached the 90% criterion after only M = 3.05 blocks (SD = 0.69, Range [2, 4]).

Participants demonstrated high competence with Colbertian orthography on the generalization task. Accuracy was 92% (SD = 8) in the Simple Discrimination condition, and 75% (SD = 19) in the Hard Discrimination condition (significantly lower, $t(19) = 4.55$, $p < 0.001$). Consistent with accuracy, RTs were significantly faster in Simple Discrimination, M = 3.56 seconds (SD = 0.86), compared to Hard Discrimination, M = 4.20 seconds (SD = 1.39), $t(19) = 3.04$, $p < 0.01$.

Though the training paradigm equated participants on Colbertian proficiency, learning rate was associated with Colbertian generalization skill. Faster learning rate in whole-word training blocks was associated with increased accuracy in Simple Discrimination, R^2 = -0.23, $p < 0.05$, and highly associated with increased accuracy in Hard Discrimination, R^2 = -0.49, $p < 0.001$. Faster learning rate was also associated with longer RTs in Hard Discrimination, R^2 = -0.27, $p <$ 0.05, but not in Simple Discrimination, R^2 = -0.03, ns.

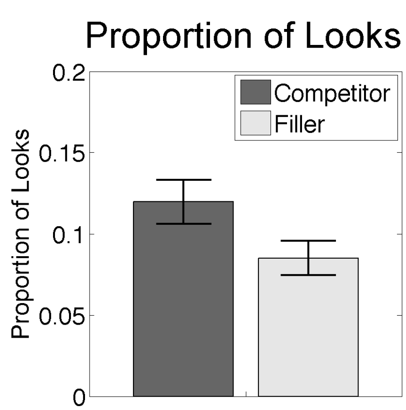

Figure 1: Proportion of looks to orthographic competitors compared to fillers. Asterisk denotes significance at the .05 level, error bars indicate standard error.

Cross-Linguistic Orthographic Interference

Proportion of Looks Visual fixations lasting at least 200 ms were analyzed (shorter fixations are mostly parts of a pre-planned path for rapidly analyzing a newly-presented scene, since eye-movements in visual world tasks take about 200 ms to plan and execute, Viviani, 1990) from auditory target onset to 1600 ms post-target onset, at which point visual fixations reached an asymptote. The proportion of looks to English orthographic competitors was compared to the average of both fillers present on the same display in a one-way repeated measures ANOVA. Participants looked more often at the orthographic competitor pictures than filler pictures, $F_1(1, 17)$ = 17.09, $p < 0.001$, $F_2(1, 23) = 3.98$, $p = 0.05$ (Figure 1).

Fixation Timecourse Proportion of looks to Competitors versus Fillers were analyzed with point-to-point t-tests in 100 ms time bins from -500 ms pre-word-onset to 2000 ms post-word onset (Figure 2). Participants looked more often at orthographic Competitors than Fillers from 0-100 ms and from 100-200 ms post-word onset (p's < 0.05 corrected).

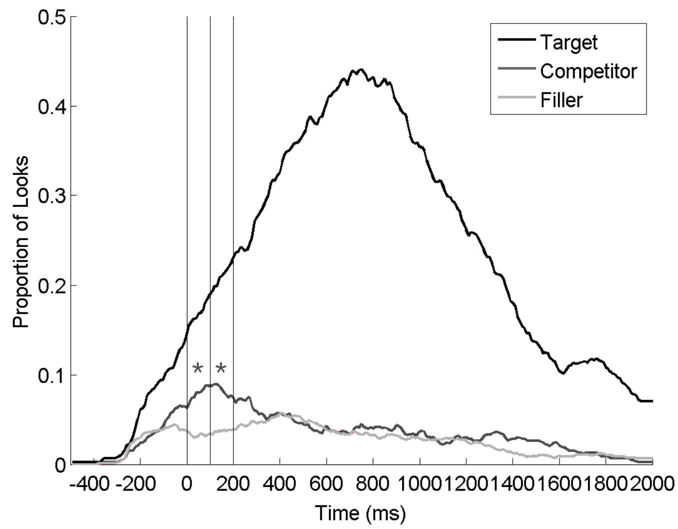

Figure 2: Proportion of looks to targets, orthographic competitors, and fillers in 100 ms time windows. Participants fixated orthographic competitors more than fillers from 0-200 ms post-target onset. Asterisks denote significance at the .05 level.

Discussion

In this experiment, we examined the role of orthography on novel language learning and auditory processing. We found that participants were successfully able to learn a novel language containing letter-sound mappings that contrasted with English. Learners successfully generalized their knowledge to novel, untrained words, suggesting that they acquired Colbertian's phonetic rules and did not rely on whole-word learning alone. In fact, faster learners were also better at identifying novel words; it may be that these participants were able to extract and make use of Colbertian's letter-sound mappings early in their training, which accelerated their learning. In contrast, those who struggled to learn the novel words appeared to have learned less about specific ortho-phono mappings, and performed more poorly identifying novel words.

