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Doubling up: The Influence of Native and Foreign Language Cues in Foreign Language Double Consonant Spelling

Marco van de Ven[1], Abe D. Hofman[2], Elise de Bree[3], Eliane Segers[1], Ludo Verhoeven[1], & Han L. J. van der Maas[2]

[1] Behavioural Science Institute, Radboud University | The Netherlands

[2] Department of Psychology, University of Amsterdam | The Netherlands

[3] Research Institute of Child Development and Education, University of Amsterdam | The Netherlands

Abstract: In this study, we investigated which spelling cues are used in word-medial consonant spelling by learners of English as a Foreign Language (EFL). Previous research has shown that native speakers of English rely on different cues to decide whether a single ("diner") or double consonant ("dinner") needs to be used in word-medial consonant spelling. These cues include phonology, orthography, morphology and lexical frequency. We investigated whether these cues play a similar role in Dutch spellers who are EFL learners, next to similarity of the English target to Dutch. We analyzed dictation task data that was part of an unsupervised digital learning environment for EFL learning. The error analyses revealed that novice EFL spellers mainly used phonological and cross-linguistic cues in consonant doubling. In contrast, more proficient spellers relied less on phonological cues, and relied on morphological cues instead. The EFL spellers did not rely on orthographic cues. Furthermore, spelling difficulty was influenced by the frequency of a word and its similarity with the native-language equivalent, in terms of cognate status (non-cognate/cognate) and consonant doubling. Together, our findings indicate that a higher number of converging cues facilitates spelling for EFL spellers and that their reliance on cues changes as spelling proficiency increases.

Keywords: spelling, double letters, phonology, morphology, second language, spelling models

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Contact: Marco van de Ven, Behavioural Science Institute, Radboud University, 6500 GD Nijmegen | The Netherlands – marco.vandeven@ru.nl

1. Introduction

Being literate in more than one language is important in a world in which written communication is pervasive. In tandem with this growing importance, scientific interest in second or foreign language (henceforth L2) literacy has increased. However, whereas attention has been devoted to L2 reading (for a review, see e.g., Koda, 2007) and L2 writing (for a review, see e.g., Silva & Brice, 2004), this has been less the case for L2 spelling. This limited attention does not match the importance of the ability to spell properly. Spelling quality influences the perception of the quality of written work (Graham, Harris & Hebert, 2011), it eases reading comprehension (Hersch & Andrews, 2012), and the availability of the orthographic information provides an additional cue for word meaning retrieval (Ricketts, Bishop & Nation, 2009).

English is a dominant international language. Spelling proficiency in this language is therefore important. However, little is known about the cues that learners of English as a second language (EFL) use in spelling and whether these cues change over time. We do know that native speakers (L1) of English are influenced by phonological, orthographic and morphological factors in their spelling of English (e.g., Deacon, Leblanc, & Sabourin, 2011; Treiman & Wolter, 2018). In the present study, we examined whether Dutch EFL learners were sensitive to these cues in their spelling in a digital learning environment. The focus was on consonant doubling, a complex aspect of English spelling (Treiman & Wolter, 2018), which induces errors even in L1 adult spellers (e.g., Holmes, & Ng, 1993).

1.1 Research background

1.1.1 L1 & L2 spelling

Spelling research has shown that L1 spelling demands the integration of many different sources of information, as there is an interplay between phonological, orthographic, morphological, and lexical frequency factors (e.g., English: Berg, 2016; Deacon et al., 2011; Samara, Singh & Wonnacott, 2019; Treiman & Boland, 2017; Dutch: De Bree, Van der Ven, & Van der Maas, 2017; French: Pacton et al., 2018; Hebrew: Bar-On & Kuperman, 2019). The contribution of these different cues matches the increased attention to the important role of statistical learning, in other words the ability to extract statistical regularities in (spelling) patterns, during spelling development (Pacton et al., 2005; Samara et al., 2019; Treiman & Kessler, 2014).

Specifically, the Integration of Multiple Patterns (IMP; Treiman & Kessler, 2014) framework distinguishes between the acquisition of orthographic patterns and the connections between these patterns and linguistic features. The framework rests on the assumption that writing systems contain large varieties of patterns, across different (e.g., phonological, morphological and orthographic) dimensions. Based on the distribution of these patterns, language learners may distill context-free or context-dependent cues to predict the spelling of unfamiliar words. Given the multitude of spelling patterns, words may contain multiple patterns which may or may not converge to the same spelling. In English, for example, the spelling of the word "pleasant" contains a phonological cue that leads to a double-consonant spelling: phonologically short vowels (in this case /e/), are typically followed by double consonants. At the same time, the spelling contains morphological and orthographic cues that converge to a single-consonant spelling. In terms of morphology, "please" combined with the suffix "-ant" suggests a single consonant. In terms of orthography, a vowel written as double letters is typically followed by single consonants. IMP claims that the spelling difficulty of a word depends on the number of (phonological, orthographic, or morphological) cues that are in line with its correct spelling. Indeed, De Bree and colleagues (2017) showed that the number of converging linguistic cues can predict spelling difficulty in L1 (Dutch). The question targeted here is whether this process of relying on and using different cues is the same in EFL.

The conditions during L2 spelling acquisition are qualitatively different from those during L1 spelling acquisition. When L1 learners start L1 spelling acquisition, they have generally acquired detailed phonological representations and strong form-to-meaning mappings. In contrast, L2 learners tend to have less specified (detailed) L2 phonological representations and, as a result, "fuzzy" form-to-meaning mappings (Cook, Pandža, Lancaster, & Gor, 2016). L2 spelling might be more error prone due to these less specified phonological representations. This leads to phonology-driven spelling errors in beginning EFL writers (He & Wang, 2009). Furthermore, in contrast to L1 learners, L2 learners already possess orthographic knowledge of their L1 and acquire L2 spoken and written language simultaneously. The L1 skills of the L2 learners could thus affect L2 spelling. Indeed, the studies that have looked into EFL spelling development have found that L1 literacy skills, most notably L1 spelling and reading abilities, are related to L2 reading and spelling development (e.g., Kahn-Horwitz, Sparks & Goldstein, 2012; Li, McBride-Chang, Wong & Shu, 2012; Sparks, Patton, Ganschow, Humbach & Javorksy, 2008). Although these findings suggest an influence of L1 literacy skills on L2 spelling, they do not provide information on the way different sources of information influence L2 spelling.

One question is whether EFL learners are sensitive to the different cues in English spelling. Instruction in EFL spelling is often limited, which means that there is no explicit instruction about these spelling patterns and related cues. Similarly, instructors are not necessarily aware of these, often implicit, cues involved in spelling (Treiman & Kessler, 2014), which means that students will have to discover the spelling patterns and cues themselves. It is also not known if and to what extent characteristics of the L1 and cross-linguistic overlap play a role in L2 spelling. It has been proposed that L1 positively influences L2 spelling when similarities between the languages exist (e.g., Schwartz, Ibrahim, & Kahn-Horwitz, 2016), and negatively when there are large differences between the languages and when the learner has not acquired sufficient knowledge of the L2 (Figueredo, 2006). A detailed account of how different L1 and L2 cues influence L2 spelling is, however, lacking. This is needed to establish whether L1 learners are sensitive to L2 spelling cues and whether L1 cues influence the spelling outcomes. Such knowledge can, in turn, inform models of L1 as well as L2 spelling acquisition.

L2 phonological, orthographic and morphological cues in L2 consonant doubling

In order to address the contributions of L1 and L2 cues to spelling, we focused on spelling single ("diner") or double word-medial consonants ("dinner"). Double word-medial consonant spelling, consonant doubling, is one of the most complex aspects of English spelling: it induces errors across levels of education (e.g., Holmes & Ng, 1983; Pollock & Zamora, 1983; Yannakoudakis & Fawthrop, 1983), yet more frequently in less able spellers (Holmes & Ng, 1983). Correctly spelling targets with or without double consonants in L1 English is dependent on phonological, orthographic, morphological, and lexical frequency factors. These will be discussed before turning to the potential influence of L1 cues to L2 English consonant doubling.

First of all, phonological cues may influence consonant doubling. In bisyllabic words, generally single-consonant spellings are preferred after phonologically long vowels, as in "diner" (/ˈdaɪnə/), and double-consonant spellings after phonologically short vowels, as in "dinner" (/ˈdɪnə/). Hence, the phonological duration of the vowel preceding the word-medial consonant may influence the spelling of the medial consonants, given that L1 spellers tend to prefer single-consonant spellings, and single-consonant spellings are typically preceded by phonologically long vowels (Cassar & Treiman, 1997). More importantly, word-medial consonants are spelled more accurately as single or double consonants if this spelling pattern is phonologically congruent (i.e., if there is a coupling of single-consonant spellings and phonologically long vowels (/aɪ/ followed by <n> in "diner") or double-consonant spellings and phonologically short vowels (/ɪ/ followed by <nn> in "dinner")) (Cassar & Treiman, 1997; Deacon et al., 2011; Treiman & Wolter, 2018). This effect increases with proficiency (Treiman & Boland, 2017; Treiman & Wolter, 2018). Furthermore, L1 spellers show this phonological congruence in choosing between single and double-consonant spellings of pseudowords (Cassar & Treiman, 1997; Deacon et al., 2011) and this effect appears to increase with proficiency in Chinese and Korean EFL learners (Yin, Joshi, Li, & Kim, 2020).

Orthographic cues may also influence consonant doubling. Single-consonant spellings (*diner*), in general, are more frequent than double-consonant spellings (*dinner*; Cassar & Treiman, 1997). It has been found that (young) L1 spellers are sensitive to this orthographic frequency pattern, both in words and pseudowords (Cassar & Treiman, 1997; Deacon et al., 2011). A more context-sensitive orthographic cue is the association between vowel quality and the number of medial consonants: double-consonant spellings are more frequent when the preceding vowel is spelled as a single (rather than a double) letter (e.g., in "rubber"). L1 spellers use this orthographic cue to choose between single and double word-medial consonant spellings (Cassar & Treiman, 1997; Hayes, Treiman, & Kessler, 2006; Treiman & Boland, 2017; Treiman & Wolter, 2018). Children become sensitive to this context-sensitive orthographic pattern later than to orthographic frequency of single versus double consonants in general (Deacon et al., 2011). A third orthographic cue also concerns the specific orthographic (i.e., graphotactic) context. A corpus study by Treiman and Boland (2017) established that word-medial consonant doubling is very likely before <en>, <er>, <est>, and <ing> (e.g., in "flipper"), somewhat likely before <age>, <is> and <ow> (e.g., in "village") and unlikely before <ic>, <id>, and <it> (e.g., in "music"). These cues from the following orthographic context appear to be used to choose between single- and double-consonant spellings in both L1 (Treiman & Boland, 2017) and Chinese and Korean EFL (Yin et al., 2020) users. In terms of orthography, then, the accuracy of word-medial consonant spellings may be influenced by the orthographic representation of the word-medial consonants, the spelling of the preceding vowel, and the orthographic congruency of the consonant spellings.

