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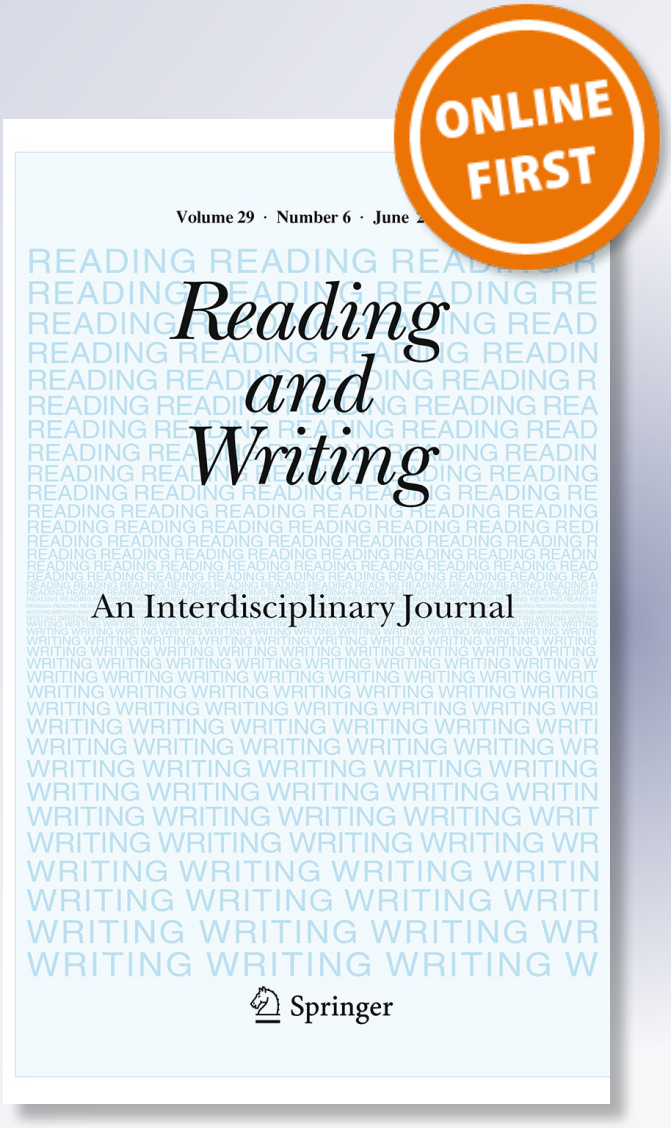

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Exploring the derivative suffix frequency effect in Spanish speaking children

Miguel Lázaro[1] · Joana Acha[2] · Saray de la Rosa[3] · Seila García[3] · Javier Sainz[1]

Abstract This study was designed to examine the developmental course of the suffix frequency effect and its role in the development of automatic morpho-lexical access. In Spanish, a highly transparent language from an orthographic point of view, this effect has been shown to be facilitative in adults, but the evidence with children is still inconclusive. A total of 90 2nd, 4th and 6th grade children performed a go/no go lexical decision task, with words containing either high or low frequency suffixes. Results showed significant main effects for grade and for derivative suffix frequency, with no interaction between both. This finding suggests that the suffix frequency effect emerges very early in reading development and that its role is well established from the beginning of reading experience, suggesting that sensitivity to suffix frequency can be a good predictor of a child's ability to internalize orthographic regularities at an early stage. These findings are interpreted in the light of previous evidence paying special attention to orthographic transparency and morpheme regularity in Spanish language.

Keywords Morpho-lexical access · Suffix frequency · Reading development · Transparent orthography

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Introduction

To be able to learn to read, children need to master several abilities. For example children need to be aware of the sounds of language and match them with the corresponding written signs. These two abilities have enormous relevance in the development of reading acquisition, but they are not the only ones. In alphabetic languages, especially in transparent orthographic systems such as Spanish, in which the same sounds correspond almost unequivocally to the same letters, children progress from phono-orthographic reading, in which grapheme to phoneme conversion takes place, to whole word processing, in which the holistic recognition of words takes place (see Coltheart, 1978 for a seminal version of the dual route model). This developmental process implies a transition from phonological recoding to whole word reading, which has been shown to be essential for reading expertise. This transition is characterized by progressive sensitivity to repeated orthographic patterns, i.e. increasing sensitivity to morphemes (Mahony, Singson, & Mann, 2000; Verhoeven & Perfetti, 2011). In other words, children are increasingly aware of certain chains of letters associated with a meaning, thus conforming meaningful processing units larger than letters and smaller than words; morphemes. The increasing relevance of morphological processing is closely related to development of reading ability so that high levels of morphological awareness lead to high levels of reading ability (Deacon, Conrad, & Pacton, 2008; Nation, Angell, & Castles, 2007).