Auditory presentation of learned words activated their corresponding orthographic forms, as evidenced by more frequent visual fixations to cross-linguistic English orthographic competitors from 0-200 ms post target word onset. The early timecourse of the effect suggests that orthography affected speech processing online rather than at a post-lexical decision level, a finding that converges with evidence from ERPs (Perre & Ziegler, 2008). Note that because of the contrasting letter-sound mappings between English and Colbertian, competitor items did not overlap with the target phonologically. By design, this rules out phonological competition, providing strong evidence for automatic activation of cross-linguistic orthographic competitors during spoken word processing. Overall, our findings indicate that not only were participants able to activate orthographic forms of novel words despite conflict with existing letter-sound mappings in their native language, but these words were also able to spread activation to similarly spelled words in the native language, suggesting some integration with the existing lexicon.

These findings suggest that when people hear words in one language, not only do they experience activation of the letters in that language, but that they also experience activation of words in other languages they know or are learning that are spelled similarly. In other words, when an English learner of German hears a German word that is pronounced /zaːgə/ and is spelled 'sage', (conjugation of the verb 'sagen,' meaning 'to say'), the English word 'sage' (pronounced /seɪdʒ/) becomes activated due to its overlapping orthography, despite having minimal phonological overlap with the actual auditory input. This spreading co-activation of phonology and orthography across languages testifies to the highly interactive and dynamic nature of the human language system.

In the present study, since all the phonemes of the novel language also exist in English, we would expect English orthographic mappings to be more easily accessible based on their greater frequency of use. However, participants were able to activate the novel language's orthographic forms, which suggests that the language system may contain a mechanism to increase activation of newly-learned letter-sound mappings, enabling them to match or exceed mappings in the native language. Although we did find that participants activated orthographic forms of spoken words using L2 letter-sound mappings (e.g., 'hane' for the spoken word /gufɔ/), it's unclear whether an orthographic form based on L1 letter-sound mappings, such as 'goofaw' was also activated. The current study was unable to probe for this kind of L1 activation, given that an orthographic competitor, like the word 'goofy,' would also overlap with the target phonologically, obscuring orthographic effects. Overall, it's unlikely that the native language was completely suppressed during the task, given that we saw fixations to competitors in the visual display based on L1 lexical knowledge, which suggests that both the novel language and the native language remained active to some degree.

The present results indicate that orthographic information plays an important role during second language learning and auditory word processing. Future work should investigate how different types of language experience affect learning and processing of a novel orthography. The English monolinguals in the current study had moderate experience with contrasting letter-sound mappings (e.g., the phoneme /s/ can be represented by either 'S' or 'C'), compared to speakers of a transparent language (low experience) or bilinguals (high experience). Transparent languages with nearly one-to-one mappings between orthography and phonology, like Italian and Finnish, may not prepare speakers well for acquisition of contrasting mappings in a novel language, resulting in more cross-linguistic interference. On the other hand, bilinguals should acquire novel mappings faster and exhibit less interference compared to English monolinguals, since bilinguals already have experience with two sets of letter-sound correspondences. Indeed, bilinguals learn novel languages better than monolinguals (Cenoz, 2003; Cenoz & Valencia, 1994; Kaushanskaya & Marian, 2009a, 2009b; Sanz, 2000; Thomas, 1992; Van Hell & Mahn, 1997) and can control phonological competition more efficiently (Bartolotti & Marian, 2012), and it's likely that these advantages will extend to acquisition of a novel orthography. In sum, language perception and learning can be shaped by existing language knowledge across modalities, which emphasizes the highly interactive nature of the language system.

In conclusion, our results show that orthography can be activated online during auditory word processing, and furthermore, that the individual links between letters and sounds can be updated as part of learning a second language. Acquiring the orthographic and phonological systems of a new language is an important step in achieving proficiency. Identifying both how previous experience with language may affect acquisition of novel letter-sound correspondences, and the rate at which novel words become integrated in the lexicon, will help uncover the essential components to successful language learning.

Acknowledgments

This research was funded in part by grant NICHD RO1 HD059858-01A to the third author. The authors would like to acknowledge Anthony Shook, Scott Schroeder, Sarah Chabal, Jen Krizman, and Tuan Lam for comments on an earlier draft of this paper.