Single-consonant spellings (e.g., "body") may generally be preferred to double-consonant spellings (e.g., "tennis"). More importantly, the orthographic context can be *congruent* with the word-medial consonant spellings (a double consonant followed by a doublet-encouraging orthographic context, as in "pepper" or a singleton followed by a doublet-discouraging context, as in "music"), *neutral* (no relevant cues from the following orthographic context, as in "legal"), or *incongruent* (a singleton followed by a doublet-encouraging context, as in "honest" (with the doublet-encouraging suffix <est>)). Likewise, the spelling of a word-medial consonant may be influenced by its congruency with the spelling of the preceding vowel, which may be *congruent* (a singleton preceded by an orthographically long vowel, as in "heating") or *incongruent* ("future").

Orthographic cues may conflict with phonological cues. For example, orthographic cues may favor a single medial consonant, whereas phonological cues favor a doublet spelling. In a target such as "rabbit" /ˈræbɪt/, for instance, consonant doubling is likely after the phonologically short vowel /æ/ and unlikely before <it>. Conversely, in a word such as "cottage" /ˈkɒtɪdʒ/, double and single consonant spellings are favored both by orthographic and phonological cues. The orthographic cue is that consonant doubling is likely after <age> and the phonological cue that consonant doubling is unlikely after phonologically short vowels. Thus, both orthographic and phonological cues contribute to L1 double-consonant spelling. It is unclear to what extent these cues influence EFL consonant doubling. Possibly, when there is a conflict between linguistic cues, EFL consonant doubling may be influenced by those factors that play similar roles in L1 consonant doubling (for example, phonological cues and a general single-consonant spelling bias; e.g., Cassar and Treiman, 1997).

A third factor influencing consonant doubling is morphology. In some words, consonant doubling may arise as a result of inflection (e.g., "flip-flipper", where consonant doubling arises due to the suffix <er>) or affixation (e.g., "day-midday", where consonant doubling arises due to the prefix <mid>). In these cases, phonology, orthography and morphology align to produce a single word-medial consonant spelling. To illustrate, "flipper" contains a double word-medial consonant because adding the suffix <er> would result in an orthographic representation "fliper" that matched the phonological representation /ˈflaɪpə/. Hence, the word-medial consonant is doubled. However, some inflected or affixed words do not result in consonant doubling, as in "skate-skater". In such cases, morphology affects root congruency, and as a result there is a conflict between phonological and orthographic cues on the one hand, and morphological cues on the other. L1 children tend to spell these latter targets morphologically consistently, as *"kniter" instead of "knitter", which would be phonologically and orthographically congruent (Deacon et al., 2011), but do show phonological congruency in monomorphemic targets ("simmer"). In terms of morphology, root congruency, which may be *congruent* (e.g., "cook-cooker" /ˈkʊkə/, which is phonologically incongruent), *neutral* (monomorphemic) or *incongruent* ("knit-knitter", where an additional <t> is inserted before the suffix <er>), may thus influence the spelling of word-medial consonants, and support or interfere with the effects of phonological and orthographic congruency.

Finally, token/lexical frequency could influence the correct spelling of word-medial consonants. Exposure frequency is likely to increase lexical entrenchment (Diependaele, Lemhöfer, & Brysbaert, 2013) and lead to a higher lexical quality, as suggested by Kim, Crossley, and Kyle (2017). This could be due to learners' familiarity with the meaning and/or form of a given word. Studies have indicated that frequency indeed influences L1 spelling accuracy as well as recognition (English: Abrams & White, 2011; Mitchell, Kemp & Bryant, 2011; Dutch: De Bree, Geelhoed, & Van den Boer, 2018; French: Lété, Peereman & Fayol, 2008). In addition to L2 (English) cues, cues from the L1 are likely to influence consonant-doubling. In fact, L2 learners of English may primarily rely on L1 spelling cues, given that orthographic cues to L2 English consonant doubling are unlikely to be taught explicitly, at least in the Netherlands.

1.1.2 L1 cues in L2 consonant doubling

One first L1 cue might be whether targets are cognates with L2. For instance, the English word "model" is a cognate with Dutch "model": both words have the same origin and meaning. In contrast, English "city" is not cognate with the Dutch word "stad". Cognates are easier to acquire than non-cognates (e.g., De Groot, 1992; De Groot, Dannenburg, & van Hell, 1994) and might thus be spelled correctly more often than non-cognates. A second L1 cue is whether the pattern of word-medial consonant doubling resembles that in L1 spelling, and is related to the relative orthographic depth of the L1 compared to the L2 (Figueredo, 2006). Learners with relatively transparent L1 orthographies and consistent phoneme-to-grapheme mappings (e.g., Dutch) tend to rely more on phonological cues to spelling than those of L1s with relatively opaque L1 orthographies and inconsistent mappings (e.g., English). This impacts on foreign language literacy (e.g., McBride-Chang et al., 2005; Wade-Woolley, 1999).

In addition, L1 consonant doubling patterns may enhance L2 consonant doubling in case of cross-linguistic congruency. For example, "leader" shares single-consonant spelling with its Dutch counterpart "leider", potentially enhancing L2 learners' spelling of word-medial consonants in such words. Interestingly, there may be a conflict between L1 and L2 cues for consonant doubling, as in English "butter" with Dutch counterpart "boter". The Dutch word contains a long vowel and therefore a single consonant, whereas the English form contains a short vowel and subsequent double consonant. In case of a conflict, reliance on L1 orthography could render incorrect EFL consonant-doubling. Such cross-linguistic incongruences may lead to incorrect spellings of the word-medial consonants.

1.2 Current study

In the present study, we assessed to what extent L1 (Dutch) and L2 (English) cues contribute to the spelling of word-medial consonants by EFL spellers. We collected and analyzed data from a word dictation task, *Ducktator*, in the digital learning environment *Words&Birds* (Prowise, 2014). This is a computer-adaptive system that is used by many primary and secondary school students in the Netherlands to practice their English language skills by means of unsupervised learning. In the dictation task, students heard a sentence that contained a target word, followed by the target word in isolation. Students were instructed to provide the correct spellings for the target words. The items were administered adaptively based on the response times and accuracies of the students' previous responses (as explained in the Methods section). A rating system assigns a difficulty to each target in the game, with a higher rating referring to a more difficult target. Our basic design is similar to that of De Bree et al. (2017) who investigated the contribution of different cues to Dutch children's spelling in Dutch using a similar type of digital learning environment.

The native language of the students in our study is Dutch. Compared to English, Dutch has a relatively transparent orthography (Seymour, Aro, & Erskine, 2003). Further, similar to English, the number of word-medial consonants relates to the preceding vowel quality. More specifically, short vowels are followed by word-medial double consonants ("mannen" "men" with short vowel /ɑ/) and long vowels are followed by a single word-medial consonant ("manen" "moons" with long vowel /a:/; Hilte & Reitsma, 2011). The Dutch word-medial single and double consonant spelling rules are generally taught in Grades 2 and 3 (e.g., Hilte & Reitsma, 2011; Landerl & Reitsma, 2005).

Dutch learners thus need to know the length of the vowel preceding a word-medial consonant for their L1 spelling. It is therefore surprising that Dutch EFL learners have been found to make more orthographic spelling errors, spelling errors that violate rules of English orthography, than phonological ones, errors that violate rules of English phonology (Schijf, 2009), although they have been taught to especially rely on spelling to deal with consonant doubling in Dutch. This suggests that they may rely on phonological EFL cues in EFL consonant doubling. Further, similar to English, morphological congruency influences the spelling of Dutch medial consonants (De Bree et al., 2018). Hence, Dutch EFL spellers may also learn to use morphological cues to English consonant doubling.

On the basis of these findings, one expectation was that single-consonant spellings (e.g., "diner") would be preferred by the EFL learners over double-consonant spellings ("dinner"), similar to the preference shown by L1 spellers (Deacon et al., 2011). This would lead to fewer consonant errors and lower item difficulty estimates for words with single-consonant spellings. More importantly, we expected fewer consonant errors and lower item difficulty estimates for phonologically congruent words (double consonants preceded by phonologically short vowels (/ˈdɪnə/) and singletons preceded by phonologically long vowels (/ˈdaɪnə/)), regardless of students' English spelling proficiency, given that Dutch has a relatively transparent orthography (e.g., Seymour et al., 2003) and that similar phonological effects occur in Dutch.

We predicted a stronger effect of orthographic and morphological congruency for students with higher spelling proficiency (and thus for items with higher item ratings), since these effects are language specific and language learners may only be able to use these cues after sufficient language exposure. Words with orthographically and/or morphologically congruent word-medial consonant spellings may thus also have somewhat lower item difficulty estimates. Furthermore, we expected fewer consonant doubling errors and lower item difficulties for items with more linguistic cues converging to the correct choice between single- and double-consonant spellings, in line with De Bree and colleagues (2017). In addition, we expected higher item difficulty estimates for words consisting of more characters, for words with lower lexical frequencies (e.g., Coltheart et al., 2001; Seidenberg, 1992), and for non-cognates compared to cognates (De Groot, 1992; De Groot et al., 1994).

2. Method

2.1 Participants

The participants were students in primary and the beginning of secondary education who were enrolled in schools that bought *Words&Birds* (including *Ducktator*) licenses. The families as well as the schools gave permission for the use of their *Words&Birds* data for scientific purposes. The schools agreed to inform the participants of their right to refuse the use of their children's data. In the Netherlands, instruction/teaching of English is compulsory from Grade 5 onwards, although some schools start teaching English at earlier grades. The implementation of teaching English in primary school varies considerably (De Bot, 2014; Unsworth, Persson, Prins & De Bot, 2015).

Table 1. Distribution of students across grades for the current sample (N = 19,373)

Grade	N	Percentage
3	257	1
4	884	5
5	2191	11
6	3541	18
7	5021	26
8	6576	34
9	903	5

The data for this study were collected from January 2015 until March 2017. During this period, *Ducktator* was played by 19,373 students, who played 12.93 of our target items on average. The gender distribution of our sample was 52 percent male; 48 percent female. The distribution of students across grades is shown in Table 1. These distributions indicate that more difficult items are played by students in the higher grades. Moreover, it can be seen that most 6th grade students and most items have estimated ratings close to zero. The students' mean age was 11;0 (SD = 1;8); their age distribution is shown graphically in Figure 1. With respect to the type of education and setting in which *Words&Birds* was used, 86.04% of the students were in primary education, 0.60% in special primary education, 5.44% in secondary education, 1.28% students in a remedial teaching institute, and 6.63% of the students had a personal account.