Although the body of evidence on morphological processing in children has grown in recent years, there is still little evidence regarding the role played by key morphological properties such as suffix frequency, a reliable marker of skilled morphological processing. Suffix frequency refers to the number of complex words that share a given suffix—type suffix frequency—or to the summed frequencies of all words that contain a given suffix–token suffix frequency. Importantly, these measurements are computed removing pseudocomplex words. For instance, for the computation of the token or type frequency of the Spanish suffix "−eza", one might want to remove words such as "cerveza" (beer) or "cabeza" (head) because they are not composed of a stem + suffix. Suffix computation without pseudocomplex words offers token and type frequencies of suffixes, some of them being more frequent than others.[1]

In adult readers, substantial research has shown that suffix frequency has an important role on visual lexical recognition. For instance, in an unprimed lexical decision task in English, Baayen, Wurm, and Ayock (2007) observed that response latencies were predicted both by surface frequency and by suffix frequency—measured as token frequency—the adults being more affected by high frequency suffixes than by low frequency suffixes. Baayen et al. (2007) proposed that suffix frequency can be an index of the strength of stored morphological units in the lexicon, and of the probability of such units boosting lexical retrieval (see also

[1] Different terms are used in the literature to refer to what we call suffix frequency. Some authors employ the term suffix productivity—usually operationalizing it as a type measure. Others employ the term suffix numerosity.

Anshen & Aronoff, 1997; Bertram, Schreuder, & Baayen, 2000b; Frauenfelder & Schreuder, 1991; Hay, 2001). In transparent languages with a shallow orthography such as Spanish, i.e. languages in which the same sounds correspond almost unequivocally to the same letters, the role of suffix frequency in lexical access has also been proved to be highly relevant. In Spanish, unlike Germanic languages, the most efficient way to coin new words is through derivation, not through composition (Valera, 1990, 2005). Intuitively, this suggests that the role of suffixes might be more relevant in Spanish than in other languages such as English, Dutch, and German, for instance. Some recent contributions to the literature (Lázaro, 2012; Lázaro, Illera, & Sainz, 2015b) provide evidence to support suffix frequency as a key factor that favors word parsing and boosts lexical access in adults. Frequent suffixes speed up responses in morphologically complex words, and increase latencies in morphologically complex pseudowords, showing that derivational suffixes are activated as significant units leading to faster word recognition (and to a greater look up process in pseudowords formed by a real suffix). The key issue here is whether these effects are a consequence of a developmental process, through which readers internalize repeated orthographic regularities directly matched to phonologically significant representations. If this is so, Spanish readers could be aware of such units at a very early stage due to morphological transparency: suffixes are regular, highly repeated patterns modulating the meaning of the stem in a consistent way. The question is to what extent the frequency of use of such units, i.e. suffix type frequency, modulates lexical access during learning to read, and the time course of its contribution to lexical access in Spanish children.

Using a naming task in children, some studies have shown that children do indeed use these regularities from the beginning of reading acquisition. In fact, Burani, Marcolini, and Stella (2002) showed that Italian children of 8 and 10 years of age named pseudowords made up of real morphemes—stems + derivational suffixes—more quickly and accurately than pseudowords without morphological constituents. They concluded that morpholexical reading is available in Italian in children as young as 8. Similar results were later found by Traficante, Marcolini, Luci, Zoccolotti, and Burani (2011), who manipulated the presence of stems and suffixes orthogonally across pseudowords, that is, non meaningful combinations of real and unreal stems and suffixes (+stem +suffix; +stem −suffix; −stem +suffix; −stem −suffix). Interestingly, "+stem" conditions generated faster and more accurate results than "−stem" condition. Similarly, the "+suffix" condition showed more accuracy than "−suffix" condition, with no difference in response latencies. The authors proposed that the effects observed with stems and suffixes cannot be merely reduced to bottom up orthographic processes, and that morpho-lexical reading does take place in young Italian children. Similarly, Suárez-Coalla and Cuetos (2013) carried out a study with Spanish children aged between 7 and 10, in which polymorphemic and simple words were compared in a naming task. Results showed shorter latencies for complex words than for simple words, with a marginal significance in the analyses of error rates. Coinciding with the conclusions of Burani et al. (2002), these results were interpreted as showing that Spanish speaking children use larger units than simple graphemes or syllables to read polymorphemic words—i.e. morpho-lexical reading.

In the case of the lexical decision task (which early and automatically taps into processes involved in word recognition unlike a naming task, which enhances phonological recoding and implies additional articulatory processes), the evidence also contributes to the view that children recognize morphological units automatically and use them to facilitate lexical access. Quémart, Casalis, and Duncan (2012) carried out a lexical decision task in French mirroring the design of Traficante et al. (2011) and obtained similar results (the presence of morphemes facilitate lexical recognition in case of words and interfere in the decision in case of pseudowords) concluding that "bases and suffixes have acquired a specific status for the word recognition system and their presence offers young children a reliable clue in lexical decision" (p. 437). In addition, this sensitivity seems to depend on the morphological transparency and consistency by which morphemes are attached to stems in the language.