References

Bartolotti, J., & Marian, V. (2012). Language learning and control in monolinguals and bilinguals. *Cognitive Science*, *36*, 1129–1147. doi:10.1111/j.1551-6709.2012.01243.x

Bates, E., D'Amico, S., Jacobsen, T., Székely, A., Andonova, E., Devescovi, A., ... Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review*, *10*(2), 344–380. doi:10.3758/BF03196494

Bitan, T., & Karni, A. (2003). Alphabetical knowledge from whole words training: Effects of explicit instruction and implicit experience on learning script segmentation. *Brain Research*, *16*(3), 323–337. doi:10.1016/S0926-6410(02)00301-4

Brysbaert, M., & New, B. (2009). Moving beyond Kucera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990. doi:10.3758/BRM.41.4.977

Cenoz, J. (2003). The additive effect of bilingualism on third language acquisition: A review. *International Journal of Bilingualism*, *7*(1), 71–87. doi:10.1177/13670069030070010501

Cenoz, J., & Valencia, J. F. (1994). Additive trilingualism: Evidence from the Basque Country. *Applied Psycholinguistics*, *15*(02), 195–207. doi:10.1017/S0142716400005324

Coltheart, M. (1981). The MRC psycholinguistic database. *Quartely Journal of Experimental Psychology*, *33*(4), 497–505. doi:10.1080/14640748108400805

Comer, W., & Murphy-Lee, M. (2004). Letter-sound correspondence acquisition in first semester Russian. *Canadian Slavonic Papers*, *46*(1), 23–35.

Davis, C. J. (2005). N-watch: A program for deriving neighborhood size and other psycholinguistic statistics. *Behavior Research Methods*, *37*(1), 65–70. doi:10.3758/BF03206399

Hallé, P. A., Chéreau, C., & Segui, J. (2000). Where is the /b/ in absurde [apsyrd]? It is in French listeners' minds. *Journal of Memory and Language*, *43*(4), 618–639. doi:10.1006/jmla.2000.2718

Jakimik, J, Cole, R., & Rudnicky, A. (1985). Sound and spelling in spoken word recognition. *Journal of Memory and Language*, *24*(2), 165–178. Retrieved from http://www.sciencedirect.com/science/article/pii/0749596X85900221

Johnston, M., McKague, M., & Pratt, C. (2004). Evidence for an automatic orthographic code in the processing of visually novel word forms. *Language and Cognitive Processes*, *19*(2), 273–317. doi:10.1080/01690960344000189

Kaushanskaya, M., & Marian, V. (2008). Mapping phonological information from auditory to written modality during foreign vocabulary learning. *Annals of the New York Academy of Sciences*, *1145*, 56–70. doi:10.1196/annals.1416.008

Kaushanskaya, M., & Marian, V. (2009a). Bilingualism reduces native-language interference during novel-word learning. *Journal of Experimental Psychology: General*, *35*(3), 829–835. doi:10.1037/a0015275

Kaushanskaya, M., & Marian, V. (2009b). The bilingual advantage in novel word learning. *Psychonomic Bulletin & Review*, *16*(4), 705–10. doi:10.3758/PBR.16.4.705

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The language experience and proficiency questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*, 940–967. doi:10.1044/1092-4388(2007/067)

McKague, M, Pratt, C, & Johnston, M. B. (2001). The effect of oral vocabulary on reading visually novel words: A comparison of the dual-route-cascaded and triangle frameworks. *Cognition*, *80*(3), 231–62. doi:10.1016/S0010-0277(00)00150-5

Morais, J, Cary, L, Alegria, J, & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition*, *7*, 323–331. Retrieved from http://www.sciencedirect.com/science/article/pii/0010027779900209

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

Salverda, A. P., & Tanenhaus, M. K. (2010). Tracking the time course of orthographic information in spoken-word recognition. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *36*(5), 1108–1117. doi:10.1037/a0019901

Sanz, C. (2000). Bilingual education enhances third language acquisition: Evidence from Catalonia. *Applied Psycholinguistics*, *21*(01), 23–44. doi:10.1017/S0142716400001028

Thomas, J. (1992). Cognitive processing in bilinguals. In *Advances in psychology* (Vol. 83, pp. 531–545). Advances in Psychology. Elsevier.

Vaden, K., Halpin, H., & Hickok, G. (2009). Irvine Phonotactic Online Dictionary, Version 2.0. [Data file]. Available from http://www.iphod.com.

Van Hell, J. G., & Mahn, A. C. (1997). Keyword mnemonics versus rote rehearsal: Learning concrete and abstract foreign words by experienced and inexperienced learners. *Language Learning*, *47*(3), 507–546. doi:10.1111/0023-8333.00018

Viviani, P. (1990). Eye movements in visual search: Cognitive, perceptual and motor control aspects. *Reviews of Oculomotor Research*, *4*, 353–93. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7492533