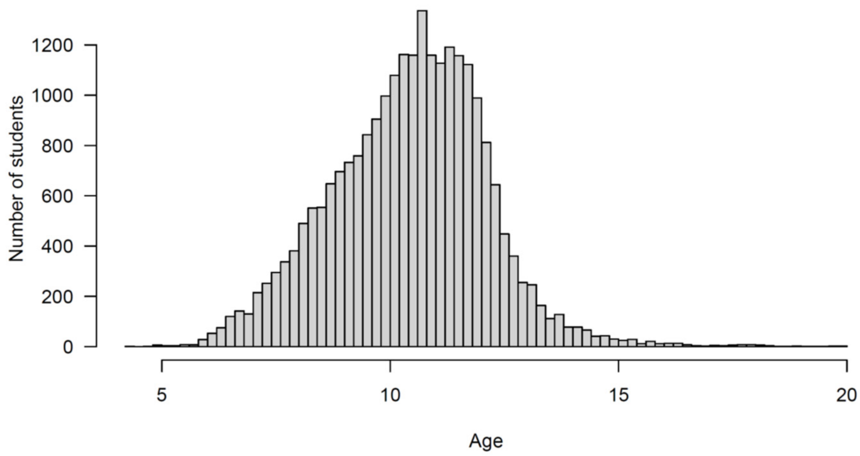


Figure 1: Age distribution of the students included in the current sample (N = 19,373)

2.2 Instruments

2.2.1 Adaptive practicing method

In the main screen, the various games in *Words&Birds* are presented as birds flying in the air, where each bird represents a single game. Students' game progress is reflected by the birds' flight heights: As students reach a higher ability level for a given game, the corresponding bird reaches a higher altitude. Once students click on a bird, the corresponding *Ducktator* game is initiated and they are presented with the game interface shown in Figure 2. When students click on the rectangle, they hear a carrier sentence that contains a target word, followed by the same target word in isolation. Subsequently, students are instructed to type the correct spelling of the target word in a white typing box, which appears after sound offset. Students can listen to a given recording multiple times, although they need to respond within 20 seconds. White blocks in the bottom right corner indicate the passing of time; each second a single block disappears. After providing an answer, coins are added or subtracted from the current score, depending on the accuracy and speed of the response (see "Adaptive item selection" for more details). Students can use the collected coins to buy eggs to decorate their prize nests. Hence, students are motivated to respond quickly and accurately and guessing behavior is discouraged. If students do not know the answer, they can skip the question by clicking on the question mark. This does not affect their coin total. Students do receive feedback after clicking on the question mark. Feedback, after clicking on the question mark or providing an incorrect response, always consisted of only the correct spelling of the target word. Each game session consists of ten items; subsequently, students return to the main landing page automatically, although students may choose to end a session earlier.

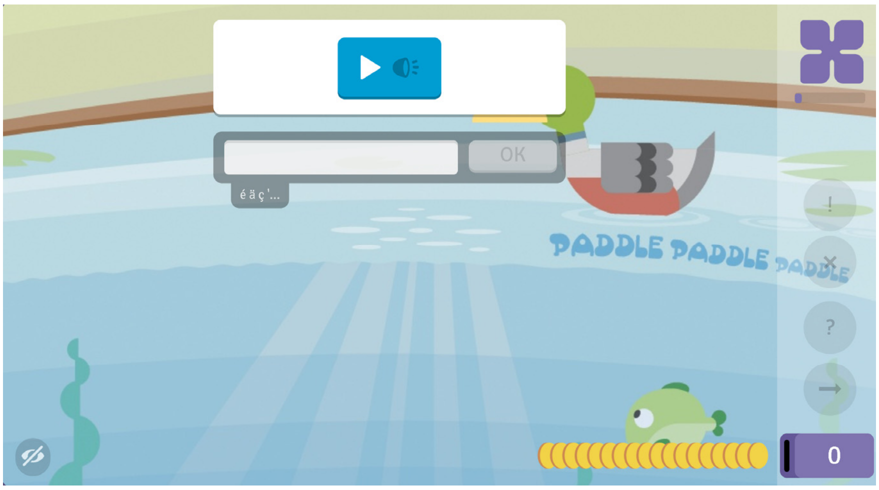


Figure 2: Illustration of the Ducktator game interface

Note. The Play button allows the user to play the audio. A response can be typed in the white bar and confirmed by clicking OK. By clicking on the question mark (near the fish), the current question is skipped. The bar on the right indicates the passing of time and the current score.

2.2.2 Adaptive item selection

The items in *Words&Birds* are administered adaptively based on the students' estimated ability (rating) and the estimated item difficulty. More specifically, *Words&Birds* uses computerized adaptive testing (Wainer, Dorans, Flaugher, Green, & Mislevy, 2000) with two important adjustments (as described by Klinkenberg, Straatemeier, & Van der Maas, 2011). First of all, *Words&Birds* uses a high speed high stakes scoring rule - which is communicated to the players through the coins that they can collect - and works as follows. If we assume a response time limit of twenty seconds, users obtain a score of +5 after providing a correct response in 15 seconds and score of -5 after providing an incorrect response in 15 seconds. This score function is defined as follows:

$$S_{pi} = (2x_{pi} - 1)(d - t_{pi}),$$

where Spi denotes the score of player p on item i, x is either 1 (correct) or 0 (incorrect), d is the deadline and t is the response time. Thus, users are rewarded for fast correct responses and penalized more heavily for fast than for slow incorrect responses (Maris & Van der Maas, 2012). The use of response times allows to select items with expected probability correct of approximately .75 (for further details, see Hofman et al., 2018). Based on the implemented scoring rule and the estimated player and item rating, an expected score can be calculated for each match between an item and a player (in a way similar to IRT modelling). This expected score is defined as follows:

$$\mathcal{E}(S_{pi}) = d\ \frac{\exp\left(2d(\theta_p - \beta_i)+1\right.}{\exp\left(2d(\theta_p - \beta_i)-1\right.} - \frac{1}{\theta_p - \beta_i},$$

where d is the deadline, θ_p is the player ability and β_i is the item rating (see Maris & Van der Maas, 2021 for more details). Second, using the Elo algorithm (see Klinkenberg et al., 2011 for more details), the ratings of both players and items are updated after every response as follows:

$$\theta p \rightarrow \theta p + K(Spi - \mathcal{E}(Spi)),$$

$$\beta i \rightarrow \beta i - K(Spi - \mathcal{E}(Spi)),$$

where K is a scaling factor that determines the weight of the new update on the estimated parameter. Hence, if a player performs better than expected (on a given item) the rating will increase and the item rating will decrease, and vice versa. New users and new items enter the program with a predetermined starting value and when new data is collected the ratings will stabilize, which happens quite quickly, given the large number of players. This method is used to circumvent the necessity of pretesting all items before they enter the program. Figure 3 shows the distributions of the user and item rating estimates obtained.

2.2.3 Stimuli

The item bank of *Ducktator,* which targets English spelling practice in general, consisted of 1499 items. The criteria for the included words were disyllabic words that take word-initial stress and that contain word-medial consonants surrounded by vowels, with potential for consonant doubling (i.e., b, c, d, f, g, k, l, m, n, p, r, s, t, w, and z), as indicated by the occurrence of their corresponding doublets in the CELEX database (Baayen, Piepenbrock, & Gulikers, 1995). This resulted in a subset of 144 items (see the online Appendix). The (token) frequencies of the English target words, again taken from the CELEX database, ranged from 0 through 967 per million word tokens (henceforth *word frequency*; mean = 57.33; SD = 111.68).

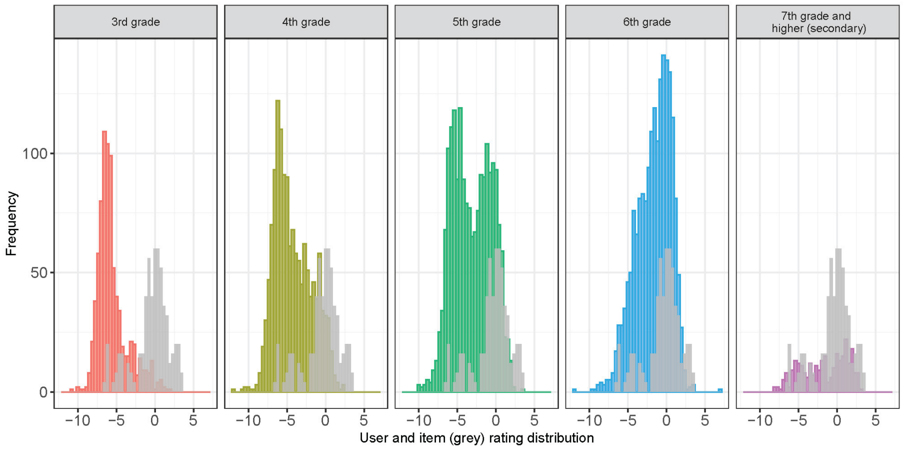


Figure 3: Frequency distribution of the user rating estimates (colored bars) and item rating estimates (grey bars) across grades

Cognates

We also determined to what extent the target words and Dutch equivalents were cognates by first creating a categorical variable that indicated whether they were cognates (e.g., English "station" and Dutch "station") or not (e.g., English "writer" and Dutch "schrijver"; henceforth *cognate status)*. Next, we created a continuous variable to indicate the orthographic similarity between the English target words and their Dutch equivalents. More precisely, we computed the Levenshtein distances (Levenshtein, 1966) between these word pairs, which indicated the number of character modifications required to change the one into the other. The Levenshtein distances ranged from 0 (full cognates) to 11 (non-cognates; mean = 3.55, SD = 2.70).

L1-L2 congruency

Moreover, we determined whether the spelling of the cognates or near-cognates contained equal numbers of word-medial consonants. The variables *Levenshtein Distance, cognate status*, and *doubling congruency* are highly correlated by design (full cognates have a Levenshtein Distance of zero and always contain equal numbers of medial consonants). To resolve this issue, we first compared the contributions of *Levenshtein Distance* and *cognate status* by observing the AIC values for models containing either of these two variables. Since these models showed lower AIC values for *cognate status*, we henceforth discarded *Levenshtein Distance* in our models. As a second step, *cognate status* and *doubling congruency* were merged into a single numeric predictor named *cross-linguistic congruency*, with the values -1 (near-cognates with different consonant doubling patterns; e.g., “butter”-“boter”), 0 (i.e., cases where the L1 and L2 words are etymologically distinct and cross-linguistic cues were thus absent; e.g., “foggy”-“mistig”), 1 (near-cognates with similar consonant doubling patterns; e.g., “leader”-“leider”), and 2 (full cognates; e.g., “meeting”-“meeting”). Subsequently, we used the criteria formulated by Treiman and Boland (2017) to assess whether our target words contained doublet-encouraging or discouraging phonological and/or orthographic (including graphotactic) cues.

Phonological congruency

In terms of phonology (henceforth *phonological congruency*), we made a distinction between VCC-congruent spellings (i.e., phonologically congruent double consonants) and VC-congruent spellings (i.e., phonologically congruent single consonants; e.g., “city”); VCC- and VC-incongruent spellings were merged because there was only one VCC-item with an incongruent spelling (i.e., phonologically incongruent double consonant spelling in “pizza”).

Orthographic congruency

Regarding the orthographic cues, on the basis of Treiman and Boland (2017), words with double consonants were coded as congruent when followed by <en>, <er>, <est>, <ing>, <age>, <is> or <ow> (e.g., “message”). They were coded as incongruent when words with a double consonant were followed by <ic>, <id> or <it> (e.g., “rabbit”). The reverse was true for words with single consonants. Words that did not contain any of these patterns were coded as neutral (e.g., “villa”).