Similarly to Traficante et al. (2011), Quémart et al. (2012), Casalis, Quèmart, and Duncan (2015) manipulated the presence of stems and suffixes orthogonally, leading to four possible conditions both with words and pseudowords, and conducted a lexical decision task with French and English children in 4th grade. While in French the results showing benefits for the +stem and +suffix condition were obtained both in latencies and error-rate analyses, in English these results were obtained only in the case of error-rate analyses. The inconsistency in the results between French and English was attributed to the fact that morphological parsing mechanisms are acquired at different speeds by French and English children because French, being a Romance language, is morphologically more productive than English, which is a Germanic one (see also Beyersman, Grainger, Casalis, & Ziegler, 2015a). Orthographic transparency of languages could also play a role. Although both French and English are considered opaque languages, French is more transparent than English from the viewpoint of spelling and therefore it could be thought that French children internalize orthographic regularities earlier than English children. As suggested by Beyersman et al. (2015a) "French children might begin to automatize morphological processing at an earlier age than English children" (p. 117) (see also Aro & Wimmer, 2003).

The reported evidence offers a general picture of whether and when morphological processing plays a major role in word recognition in children. None of these studies, however, provides evidence concerning the developmental course of morphological processing in transparent languages. In this study we explore the role of derivational suffixes from a developmental perspective as a strategy to assess, first of all, the suffix frequency effect itself and consequently the emergence of morphological processing in reading acquisition and its development. Is the suffix frequency effect significant in children? If so, when do suffixes become relevant to lexical recognition? And, how is the role of morphological processing modulated by reading experience?

As previously mentioned, Spanish is a transparent language and derivation plays a major role in coining new words. This fact might favor the automatic recognition of such units very early in Spanish. According to this hypothesis, morphological processing might be an early marker of a child's sensitivity to orthographic and morphological regularities enhancing automatic access to lexical entries.

Our developmental approach will also allow us to compare our results with those obtained in other languages with children of the same age. For comparison purposes, it should be noted that the status of stems and affixes varies across languages according to language-specific properties. Semitic languages are especially useful to exemplify this. In these languages, in derivational morphology, stems and derivational suffixes are not appended linearly, but rather the consonants of the roots are intertwined with phonemes. In other words, this is not a lineal morphological system. Letter patterns configure the stems and they are derived by changing inner vowels (Abu-Rabia & Taha, 2006; Frost, Kluger, Deustch, & Forstser, 2005). Differences in morphological constituency between languages, despite not being as evident as the one shown, are a key issue in morphological processing (Berent & Perfetti, 1995; Sainz, 2006). Specifically, in this study we explore the suffix frequency effect to examine its role in Spanish children and to determine the time course of its acquisition.

To assess these issues, we designed a lexical decision task experiment for 2nd, 4th, and 6th grade children, manipulating the suffix frequency of the displayed words. Children's sensitivity to suffix frequency—showing faster and more accurate responses to words with frequent suffixes than to words with infrequent suffixes—will indicate that they are processing suffixes for lexical recognition of complex words. Any significant interaction between group and suffix frequency would mean that a reader group behaves differently according to age, and that suffix frequency is subject to the development of reading proficiency.

Method

Participants

A total of 90 children took part in the experiment with the written consent of their parents. Children were recruited from a primary school, Colegio del Santísimo Cristo de la Sangre, a privately owned state-aided school, forming part of the public education system, located in a middle class neighborhood in a small town in the province of Toledo. Children were recruited from 2nd grade (M age years = 7.5), 4th grade (M age years = 9.7), and 6th grade (M age years = 11.5) with 30 students per group. Parents were all Spanish native speakers and Spanish was the only language spoken at home.

All the selected children were considered typical readers by teachers and parents. They had no record of speech and language therapy nor had any need of special attention due to learning problems. They belonged to the same SES and were subject to the same reading instruction policy (the usual synthetic approach in Spanish in which grapheme to phoneme conversion is exhaustively applied). To make sure they were typical readers, they all took the Prolec-R reading test (Cuetos, Rodríguez, Ruano, & Arribas, 2007) as well as the Spanish version of the Peabody test (Dunn, Dunn, & Arribas, 2011) to discard children with dyslexia and/or reading difficulties, who tend to have a restricted vocabulary (Lázaro, 2012; Lázaro, García, & Burani 2015a, Lázaro, Sainz, & Illera, 2015c). Furthermore, it is widely known

that differences in vocabulary size lead to different results in reading tasks (e.g., Lee, 2011; Stanovich, 1986; Verhoeven & van Leeuwe, 2008), so we decided to control for this variable in each age group. The Prolec-R test is a very common test to assess the reading level of children between 6 and 12 years. This test evaluates nine different abilities: letter identification, same–different, word reading aloud, pseudoword reading aloud, grammatical structures, punctuation marks, simple sentence comprehension, text comprehension and oral comprehension. This test gives three possible scores "normal", "below normal", and "well below normal" for each ability, based on accuracy data, generating a final profile per subject. The Peabody test is widely used to evaluate the receptive vocabulary of children and also offers normality values based on accuracy. This test gives a direct score which can be compared to standard scores for each age. The results obtained for all children in both tests were within the expected ranges of the tests so we decided to include them all in the experiment. Direct measures obtained in the Peabody test as well as in the Prolec-R are shown in Table 1.