Morphological congruency

In addition, we determined the *root congruency* of our target words using the criteria provided by Deacon et al. (2011). More precisely, a word was coded as congruent when the spelling of its medial consonant(s) matched the spelling as resulting from a combination of its root and affix, and as incongruent when there was a mismatch between these spellings. For example, the word "meeting" consists of the root "meet" and the affix "-ing", which combined matches the spelling of "meeting". In contrast, the word "winner" consists of the root "win" and the affix "-er", which leads to the combined spelling "winer" (mismatching the correct spelling "winner"). Other words were coded as neutral (e.g., "station").

Finally, we determined, for each target, the number of cues converging to the correct spelling of the word-medial consonant(s). The number of converging cues ranged from 1 to 5 (mean = 2.80; SD = 1.08). Examples of items across the different linguistic and cross-linguistic dimensions are provided in Figures 4 and 5. For example, Figure 4 illustrates that "pepper" contains a double medial consonant preceded by a vowel (i.e., VCC), is phonologically congruent (i.e., it contains a short vowel followed by a double consonant) and orthographically congruent (i.e., <er> tends to be preceded by a double consonant). Likewise, Figure 5 shows that "winner" contains a doublet, similar to the Dutch equivalent "winnaar", although the double consonant spelling is not morphologically congruent (i.e., the root "win" combined with the suffix "er" results in the incorrect spelling "winer"). As can be seen in these figures, some of the items contain contradictory cues, which allows us to directly compare the contributions of the different cues to the spelling of word-medial consonant(s).

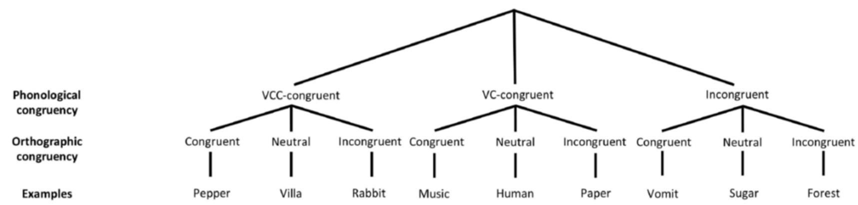


Figure 4: Tree diagram depicting phonological and orthographic congruency for the items in Ducktator

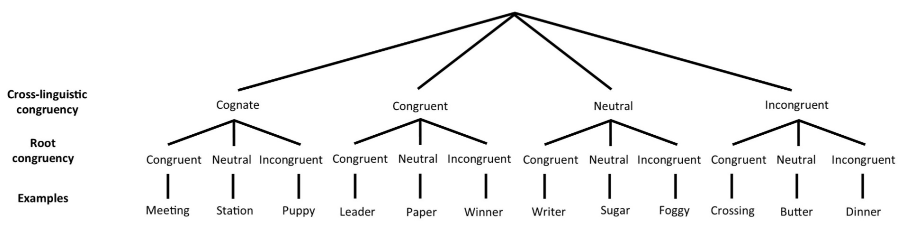


Figure 5: Tree diagram depicting cross-linguistic congruency and root congruency for the items in Ducktator

In addition, Table 2 provides an overview of all predictors included in the analyses and their corresponding (linguistic) cues.

Table 2. Overview of targeted cues and their corresponding predictor(s)

Targeted cue	**Associated predictor(s)**
Phonological congruency	Phonological congruency
Orthographic congruency	Orthographic congruency; Orthographic vowel congruency
Cross-linguistic congruency	Cross-linguistic congruency (L1-L2 consonant doubling congruency & cognate status combined); Levenshtein Distance
Morphological congruency	Root congruency
L2 spelling ability	Item rating

2.2.4 Preliminary data analysis

Below, we report the analyses of two separate, related datasets, namely (1) a dataset concerning error classification of individual spelling errors produced by the students playing *Words&Birds* and (2) a dataset consisting of the item difficulties (i.e., item ratings) of the target items in *Words&Birds*. The error classification analysis focused on incorrectly spelled items and was used to assess to what extent factors related to consonant doubling influence the likelihood of the occurrence of a consonant doubling error (i.e., an error in which a double consonant was spelled as a singleton or vice versa) rather than other types of spelling errors. The item ratings analysis was used to assess the extent to which factors related to consonant doubling influence general spelling difficulty. Depending on the dataset, different analyses were used. The error classification data were analyzed using logistic mixed effects regression, including random effects for *item*. We did not include a random intercept for *participant* because (1) the number of items per participant was too limited and (2) there was a dependency between *participant* and *item*, as a result of adaptive item selection. We used backward stepwise regression to eliminate non-significant variables/interactions. The item rating data, on the other hand, were analyzed using simple linear regression. We decided not to eliminate non-significant variables in these analyses because item ratings may vary across time (due to the algorithms used for adaptive item selection; see above), as may the results from the regression analyses. Instead, we decided to refit the regression analysis, including all variables, across fourteen months, to assess the stability of the item ratings as well as the statistical results, given that these ratings fluctuate with time. For each time point, we fitted the same regression model with updated ratings.

The cues that were included in our analyses partly consisted of continuous variables (e.g., *word frequency*). In addition, we included several categorical variables of ordinal scale (e.g., *orthographic congruency*, *root congruency* and *cross-linguistic congruency*). Given the ordinal nature of these variables, they were converted into numeric variables. For example, the variable *cross-linguistic congruency* contained the values -1 (near-cognates with different consonant doubling patterns; e.g., "butter"-"boter"), 0 (i.e., cases where the L1 and L2 words are etymologically distinct and cross-linguistic cues were thus absent; e.g., "foggy"-"mistig"), 1 (near-cognates with similar consonant doubling patterns; e.g., "leader"-"leider"), and 2 (full cognates; e.g., "meeting"-"meeting"). Importantly, the variable *phonological congruency* was not truly ordinal, as it contained the levels VCC-congruent, VC-congruent and incongruent. Hence, this variable was included as a categorical variable in our statistical models.

3. Results

3.1 Error classification steps

In total, the data set contained 173,559 correct spellings, 75,375 spelling errors, 1,143 task execution errors (e.g., performing a translation instead of a spelling task) and 400 empty responses for the 144 items selected. The spelling of the English target words resulted in different types of errors, including nonsense responses (e.g., "8+25" instead of *robot*). As a first step, we removed responses that were provided by only one participant (e.g., "calkin" as a possible spelling for *cotton*).

Second, we computed, for each response, the Levenshtein distance between the target word and the response provided. The average Levenshtein distance for the incorrect responses was 1.537 (SD = 0.84). We selected incorrect spelling responses for which the Levenshtein distance between the response and the target word was equal to one, reducing the dataset to 10,833 consonant doubling errors (e.g., "vommit" instead of *vomit*) and 17,430 non-consonant doubling errors (e.g., "mody" instead of *moody*). We thus focused on spelling errors in which only one grapheme was spelled incorrectly and avoided more complex spelling errors in which the occurrence of consonant doubling errors may interact with the occurrence of other spelling errors (e.g., “grandmy” instead of *granny*, where the single <n> may be due to the following consonants). Two items (“denim” and “ferret”), for which there were only a few responses in our data, did not contain any incorrect responses that met the abovementioned criteria. They are therefore absent in the error analyses presented in this study. The items with the largest and smallest proportions of doubling errors are listed in Table 3.

Table 3. The items from Ducktator with the largest and smallest proportions of doubling errors respectively

Most frequent errors	**Proportion**	**Least frequent errors**	**Proportion**
Linen	.94	Moody	.00
Desert	.89	Ferry	.00
Luggage	.80	Writer	.00
Colour	.56	Stomach	.00
Vomit	.42	Honest	.03

3.2 Error classification results

We applied mixed effects logistic regression with the logit link function (e.g., Jaeger, 2008) in R (R Development Core Team, 2017)[1]. Visualizations of the predicted probabilities derived from the regression models reported in this study were created using the R package sjPlot (Lüdecke, 2018). We included the dependent variable *doubling error* (yes/no; no on the intercept), and the independent variables *word frequency* (frequency per million word tokens), *consonant doubling* (yes/no; no on the intercept), *doubling congruency* and *cross-linguistic congruency*, with the values -1 (near-cognates with different consonant doubling patterns; e.g., “butter”-“boter”), 0 (i.e., cases where the L1 and L2 words are etymologically distinct and cross-linguistic cues were thus absent; e.g., “foggy”-“mistig”), 1 (near-cognates with similar consonant doubling patterns; e.g., “leader”-“leider”), and 2

[1] Based on comments from an anonymous reviewer, separate models were fitted for targets with double consonant spellings and single consonant spellings. Since these models showed similar results compared to the combined model, this rules out the possibility of an underlying three-way interaction with *consonant doubling*.

(full cognates; e.g., "meeting"-"meeting"). In addition, we included the numeric variables *orthographic congruency* (-1 for incongruent, 0 for neutral, and 1 for congruent), *root congruency* (-1 for incongruent, 0 for neutral, and 1 for congruent), *item rating* (where higher item rating values correspond to more difficult items) and the categorical variable *phonological congruency* (incongruent, VCC-congruent, or VC-congruent; incongruent on the intercept). We used a backwards stepwise selection procedure, in which predictors were removed that did not attain significance. In all regression analyses reported in this study, continuous variables were centered and standardized to a mean of zero (Belsley, Kuh, & Welsch, 1980). We included a random intercept for *item.* Further, the beta values (i.e., logits) in our models estimated the probability of producing a consonant-doubling error. The regression results are provided in Table 4; percentages of doubling errors across categories can be seen in Table 5.

Table 4. Logistic regression analysis explaining the occurrence of consonant versus non-consonant doubling errors for incorrect responses with Levenshtein Distances of one

Predictor: Random effects	**Variance**	**SD**	
Item	2.943	1.72	
Predictor: Fixed effects	***β***	***Z***	***p***
Intercept	-0.110	-0.29	.77
Item rating	-0.337	-2.86	.004*
Word frequency	-0.250	-1.49	.14
Cross-linguistic congruency	-0.359	-2.09	.04*
Root congruency	-0.026	-0.08	.94
Phonological congruency (VCC-congruent)	0.357	0.81	.42
Phonological congruency (VC-congruent)	-2.465	-5.30	.0000001*
Item rating x Word frequency	0.117	2.80	.005*
Item rating x Cross-linguistic congruency	0.180	4.60	.000004*

Item rating x Phonological congruency (VCC-congruent)	-0.089	-0.78	.44
Item rating x Phonological congruency (VC-congruent)	0.238	1.97	.049*
Item rating x Root congruency	-0.280	-4.17	.00003*

Note. * indicates significance at the p <.05 level.

Table 5. Percentages of doubling errors across categories

Variable	**Doubling errors (%)**
Cross-linguistic congruency	
Incongruent	67.03%
Neutral	26.21%
Congruent	54.61%
Cognate	37.64%
Phonological congruency	
Incongruent	35.91%
VCC-congruent	58.41%
VC-congruent	13.27%
Root congruency	
Incongruent	61.57%
Neutral	32.51%
Congruent	45.24%

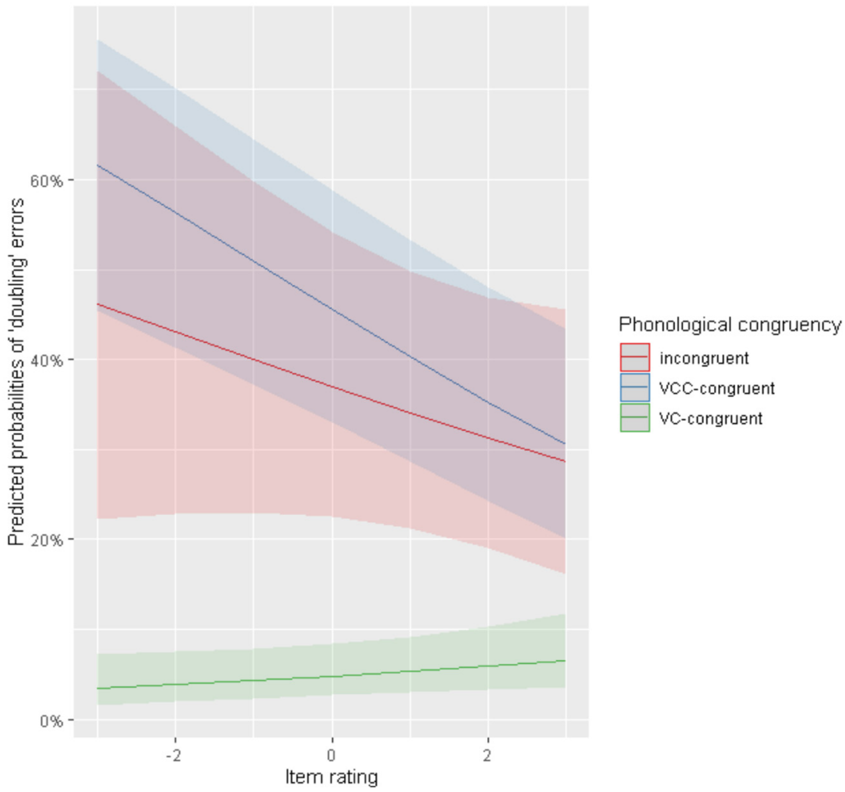


Figure 6: Combined effects of item rating and phonological congruency on the predicted probabilities of doubling errors

First of all, we found main effects of and an interaction between *phonological congruency* and *item rating* (see Figure 6), which indicated that words with phonologically congruent single-consonant spellings resulted in fewer consonant doubling errors (compared to incongruent and phonologically congruent double-consonant spellings), but to a smaller extent if these words had relatively high item ratings (and were thus difficult to spell).

Secondly, we found a two-way interaction between *root congruency* and *item rating*, indicating that words with morphologically congruent spellings resulted in fewer consonant doubling errors if these words had high item ratings and the reverse was true for words with morphologically incongruent spellings (see Figure 7).

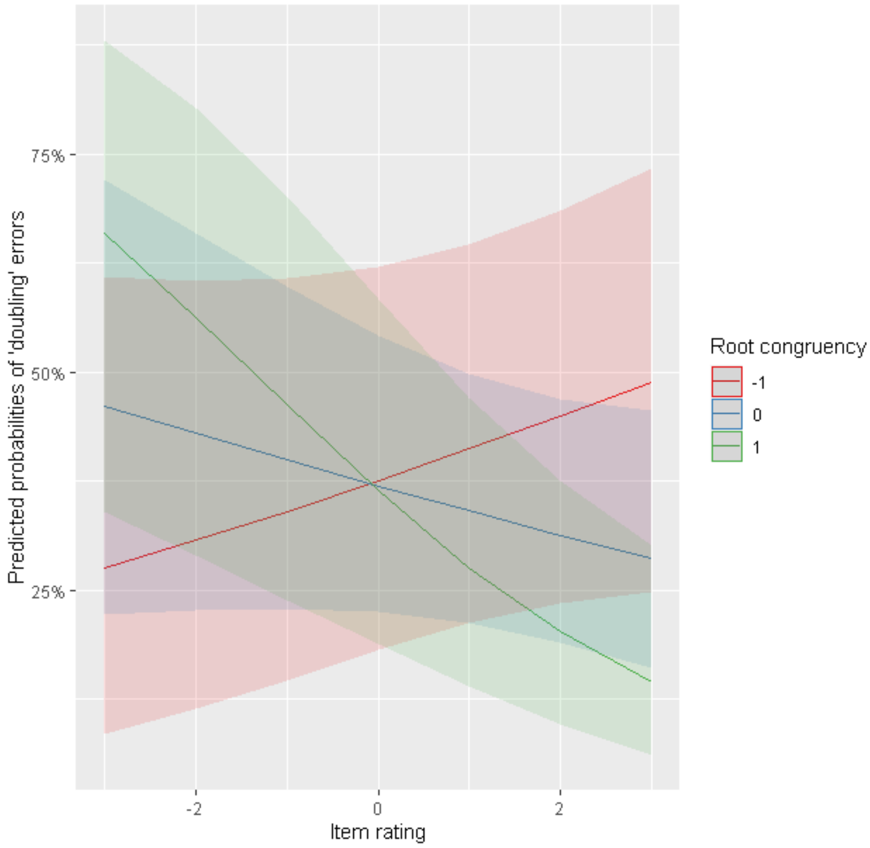


Figure 7: Combined effects of item rating and root congruency on the predicted probabilities of doubling errors

In addition, we found a two-way interaction between *word frequency* and *item rating*, which is visualized in Figure 8. This interaction indicated that relatively low item ratings elicited more consonant doubling errors for items with low or intermediate word frequencies. For high frequency items, this effect appears to be marginal at best.

Finally, we found an interaction between *cross-linguistic congruency* and *item rating*, which indicated that words with more cross-linguistic overlap resulted in fewer consonant doubling errors, although this effect decreased or even reversed for words with very high item ratings.

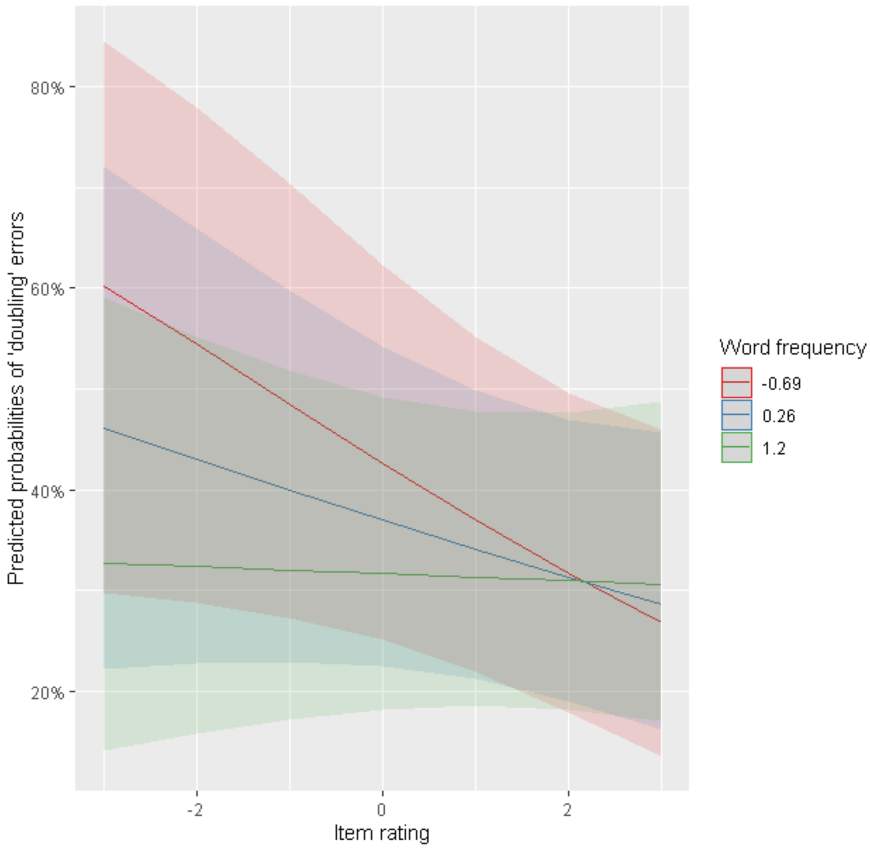


Figure 8: Combined effects of item rating and word frequency on the predicted probabilities of doubling errors

Interestingly, compared to the effects of the other variables, there was a large effect of phonological congruency on the occurrence of consonant doubling errors. We did not find main effects of *consonant doubling* (X^2 (1, N = 28,263) = 1.0, p = .31) or *orthographic congruency* (X^2 (1, N = 28,263) = 0.1, p = .79) or two-way interactions between *item rating* and *consonant doubling* (X^2 (1, N = 28,263) = 0.1, p = .40) or *item rating* and *orthographic congruency* (X^2 (1, N = 28,263) = 0.1, p = .72).
In a separate model, we tested the significance of *number of converging cues* (the number of linguistic cues that were congruent with the single- or double-consonant

spelling of the medial consonants) on doubling error (yes/no). This predictor could not be included alongside the other linguistic predictors, because they were intrinsically related. We did not find any effects of *number of converging cues*.

Having established which predictors influence the occurrence of consonant-doubling errors, we subsequently investigated which predictors influenced the overall spelling difficulty of the items.

3.3 Item difficulty

In order to investigate which linguistic predictors contribute to the L2 spelling difficulty of English disyllabic words with word-medial consonants surrounded by vowels, we fitted a linear regression analysis in R (R Development Core Team, 2017). We included the dependent variable *item rating*, and the same predictors as for the logistic regression analysis reported above, except for *item rating* and *item*. Since the effects of the predictor variables as well as the item ratings were highly variable across time and the analysis only contained one cell per item, the resulting models were more susceptible to small deviations in the data.