Table 1 Descriptive statistics of the participants and scores at tests

Group	2nd graders	4th graders	6th graders
Age (months) *M* (*SD*)	90 (2.9)	117 (1.9)	139 (2.5)
	Range 85–95	Range 111–119	Range 134–143
Peabody *M* (*SD*)	82.6 (10.7)	97.7 (12.4)	111.5 (8.5)
	Range 65–119	Range 72–117	Range 90–122
Prolec LN *M* (*SD*)	18.9 (1.2)	19.7 (0.5)	19.8 (0.3)
	Range 16–20	Range 18–20	Range 19–20
Prolec SD *M* (*SD*)	19.06 (1)	19.3 (.6)	19.4 (.6)
	Range 16–20	Range 18–20	18–20
Prolec WR *M* (*SD*)	39.3 (1.3)	39.7 (.5)	39.8 (.3)
	Range 35–40	Range 38–40	39–40
Prolec PSR *M* (*SD*)	36.3 (2.3)	37.9 (1.7)	38.4 (2)
	Range 30–40	Range 33–40	Range 33–40
Prolec GS *M* (*SD*)	13.9 (1.3)	14.9 (1.0)	15.0 (0.8)
	Range 12–16	Range 13–16	Range 14–16
Prolec PS *M* (*SD*)	8.0 (2.0)	8.2 (1.5)	9.1 (1.4)
	Range 4–11	Range 4–11	Range 5–11
Prolec SC *M* (*SD*)	14.4 (1.5)	14.9 (1.0)	15.1 (0.7)
	Range 11–16	Range 13–16	Range 13–16
Prolec TC *M* (*SD*)	14.6 (1.3)	15.5 (0.9)	15.4 (0.9)
	Range 12–16	Range 13–16	Range 13–16
Prolec OC *M* (*SD*)	6.8 (1.4)	6.9 (1.2)	6.8 (1.3)
	Range 3–8	Range 4–8	Range 4–8

LN letter naming, *SD* same–different, *WR* word reading, *PSR* pseudoword reading, *GR* grammatical structures, *PS* punctuation marks, *SC* sentence comprehension, *TC* text comprehension, *OC* oral comprehension

Stimuli

A total of 160 items were presented, half of them words and half pseudowords. Words and pseudowords were pronounceable letter-strings in Spanish according to the same letter-sound conversion rules. To make possible the assessment of the Suffix frequency effect, we selected 20 polymorphemic words with frequent suffixes and another 20 with infrequent suffixes (see "Appendix 1" for the stimuli). Since "low" and "high" frequency is not an objective measure, we decided to maximize differences between groups and select complex words in which derivational suffixes clearly differed in frequency. For example, 1413 Spanish words contain the agentive suffix "−dor" and it has a token frequency of 1448 appearances per million. In contrast, the suffix "−azgo" is present in 26 complex words and has a token frequency of 29 appearances per million (all data excluding pseudocomplex words). The type suffix frequency was computed using the database of Lázaro, Acha, Illera and Sainz (submitted). This database includes child frequency measures obtained with the following logic. The largest child lexical database available for children in Spanish (LEXIN children word count database, Corral, Ferrero, & Goikoetxea, 2009) was downloaded and organized in reverse order i.e. words were listed starting from the last letters. This immediately enables the count of complex and pseudocomplex words containing certain suffixes. Pseudocomplex words were removed from the count by applying linguistic criteria word by word, finally obtaining highly reliable type (all words containing each suffix in the database) and token frequency (summed word frequencies of such words) of fifty debugged derivational suffixes.

Another set of 40 simple—non morphological—words, paired in all respects with the morphological word set, was selected. A pseudoword list was generated mirroring the list of words by changing up to two letters from the stem to create pseudowords (escudero vs. esdutero). Key variables controlled are shown in Table 2. The Onesc (Martínez & García, 2009) database for children was used to control all other word variables except suffix frequency. This database provides with additional lexical measures that influence lexical decision times such as neighborhood frequency (N).

Procedure

We conducted a lexical decision go/no-go task, similar to those conducted by Schmalz, Marinus, and Castles (2013) or Lázaro, García and Burani (2015).