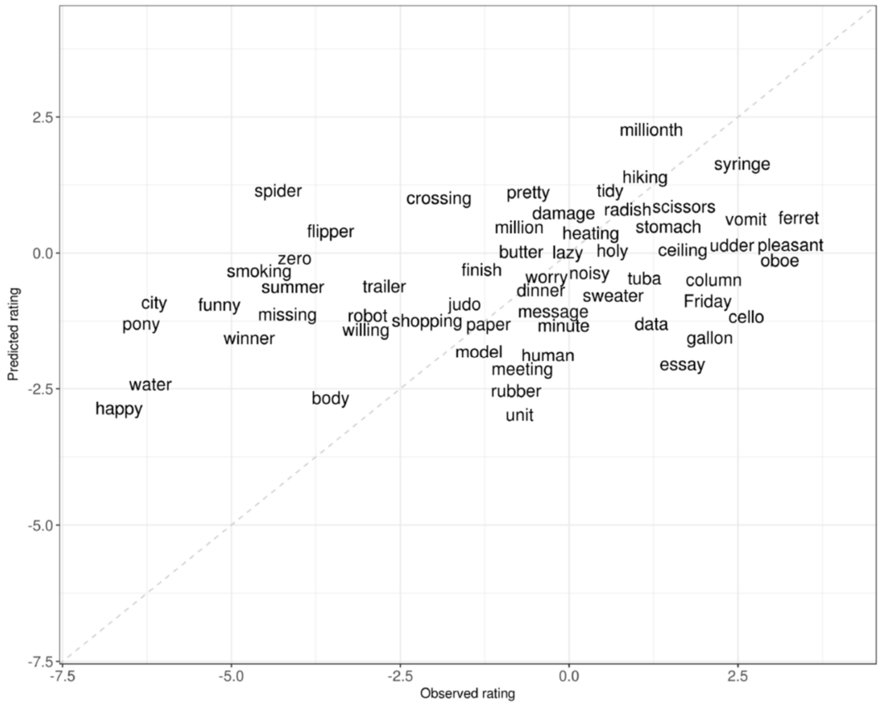


Figure 9: The predicted and observed item rating estimates for all non-overlapping items based on the regression models shown in Tables 6-7

Hence, we did not use backward selection. Instead, our regression model contained all predictor variables, regardless of their significance. We did, however, construct a separate model for *number of converging cues*, for the same reason as for the error classification models reported above. The results for both models are shown in Tables 6 and 7. Predicted and observed rating estimates are shown graphically for all non-overlapping items in Figure 9.

We found that items were easier to spell if they had a higher frequency and if there was a larger cross-linguistic overlap. Furthermore, if items contained a larger number of converging cues, they were easier to spell. The amount of explained variance was slightly higher when *number of converging cues* was entered. Subsequently, we assessed the stability of these results by refitting the same regression model during fourteen months, for cross-validation purposes. During this period, 146,720 data points were collected for our target items, ensuring the reliability of the cross-validation. We found similar (significant) results for cross-linguistic congruency and word frequency for the cross-validation, as can be seen in Figure 10. The effects of word length, orthographic congruency and orthographic vowel congruency approached significance in a few occasions, and the remaining variables consistently had non-significant t-values (between 1.96 and -1.96).

Table 6. Results for the regression analysis explaining item difficulty of the target items (n = 144)

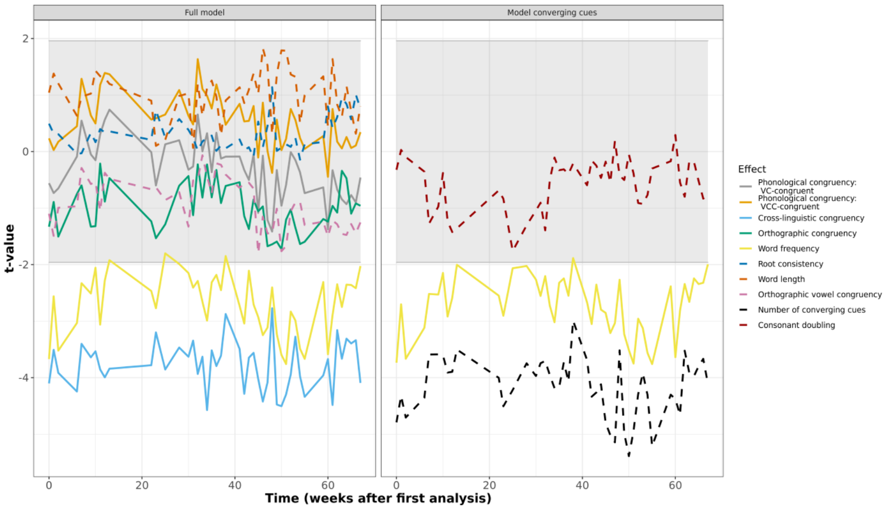
Variable	***β***	***SE***	***t***	***p***
Control				
Intercept	-0.762	1.11	-0.69	.49
Word frequency	-0.677	0.18	-3.79	.0002*
Word length	0.198	0.18	1.13	.26
Experimental				
Cross-linguistic congruency	-0.789	0.19	-4.18	00005*
Orthographic congruency	-0.469	0.35	-1.32	.19
Orthographic vowel congruency	-0.348	0.31	-1.14	.26

Phonological congruency (VCC-congruent)	-0.215	0.74	-0.29	.77
Phonological congruency (VC-congruent)	-0.600	0.48	-1.24	.22
Root congruency	0.192	0.41	0.47	.64
Adjusted R2	.16			

Note. * indicates significance at the p <.05 level.

Table 7. Results for the regression analysis explaining item difficulty of the target items by means of *Number of converging cues*, in addition to the control variable *word frequency* (*n* = 144)

Variable	***β***	***SE***	***t***	***p***
Control				
Intercept	1.915	0.49	3.91	.0001*
Word frequency	-0.667	0.18	-3.80	.0002*
Experimental				
Consonant doubling (yes/no)	-0.115	0.35	-0.33	.74
Number of converging cues	-0.819	0.16	-5.04	.000001*
Adjusted R2	.18			



Note. * indicates significance at the p <.05 level.

Figure 10 : Results obtained for the regression analyses over time. Values below the grey area are statistically significant at the five percent level (two-tailed)

4. Discussion

One of the most complex areas of English spelling is consonant doubling; the selection between single ("diner") and double ("dinner") consonant spellings in word-medial positions. For L1 English spellers, consonant doubling involves a complex interplay of phonological, orthographic, and morphological factors (e.g., Berg, 2016; Deacon et al., 2011). It is unclear to what extent these cues are used by second language (L2) learners and whether word-similarity to L1 words affects the spelling outcomes. In the present study, we assessed word-medial consonant spelling in English by Dutch EFL learners. Following the assumption that different cues contribute to spelling outcomes (IMP, Treiman & Kessler, 2014), we analyzed to what extent phonological, orthographic, and morphological cues, as well lexical frequency and cues related to the students' L1 (Dutch), contributed to the spelling of word-medial consonants in English. We used data from the dictation task *Ducktator* in the unsupervised digital learning environment *Words&Birds* (Prowise, 2014). This design allowed us to gain more insight into the processes that are involved in the mostly implicit acquisition of EFL spelling.

First, we addressed the role of phonology in EFL consonant doubling. Our results revealed that phonological congruency (e.g., *diner*) enhanced correct single-consonant spellings of words that were generally relatively easy to spell. Thus, bisyllabic words generally take single-consonant spellings after phonologically long vowels (diner, /ˈdaɪnə/). Interestingly, the phonological congruency of the word-medial consonants was not reflected in spelling difficulty at the word level, as measured by the item difficulty estimates. Phonological congruency cues appear to play a role for items that were relatively easy to spell, i.e., items with low item difficulties. These item difficulty estimates serve as a proxy of spelling proficiency, given that, for each student, items are selected with a mean probability of a correct spelling of .75 at that particular time. Hence, our results showed that EFL spellers, similar to L1 spellers (e.g., Cassar & Treiman, 1997; Deacon et al., 2011; Treiman & Wolter, 2018), were more likely to provide single-consonant spellings after phonologically long vowels.

These results show that the use of phonological cues to correctly provide single-consonant spellings after phonologically long vowels is modulated by spelling proficiency. In contrast to previous research by Yin, Joshi, Li, and Kim (2020), who found a stronger influence of phonological cues on consonant doubling in more skilled Chinese and Korean EFL spellers, our study found that more skilled Dutch EFL spellers relied less heavily on phonological cues to consonant doubling. Combined, these findings indicate that which cues are used by EFL learners depends on L1 experience combined with cue reliability. Since Dutch EFL learners are familiar with phonological cues to consonant doubling from their L1, these cues are already used by novice Dutch EFL learners. More skilled Dutch EFL learners combine phonological cues with morphological cues to consonant doubling. Chinese and Korean EFL learners, however, are unfamiliar with these phonological cues and learn to rely on these cues first.

Second, we focused on the role of orthography. L1 English spellers tend to use double-consonant spellings preceding a short vowel (Cassar & Treiman, 1997; Hayes et al., 2006; Treiman & Boland, 2017; Treiman & Wolter, 2018), as in *dinner* /ˈdɪnə/. Moreover, they tend to rely on the orthographic context (Treiman & Boland, 2017): for instance, word-medial consonant doubling is very likely before <en>, but unlikely before <ic>. Our findings did not show any effects of orthographic cues on L2 English consonant doubling. Hence, early EFL learners do not (yet) appear to rely on the spelling of the preceding vowel or the orthographic context to choose between single- and double-consonant spellings. Possibly, EFL learners require more experience to use these language-specific cues to consonant doubling, similar to findings regarding past tense spelling in L1 (Van Der Ven & De Bree, 2019).

Third, we examined the contribution of morphology to EFL consonant doubling. Our findings indicated that, for difficult words (words with relatively high item difficulty ratings), EFL spellers tended to provide more double-consonant spellings when consonant doubling was the result of morphological processes (e.g., affixation: "day-midday"). Students also often provided single-consonant spellings for words with high difficulty ratings when these processes lead to single word-medial consonants (e.g., inflection: "heat-heating"). In the absence of morphological effects on item difficulty, we interpret item rating as a measure of spelling proficiency. In L1 English, sensitivity to root congruency emerges during early childhood (at approximately age seven; Deacon et al., 2011). This sensitivity to root congruency cues in EFL consonant doubling is also visible in more advanced EFL spellers. The increasing use of morphological information is consistent with existing developmental studies, showing that the acquisition of a proficient morphological processing system is a relatively late acquired milestone in children's written language acquisition (e.g., Beyersmann, Castles, & Coltheart, 2012; Beyersmann, Grainger, & Castles, 2019; Dawson, Rastle, & Ricketts, 2018; Rastle, 2019).

Fourth, we evaluated the role of cross-linguistic influences during EFL consonant doubling. Words with more cross-linguistic overlap resulted in fewer consonant doubling errors but this effect was absent in words with high item difficulty ratings. Apparently, cross-linguistic influence on patterns in consonant doubling errors decreases with EFL proficiency. Further, words that showed cross-linguistic overlap (in terms of cognate status and similarity in consonant doubling) had lower item ratings and were thus considered easier to spell. This result is in line with previous findings suggesting that cross-linguistic similarities may enhance the development of EFL spelling (e.g., Figueredo, 2006; Schwartz, Ibrahim & Kahn-Horwitz, 2016). Together, these four findings show that beginning Dutch EFL learners tend to rely on cues that relate to Dutch consonant doubling (i.e., phonological congruency and cross-linguistic overlap), whereas more advanced learners also rely on language-specific cues, such as root congruency.