Table 2 Key variables controlled in the experiment

Words	F	N	LL	BF	SF
High frequency suffixes	10.5 (9.7)	0.9 (0.8)	7.3 (1.5)	184 (212)	1547 (1115)
Low frequency suffixes	9.4 (15.1)	0.3 (0.7)	7.3 (0.6)	175 (202)	200 (367)

Standard deviations in parentheses

F frequency, *N* neighborhood density, *LL* letter length, *BF* base frequency, *SF* suffix type frequency

Participants were requested to judge as quickly as possible whether the letter-string presented was an existing word, trying to avoid errors. When the letter-string was a word, participants were required to press a key on the keyboard as quickly as possible; when the letter-string was not a real word no key was to be pressed. The go/no-go procedure is aimed at keeping error rates to a minimum, accelerating response latencies and decreasing variability in latency data (Moret-Tatay & Perea, 2011) relative to when a yes/no lexical decision task is administered to children (e.g., Laxon, Coltheart, & Keating, 1988; Lázaro et al., 2013).

Participants sat about 50 cm away from a laptop screen in a quiet room. The screen showed a fixation point "+" for 1 s, followed by a word or pseudoword target for 2.5 s or until participants responded. After a response was made or the time was over, a blank screen was displayed for 500 ms. The order of the presentation of stimuli was randomized. All children had normal or corrected-to-normal vision.

Results

Prior to any analysis, outliers were removed. No child neither item was removed from the analysis. Rather than remove latencies faster or slower than a certain limit, we made a visual inspection of the data for each group of children in R (version 3.0, RDevelopmentCoreTeam, 2008) thanks to the qqnorm command and then proceeded with trimming (see Fig. 1).

After removing 89 outliers from the total number of observations (2.4 % of the data), latencies and error rates were analyzed using mixed-effects models (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). The models were analyzed using the lme4 package (Bates, Maechler, Bolker, & Walker, 2014). *p* values were obtained using the lmerTest package version 2.0 (Kuznetsova, Brockhoff, & Christensen, 2014). Group and Suffix frequency were introduced as fixed factors, avoiding the

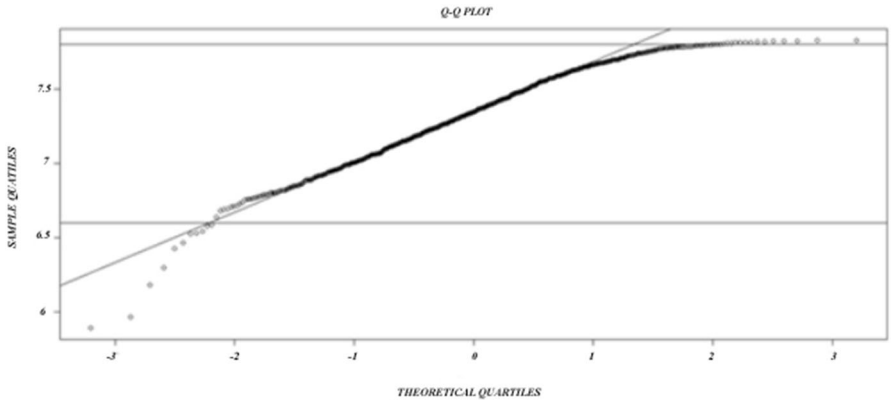

Fig. 1 Distribution of latencies of 2nd grade children. The *diagonal line* shows theoretical normal distribution and parallel *horizontal lines* show trimming criteria

introduction of the controlled variables in the model (Barr, Levy, Scheepers, & Tily, 2013). Response latencies were log-transformed to reduce skewness in the distribution. The formula used was:

$$= (lmer(logRT \sim Group * SuffixFreq + (1|words) + (1 + SuffixFreq|participants), data =)$$

Results on response latencies showed a significant effect of suffix frequency ($t = 2.16$, $p < .05$). Words with frequent suffixes were read faster than words with infrequent suffixes. General group effects revealed a significant difference between 2nd and 4th age children ($t = 3.7$, $p < .001$), as well as between 2nd and 6th grade children ($t = 5.2$, $p < .001$). Differences between fourth and sixth graders were not significant ($t = 1.6$, $p = .1$). Concerning the interaction between suffix frequency and group, the results showed no differences between groups—see Table 3 and Fig. 2 for a visual inspection of the data and "Appendix 2" for a detailed summary of the linear mixed-effects results.

Error rates were analyzed by means of generalized linear mixed models (glmer) fitted by the Laplace approximation for binomial data. Since the model failed to converge with the same formula as for response latencies, we simplified the model as follows:

$$= (glmer(logRT \sim Group * SuffixFreq + (1|words) + (1|participants), data =)$$

Again, the results show a significant effect of suffix frequency ($z = 2.65$, $p < .05$). Also group effects reveal a significant difference between 2nd and 4th grade children ($z = 3.7$, $p < .001$) as well as between those in 2nd and 6th ($z = 6.7$, $p < .001$). Differences between fourth and sixth graders were also significant ($z = 3.2$, $p = .01$). Concerning the interaction between suffix frequency and group, the results show no differences between groups—see Table 3 and Fig. 3 for a visual inspection of the data and "Appendix 2" for a detailed summary of the linear mixed-effects results.