Combined, abovementioned findings suggest that there is a predominant effect of phonological congruency in Dutch EFL consonant doubling, which may, at least partly, be due to Dutch EFL learners' familiarity with similar phonological cues in Dutch spelling. Moreover, our findings suggest that the effects of phonological and cross-linguistic cues decrease with growing EFL proficiency, whereas the effect of morphological cues increases. Again, these findings may be due to Dutch learners' familiarity with specific English spelling patterns. As Dutch EFL learners are familiar with phonological cues and with general spelling patterns that resemble Dutch spelling (reflected by cross-linguistic congruency), these cues are likely to influence consonant-doubling especially in relatively easy items (i.e., items with low item ratings, played by users with similarly low user ratings). Morphological cues, in contrast, do not resemble Dutch spelling, and are hence likely to influence Dutch EFL consonant-doubling in relatively difficult items (i.e., items with high item ratings, played by users with more advanced English spelling skills and similarly high user ratings).

Additional analyses revealed that the number of congruent linguistic cues, the accumulation of congruency of abovementioned linguistic cues, did not influence a doubling error (yes/no), but did influence item difficulty: Words with more congruent cues were easier to spell. These results agree with the conclusions from Figueredo (2006) that information from the L1 contributes to EFL/L2 outcomes. Importantly, the present study shows, in more detail, the L1 factors that contribute to L2 spelling outcomes and identifies the L2 variables that also play a role. The inclusion of both L1 and L2 variables, not limited to the level of the phoneme or grapheme, thus provides more insight into the L2 spelling process.

Our findings can be accommodated in the Integration of Multiple Patterns (IMP; Treiman & Kessler, 2014) framework, which assumes that spelling accuracy may be determined by the number of linguistic cues that are in line with the correct spelling. Similar to De Bree and colleagues (2017) for L1, our results showed that the number of converging cues predicts spelling difficulty in L2; a higher number of converging cues leads to lower spelling difficulty. However, whereas De Bree and colleagues (2017) found that the contribution of the cues separately rendered a higher amount of explained variance than the number of converging cues for each item, the percentages of explained variance in the present study were similar for number of converging cues and for the contribution of cues separately. However, our study indicates that the spelling errors that L2 learners make may be predicted by cross-linguistic, phonological, and morphological cues, not by the number of converging cues. This finding suggests that, similar to L1 (De Bree et al., 2017), the extent to which linguistic cues contribute to L2 spelling varies substantially. In fact, it appears that some linguistic cues are not used at all by (relatively early) EFL learners. This probably explains why the number of converging cues did not predict the occurrence of consonant doubling errors.

This finding regarding the differential use of linguistic cues by L2 learners can be used to extend IMP. The framework is not specific about the trajectory of acquisition, such as *when* the different cues become available to learners, only that spelling develops due to more print exposure, more statistical support for the pattern, better convergence of the pattern with other patterns and more linguistic knowledge by the learner (Treiman & Kessler, 2014, p.272). Our findings indicate that there may be patterns in acquisition for specific spelling regularities that need to be acquired (for L2). Specifically, IMP should take L2 proficiency into account in order to explain that, for English consonant doubling, early L2 users appear to rely more heavily on phonological and other cross-linguistic cues, whereas more advanced L2 users rely more heavily on L2-specific (morphological) cues. Our findings therefore underscore the importance of implicit cues in spelling as well as specify the contributions of these cues in different levels of L2 proficiency.

Finally, our findings indicated strong effects of word frequency on the occurrence of consonant doubling errors as well as on spelling difficulty. To begin with, we found that more frequent words are easier to spell, which is in line with the IMP and with previous studies showing that word frequency influences L1 spelling accuracy (e.g., Abrams & White, 2011; De Bree et al., 2018; Lété et al., 2008; Mitchell et al., 2011). Moreover, this finding is in line with a lexical entrenchment account of second language learning, which claims that the more often learners are exposed to a word, the stronger the lexical representation of the word becomes (Diependaele et al., 2013; Kim et al., 2017). Our findings suggest that this also holds for a word's orthographic representation, given that learners were more likely to provide correct spellings of word-medial consonants in words with higher lexical frequencies. Interestingly, error patterns revealed that low item ratings elicited more consonant doubling errors for items with low or intermediate word frequencies. Apparently, more advanced learners (as reflected by high item ratings, which are typically played by learners with high user ratings) tend to make relatively few consonant doubling errors regardless of word frequency, whereas less advanced learners make more such errors for less frequent words.

Our study has several limitations that merit mention. First, the individual characteristics of the L2 learners who participated were unknown, and therefore L2 spelling outcomes could not be related to learners' spelling-related abilities, such as L1 or L2 reading ability, or their cognitive skills. Reading has an impact on spelling acquisition (e.g., Georgiou et al., 2019); the assumption is that print exposure aids in constructing orthographic representations. Indeed, it has been found that L1 learners whose spelling is determined by more detailed implicit orthographic cues in their L1 are those who are better readers (Van Der Ven & De Bree, 2019). Information on L1 and L2 reading could provide more information on the path of EFL spelling acquisition. The primary focus here was to gain more understanding of the L1 and L2 cues that contribute to L2 spelling outcomes. Future research could extend the scope by adding both item-related information as well as child-related abilities (e.g., Kim, Petscher & Park, 2016; Van Der Ven & De Bree, 2019). Furthermore, in order to gain more insight into the order in which cues become used, a longitudinal study could be conducted following students' spelling over time. Alternatively, a cross-sectional comparison of spelling and cues can be made between different L2 ability students. The study by Van der Ven and De Bree (2019) into L1 Dutch spelling, for instance, found that spelling of children in Grade 6 and with better reading fluency was affected more by implicit cues than those of children in Grade 3 and with lower reading fluency.

In addition, the corpus data used for lexical frequency measures may not provide the most adequate estimate of EFL learners' frequency of exposure to the target words used in this study. Ideally, future studies should incorporate exposure frequency estimates that take into account the different (L1/L2) settings in which words occur, as suggested by Brysbaert, Mandera, and Keuleers (2018). After all, certain words may be highly frequent in L1 but not in L2 and vice versa.

The results presented in this study hold some practical implications for foreign language teaching. Our findings imply that L2 spellers are able to detect the cues relevant for consonant doubling spelling implicitly during L2 spelling. Specifically, L1 phonological, L1 morphological cues, and cues relying on cross-linguistic knowledge were used. This means that feedback on L2 spelling should pay attention to the types of errors that are made. This, in turn, stresses the importance of EFL teachers' possessing knowledge about the spelling patterns and origins of the different errors. This is needed to distinguish phonological from morphological from orthographic and cross-linguistic errors. The type of error an L2 student makes determines which feedback and instruction is required.

Furthermore, EFL spelling generally receives very limited attention in the Dutch curriculum and is thus acquired implicitly. The assumption is that explicit instruction 'can be seen as enabling statistical learning, and timely, targeted instruction can further accelerate it' (Seidenberg, Borkenhagen, & Kearns, 2020, p. 127). Thus, integrating activities in which explicit instruction and implicit learning can take place might support teaching and benefit spelling acquisition (Seidenberg et al., 2020). Furthermore, in such an approach, connecting reading and writing instruction is likely to be beneficial, as the words and patterns encountered during reading provide information about spelling and vice versa (see also Graham, 2020). Indeed, a recent study by Lee and Schallert (2016) found that reading-writing/writing-reading instruction was successful in general literacy outcomes for South Korean EFL learners. Future research could evaluate whether instruction relying on this connection could aid acquisition of specific spelling patterns, such as consonant doubling, and whether it is equally beneficial for all EFL learners. Related, such a study could also evaluate whether and how spelling strategies that students report to rely on affect their spelling, as a reciprocal relationship has been reported between reported spelling strategies and orthographic knowledge for L1 learners (Sharp, Sinatra & Reynolds, 2008).

In conclusion, the current study shows that EFL spellers can use phonological and cross-linguistic cues to English consonant doubling early on in development and gradually learn to use morphological cues as well. Similar to L1 spellers, EFL spellers can combine different linguistic cues to choose between single and double consonant spellings in English.

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Appendix A: Words and Birds Target Items, Item Rating, Levenshtein distance, Consonant Doubling, Vowel Length, Phonological Congruency, Orthographic Congruency, Root Congruency, Orthographic Vowel Congruency, Cross-linguistic Congruency, and Number of Converging Cues

Target	Dutch	Item_rat	Levens	Freq	CDoub	VLength	Phon	Orth	Root	OrthoVowel	Crossling	NrCues
Any	Ieder	-0.393	5	53	No	short	incongruent	neutral	neutral	incongru	neutral	1
City	Stad	-6.141	4	257	No	short	incongruent	neutral	neutral	incongru	neutral	1
Closet	Kast	0.320	4	11	No	short	incongruent	neutral	neutral	incongru	neutral	1
Colour	Kleur	0.973	3	111	no	short	incongruent	neutral	neutral	incongru	neutral	1
Damage	Schade	-0.081	4	44	no	short	incongruent	incongru	neutral	incongru	neutral	1
Decade	Decennium	1.774	6	78	no	short	incongruent	neutral	neutral	incongru	neutral	1
Desert	Woestijn	0.651	6	41	no	short	incongruent	neutral	neutral	incongru	neutral	1
Forest	Bos	-1.186	4	95	no	short	incongruent	incongru	neutral	incongru	neutral	1
Honest	Eerlijk	0.980	7	36	no	short	incongruent	incongru	neutral	incongru	neutral	1
Linen	Linnen	2.640	1	17	no	short	incongruent	incongru	neutral	incongru	incongru	1
Many	Veel	-0.793	4	967	no	short	incongruent	neutral	neutral	incongru	neutral	1
Spanish	Spaans	1.222	3	30	no	short	incongruent	neutral	neutral	incongru	neutral	1
Stomach	Maag	1.469	5	43	no	short	incongruent	neutral	neutral	incongru	neutral	1
Sugar	Suiker	-0.794	3	57	no	short	incongruent	neutral	neutral	incongru	neutral	1
Alley	Steeg	0.353	4	12	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Belly	Buik	-0.014	4	20	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Billion	Miljard	0.234	5	10	yes	short	ccCongruent	neutral	neutral	congruent	incongru	2
Buttocks	Zitvlak	2.967	6	9	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Camel	Kameel	0.353	2	25	no	short	incongruent	neutral	neutral	incongru	congruent	2

Cannot	Kan niet	0.660	4	247	yes	short	ccCongruent	neutral	congruent	congruent	neutral	2
Cellar	Kelder	3.112	3	13	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Channel	Kanaal	-1.227	4	33	yes	short	ccCongruent	neutral	neutral	congruent	incongru	2
Colleague	Collega	2.932	3	51	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Column	Kolom	2.142	3	39	no	short	incongruent	neutral	neutral	incongru	congruent	2
Cooker	Kookplaat	0.573	6	5	no	short	incongruent	incongru	congruent	congruent	neutral	2
Copy	Kopie	-0.695	3	51	no	short	incongruent	neutral	neutral	incongru	congruent	2
Cotton	Katoen	1.710	4	28	yes	short	ccCongruent	neutral	neutral	congruent	incongru	2
Cousin	Neef	0.008	6	32	no	short	incongruent	neutral	neutral	congruent	neutral	2
Female	Vrouw	0.309	6	30	no	long	cCongruent	neutral	neutral	incongru	neutral	2
Fennel	Venkel	2.219	2	1	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Ferret	Fret	3.400	2	2	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Ferry	Veerboot	2.560	6	8	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Foggy	Mistig	0.639	6	2	yes	short	ccCongruent	neutral	incongru	congruent	neutral	2
Funny	Grappig	-5.177	7	51	yes	short	ccCongruent	neutral	incongru	congruent	neutral	2
Future	Toekomst	-0.119	8	138	no	long	cCongruent	neutral	neutral	incongru	neutral	2
Granny	Oma	-0.251	5	7	yes	short	ccCongruent	neutral	incongru	congruent	neutral	2
Honey	Honing	0.662	3	21	no	short	incongruent	neutral	neutral	incongru	congruent	2
Human	Humaan	-0.314	1	285	no	long	cCongruent	neutral	neutral	incongru	congruent	2
Lazy	Lui	-0.016	3	13	no	long	cCongruent	neutral	neutral	incongru	neutral	2
Lonely	Eenzaam	-0.315	6	28	no	long	cCongruent	neutral	congruent	incongru	neutral	2
Married	Getrouwd	-0.128	6	55	yes	short	ccCongruent	neutral	congruent	congruent	neutral	2