A main question in our study concerned the issue of whether the sensitivity toward morphological units (indexed by suffix frequency effects) was related to vocabulary level and reading performance. To test this, we carried out a correlation analysis for each grade, testing the relation between the suffix frequency effect, mean decision times in the go–no go task, and vocabulary and reading accuracy scores. It has to be noted that there is an inconvenience with the Prolec-R test: the ceiling effect in typically developing children (the test was designed for diagnosis purposes). This is exactly what we found with our children. None of the subtests in

Table 3 Results of the experiment

Words	2nd	4th	6th
High frequency suffixes	1543 (30 %)	1256 (8.5 %)	1165 (4 %)
Low frequency suffixes	1626 (47 %)	1334 (26 %)	1248 (16 %)

Latencies in milliseconds. Error rates in parentheses

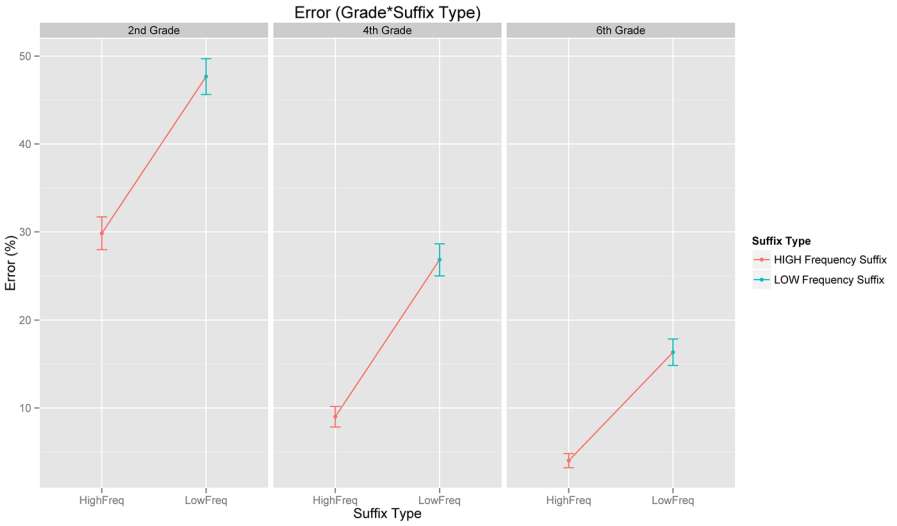

Fig. 2 Results of response latencies

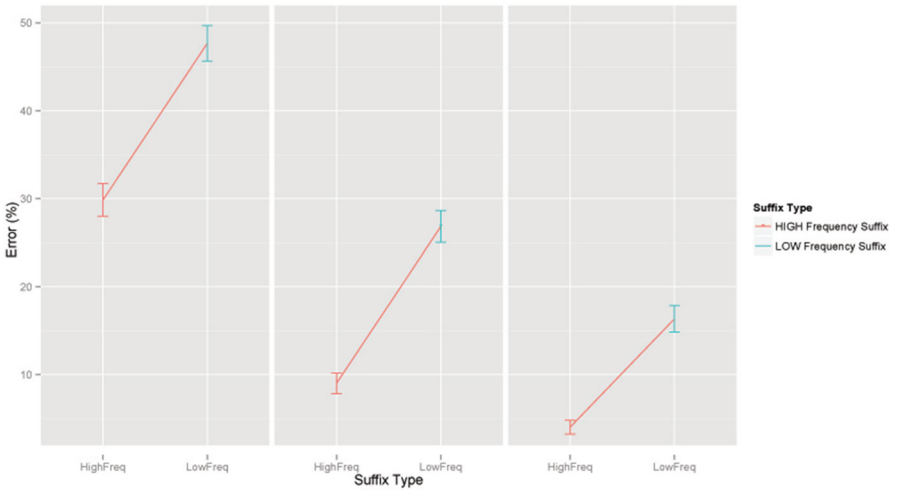

Fig. 3 Results of the error rates

the Prolec-R correlated with the suffix frequency effect or with the mean decision times in the go–no go task. The same was observed with the vocabulary measures. We found however some significant correlations that brought some light in the interpretation of the effect under study.