Million	Miljoen	-0.739	3	47	yes	short	ccCongruent	neutral	neutral	congruent	incongru	2
Millionth	Miljoenste	1.218	5	1	yes	short	ccCongruent	neutral	neutral	congruent	incongru	2
Minute	Minuut	-0.081	2	283	no	short	incongruent	neutral	neutral	incongru	congruent	2
Native	Inheems	0.611	6	7	no	long	cCongruent	neutral	neutral	incongru	neutral	2
Parrot	Papegaai	1.023	6	4	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Pleasant	Aangenaam	3.280	8	42	no	short	incongruent	neutral	congruent	congruent	neutral	2
Pretty	Mooi	-0.604	6	0	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Rabbit	Konijn	0.285	6	19	yes	short	ccCongruent	incongru	neutral	congruent	neutral	2
Radish	Radijs	0.871	2	1	no	short	incongruent	neutral	neutral	incongru	congruent	2
Ruler	Heerser	1.386	5	18	no	long	cCongruent	incongru	congruent	incongru	neutral	2
Scissors	Schaar	1.702	5	4	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Special	Speciaal	-1.253	1	9	no	short	incongruent	neutral	neutral	incongru	congruent	2
Spider	Spin	-4.308	3	7	no	long	cCongruent	incongru	neutral	incongru	neutral	2
Story	Verhaal	-5.073	7	228	no	long	cCongruent	neutral	neutral	incongru	neutral	2
Study	Studie	0.119	2	165	no	short	incongruent	neutral	neutral	incongru	congruent	2
Tidy	Ordelijk	0.611	7	0	no	long	cCongruent	neutral	neutral	incongru	neutral	2
Vomit	Braken	2.616	6	3	no	short	incongruent	congruent	neutral	incongru	neutral	2
Wooden	Houten	-1.283	3	43	no	short	incongruent	incongru	congruent	congruent	neutral	2
Worried	Bezorgd	-0.046	6	44	yes	short	ccCongruent	neutral	congruent	congruent	neutral	2
Worry	Zorgen	-0.334	4	22	yes	short	ccCongruent	neutral	neutral	congruent	neutral	2
Writer	Auteur	2.227	4	66	no	long	cCongruent	incongru	congruent	incongru	neutral	2
Zero	Nul	-4.064	4	17	no	long	cCongruent	neutral	neutral	incongru	neutral	2

Body	Body	-3.532	0	363	no	short	incongruent	neutral	neutral	incongru	cognate	3
Butter	Boter	-0.708	2	27	yes	short	ccCongruent	congruent	neutral	congruent	incongru	3
Cabbage	Kool	1.626	7	10	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Ceiling	Plafond	1.683	6	30	no	long	cCongruent	incongru	neutral	congruent	neutral	3
Cloudy	Bewolkt	-0.332	6	3	no	long	cCongruent	neutral	congruent	congruent	neutral	3
Cottage	Huisje	1.339	6	38	yes	short	ccCongruent	congruent	incongru	congruent	neutral	3
Crossing	Kruising	-1.926	3	10	yes	short	ccCongruent	congruent	congruent	congruent	incongru	3
Daily	Dagelijks	0.305	6	1	no	long	cCongruent	neutral	congruent	congruent	neutral	3
Denim	Denim	1.490	0	3	no	short	incongruent	neutral	neutral	incongru	cognate	3
Dinner	Diner	-0.416	1	98	yes	short	ccCongruent	congruent	incongru	congruent	incongru	3
Finish	Finish	-1.295	0	3	no	short	incongruent	neutral	neutral	incongru	cognate	3
Flipper	Vin	-3.528	6	1	yes	short	ccCongruent	congruent	incongru	congruent	neutral	3
Follow	Volgen	-1.511	4	296	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Friday	Vrijdag	2.053	3	45	no	long	cCongruent	neutral	neutral	incongru	congruent	3
Heating	Verwarming	0.321	5	21	no	long	cCongruent	incongru	congruent	congruent	neutral	3
Hiking	Hiken	1.125	2	0	no	long	cCongruent	incongru	congruent	incongru	congruent	3
Holy	Heilig	0.641	4	1	no	long	cCongruent	neutral	neutral	incongru	congruent	3
Legal	Legaal	0.451	7	64	no	long	cCongruent	neutral	neutral	incongru	congruent	3
Luggage	Bagage	2.548	3	11	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Matter	Materie	-0.170	3	279	yes	short	ccCongruent	congruent	neutral	congruent	incongru	3
Message	Bericht	-0.233	6	89	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Mobile	Mobiel	0.285	1	1	no	long	cCongruent	neutral	neutral	incongru	congruent	3

Model	Model	-1.334	0	81	no	short	incongruent	neutral	neutral	incongru	cognate	3
Moody	Humeurig	0.767	7	2	no	long	cCongruent	neutral	congruent	congruent	neutral	3
Music	Muziek	-2.100	3	133	no	long	cCongruent	congruent	neutral	incongru	neutral	3
Noisy	Luidruchtig	0.304	10	14	no	long	cCongruent	neutral	congruent	congruent	neutral	3
Oboe	Hobo	3.122	2	2	no	long	cCongruent	neutral	neutral	incongru	congruent	3
Offer	Aanbod	-1.253	6	41	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Paper	Papier	-1.194	1	225	no	long	cCongruent	incongru	neutral	incongru	congruent	3
Passive	Passief	0.119	2	0	yes	short	ccCongruent	neutral	neutral	congruent	congruent	3
Pepper	Peper	0.285	1	9	yes	short	ccCongruent	congruent	neutral	congruent	incongru	3
Photo	Foto	-0.107	2	16	no	long	cCongruent	neutral	neutral	incongru	congruent	3
Pillow	Hoofdkussen	-0.114	11	19	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Pizza	Pizza	-6.187	0	2	yes	long	incongruent	neutral	neutral	congruent	cognate	3
Rainy	Regenachtig	-0.028	9	5	no	long	cCongruent	neutral	congruent	congruent	neutral	3
Raisin	Rozijn	2.902	4	4	no	long	cCongruent	neutral	neutral	congruent	neutral	3
Running	Lopend	-4.659	6	17	yes	short	ccCongruent	congruent	incongru	congruent	neutral	3
Season	Seizoen	-0.276	3	59	no	long	cCongruent	neutral	neutral	congruent	neutral	3
Shallow	Ondiep	0.821	7	0	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Soccer	Voetbal	-0.543	6	4	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Summer	Zomer	-4.087	3	124	yes	short	ccCongruent	congruent	neutral	congruent	incongru	3
Udder	Uier	2.411	2	1	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Village	Dorp	-0.904	7	164	yes	short	ccCongruent	congruent	neutral	congruent	neutral	3
Cello	Cello	2.626	0	2	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4

Data	Gegevens	1.221	0	6	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Drama	Drama	-0.784	0	25	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Essay	Opstel	1.682	0	22	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4
Gallon	Gallon	2.086	0	11	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4
Happy	Gelukkig	-6.664	0	151	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4
Judo	Judo	-1.549	0	2	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Junior	Junior	-0.018	0	4	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Kilo	Kilo	-2.119	0	4	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Leader	Leider	-1.684	1	143	no	long	cCongruent	incongru	congruent	congruent	congruent	4
Leggings	Leggings	-0.699	0	1	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4
Missing	Missend	-4.170	2	22	yes	short	ccCongruent	congruent	congruent	congruent	congruent	4
Pony	Pony	-6.333	0	14	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Puppy	Puppy	-1.107	0	7	yes	short	ccCongruent	neutral	incongru	congruent	cognate	4
Robot	Robot	-2.985	0	7	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Shopping	Shoppen	-2.100	2	22	yes	short	ccCongruent	congruent	incongru	congruent	congruent	4
Smoking	Smoking	-4.586	0	13	no	long	cCongruent	incongru	congruent	incongru	cognate	4
Station	Station	-1.589	0	117	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Steward	Rentmeester	0.871	0	17	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Student	Student	-0.731	0	304	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Sweater	Sweater	0.652	0	15	no	short	incongruent	incongru	congruent	congruent	cognate	4
Tissue	Zakdoek	0.286	0	16	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4
Tourist	Toerist	0.760	1	35	no	long	cCongruent	neutral	congruent	congruent	congruent	4

Tuba	Tuba	1.117	0	0	no	long	cCongruent	neutral	neutral	incongru	cognate	4
Villa	Villa	-0.826	0	11	yes	short	ccCongruent	neutral	neutral	congruent	cognate	4
Water	Water	-6.198	0	460	no	long	cCongruent	incongru	neutral	incongru	cognate	4
Willing	Gewillig	-3.009	3	43	yes	short	ccCongruent	congruent	congruent	congruent	congruent	4
Winner	Winnaar	-4.734	2	17	yes	short	ccCongruent	congruent	incongru	congruent	congruent	4
Kitten	Katje	-1.297	0	7	yes	short	ccCongruent	congruent	neutral	congruent	cognate	5
Meeting	Meeting	-0.694	0	173	no	long	cCongruent	incongru	congruent	congruent	cognate	5
Rubber	Rubber	-0.784	0	26	yes	short	ccCongruent	congruent	incongru	congruent	cognate	5
Spelling	Spelling	-5.262	0	9	yes	short	ccCongruent	congruent	congruent	congruent	cognate	5
Tennis	Tennis	-6.223	0	22	yes	short	ccCongruent	congruent	neutral	congruent	cognate	5
Thriller	Thriller	0.285	0	3	yes	short	ccCongruent	congruent	congruent	congruent	cognate	5
Trailer	Aanhangwagen	-2.734	0	4	no	long	cCongruent	incongru	congruent	congruent	cognate	5
Trainer	Trainer	-4.509	0	5	no	long	cCongruent	incongru	congruent	congruent	cognate	5
Twitter	Twitter	-3.483	0	0	yes	short	ccCongruent	congruent	neutral	congruent	cognate	5
Unit	Unit	-0.735	0	114	no	long	cCongruent	congruent	neutral	incongru	cognate	5