The suffix frequency effect—mean latencies of words with low frequent suffixes minus mean latencies of words with high frequent suffixes—was related to mean decision times only in 2nd grade, $r(30) = -.38$, $p = .03$, but not in 4th and 6th

grade (both $ps > .05$). In addition, a negative linear relation was found between the suffix frequency effect and reaction times of words with frequent suffixes in 2nd, $r(30) = -.62$, $p < .01$, and 4th grade, $r(30) = -.48$, $p < .01$, but not in 6th grade, revealing that the magnitude of the suffix frequency effect was related to the speed with which words with higher frequency suffixes are detected at these ages. The lack of correlation between suffix frequency effects and the paper and pencil tasks when the analysis was made by grade could be attributed to the ceiling effects and lack of variability in each sample. In addition these ceiling effects were evident even from 2nd grade. Due to this fact, we conducted a correlation analysis taking all children into account. Results are summarized in Table 2. This analysis showed that mean decision times were related to vocabulary measures. Taking all children into account, as long as Peabody measures increased, word recognition times decreased, $r(90) = -.56$, $p < .001$. In addition, recognition times of words with frequent suffixes were related with the Peabody scores, $r(90) = -.50$, $p < .001$; and with the Prolec-R subtests that tap into sublexical and lexical abilities: letter naming, $r(90) = -.26$, $p < .001$; word reading, $r(90) = -.28$, $p < .001$, and pseudoword reading, $r(90) = -.29$, $p < .001$. The highest scores in the vocabulary and reading tests led to the lowest decision times for words containing frequent suffixes. Finally, the suffix frequency effect was related to the speed with which words with frequent suffixes were identified, $r(90) = -.39$, $p < .001$. See Table 4 for a review of reported correlations.

Discussion

Although previous evidence has shown the key role of morphological processing in learning to read, thus far, studies have not offered a clear picture of how and when children internalize and exploit morphological regularities in reading. In this study, we examined the suffix frequency effect from a developmental perspective to assess

Table 4 Partial correlation coefficients between go–no go response times and vocabulary and reading measures with the 90 children in the sample

	1. RT frequent suffix word	2. Mean word RT	3. Suffix frequency effect	4. Peabody	5. Prolec-R LN	6. Prolec-R WR	7. Prolec-R PSR
1.	1	.941*	−.394*	−.505*	−.263*	−.281*	−.293*
2.		1	−.149	−.564*	−.252*	−.273*	−.308*
3.			1	.046	.300*	.219*	.275*
4.				1	.021	.085	−.038
5.					1	.336*	.258*
6.						1	.223*
7.							1

Prolec-R LN letter naming, *WR* word reading, *PSR* pseudoword reading

* $p < .01$

children's ability to identify and access morphological representations in Spanish. Our hypothesis was that if suffix frequency is a measure of how strongly a morphological unit is stored and retrieved for lexical access, the role of suffix frequency should change as the reader is exposed to meaningful orthographic regularities of derivational suffixes.

We expected that young children with limited reading experience and relative low vocabularies would not be significantly sensitive to suffix frequency, but that older children would show similar results to Spanish adults. Reading experience and vocabulary size are fundamental variables in the foundation of lexical representations (Perfetti, 2007; Stanovich, 1986; Verhoeven & van Leeuwe, 2008), therefore, sensitivity to suffix frequencies was more expected in older than in younger children. Our data reveal that suffix sensitivity is developed very early in Spanish and that suffix frequency could be a reliable marker of such sensitivity in this language even from second grade.

The fact that frequent suffixes contribute to lexical recognition more than infrequent suffixes suggests a different and more automatic activation in the first case, which in turn, implies that, even in children, facilitation during word recognition occurs according to suffix frequencies. In the case of error rates, it is worth noting that we have analyzed the false negatives i.e. no responses for words. Once we control the surface frequency of complex words (see Table 1), differences cannot be attributed to word frequency. Instead, we consider that the presence of a word with a suffix of high frequency biases children to press the "go" button in comparison to words with infrequent suffixes. Under this interpretation, when the presentation of a letter-string generates uncertainty, children make lexical responses paying special attention to suffixes. Under conditions of uncertainty about the lexicality of an item, the suffix frequency plays a major role in biasing children's go-responses depending on the frequency.

These outcomes also show that the effect of suffix frequency is present in all three groups of participants, in both response latencies and error rates. Contrary to our hypothesis, 2nd grade children do indeed benefit from suffixes of high frequency. In our view, such an early effect can be explained by two factors. First, derivation is the usual procedure to coin new words, so that children are used to find these structures in print, and second, Spanish is a highly transparent language i.e. the same sound corresponds straightforwardly to the same letter, so that orthographically and phonologically significant units can be easily integrated. In other words, we believe that the early effect of suffix frequency is a consequence of the productivity and regularity of derivational morphology in Spanish, two factors that might facilitate the early detection and internalization of morphological representations (Suárez-Coalla & Cuetos, 2013). Our results also reveal that reading efficiency is related to vocabulary increase, and that the suffix frequency effect on early ages might be modulated by the efficiency to identify high frequency suffixes into words. The relation between the suffix frequency effect and identification times of high frequency suffix words in 2nd and 4th grades, confirms this idea. This reveals that frequent suffixes might be well internalized units very early on infancy, probably due to the fact that most words in the child's vocabulary contain such endings.

It is important to consider that there are two variables that may play a role in word recognition and could potentially affect the interpretation of the suffix frequency effect found: word stress and syllable parsing. According to a syllable-based parsing hypothesis, in word recognition the suffix effect would be interpreted as an epiphenomenon of syllabic parsing. Syllables play a key role in reading acquisition in Spanish because of the methods being used in reading training, the construction of phonological representations (Goikoetxea, 2005) and the integration of such representations with orthographic patterns (Defior, Justicia, & Martos, 1996). Since, syllables were not explicitly manipulated in this experiment, it could be argued that selection of word patterns could be due to other factors such as syllabic frequency. An issue would be represented by the well known inhibitory effect of positional frequency syllable: high-frequency syllables require extra time for deactivating syllabic neighbors in lexical access (Carreiras, Álvarez, & de Vega, 1993; Jiménez, García, O'Shanahan, & Rojas, 2010; Luque, López-Zamora, Álvarez, & Bordoy, 2013). Carreiras et al. (1993) and Jiménez et al. (2010) provide evidence that initial and medial syllables consistently anticipate word targets that contain the critical syllable when the syllable pattern is lexically congruent with syllabic parsing. Luque et al. (2013) went beyond by showing that ordinary and dyslexic readers were differentially sensitive to inhibitory effects of positional syllable frequency, in such a way that the effect might be used as a diagnostic criterion. Even considering that the role of syllables in lexical word recognition is still a controversial issue (see for Spanish Álvarez, Carreiras, & Taft, 2001; Sainz & García-Zurdo, 2007), the positional frequencies of all syllables of the words being used in this research were computed in order to empirically refute that the suffix frequency effect observed is an epiphenomenon of syllabic parsing. Differences between positional frequencies in both suffixed conditions were not significant (all $ps > .05$) and indeed the syllabic frequency in the HF suffix condition was numerically higher (mean positional syllabic frequencies were 3.2 and 2.3 in the High and low suffix frequency conditions respectively, and the same balance across positions, according to the Syllabarium Spanish syllabic database, Duñabeitia, Cholin, Corral, Perea, & Carreiras, 2010). Additionally, the suffix −dor was the only one which matched a complete stressed syllable boundary. This could lead either to syllabic parsing or to positional syllable frequency effects in words containing such high frequency suffix. For that reason the same statistical analyses eliminating these items were conducted and the same effects were obtained: Significant effects of suffix frequency ($t = 2.13$, $p = .038$), and significant group differences between 2nd and 4th age children ($t = 4.1$, $p < .001$), as well as between 2nd and 6th grade children ($t = 5.2$, $p < .05$). This reinforces the idea that the facilitative effect in this condition was due to a suffix frequency effect and not to sub-lexical syllable-based parsing. Syllable parsing may play indeed a role in Spanish, but it cannot account for the suffix frequency effect observed in this research.

The fact that 7-year-olds showed the suffix frequency effect than older children suggests the need to assess even younger children. However, the error rates are quite high for second graders (see Table 2) and therefore we predict intolerably high error rates for younger readers. This supposes that to be able to detect the first signs of the

suffix frequency effect, a lexical decision task, even in a go–no go paradigm in which the cognitive load is reduced, is not an optimal procedure. Other tasks, such as a definition task (Bertram et al., 2000b; Burani, Bimonte, Barca, & Vicari, 2006; Lázaro, Schreuder, & Aceituno, 2011; Nicoladis & Krott, 2007), might be appropriate to explore the same aim in the future.

The purpose of this study was intended specifically to explore in detail the suffix frequency effect from a developmental perspective. Nevertheless, in theoretical terms, results of our study are in line with the assumption of full parsing models, in which morphemes are activated at a prelexical level (Taft, 1994). Our data suggest that the rule application system that underlies the recognition of morphemic words is sensitive to frequently encountered regularities. According to this model, lexical items could be accessed by a previous recognition of the morphological units. However, this does not neglect the role of whole word frequencies in this process, as assumed by the supralexical account (Giraudo & Grainger, 2000), or of the balance between whole word and suffix frequency in the process of word recognition as assumed by the race model (Frauenfelder & Schreuder, 1991). In such models, lexical access is the result of a double mechanism in which whole forms are examined first and constituents afterwards. Time for lexical access would thus depend on the activation weights of whole forms and the relative weighs of its constituents. In this study the aim was to test whether, once whole forms are controlled, the activation weight of certain units, measured in terms of frequency, could lead to greater activation than others. Our results imply that even a young cognitive system is sensitive to the frequency of such units beyond whole word frequencies. More research is needed to develop critical experiments to test predictions of these different models. Our data show that younger readers are sensitive to suffix frequency beyond whole word frequency. In this scope, the issue under evaluation concerns the role of orthography and derivation in Spanish as compared to other languages with a less transparent and non-shallow orthography. Let us first consider French, a Romance language like Spanish, still with a more opaque and deep orthography. As seen in the introduction, Casalis et al. (2015) presented evidence showing sensitivity to suffixes in children of 8.1 years, along the same line of our study, both in reaction times an error rates. Focusing on the suffix frequency effect, using a masked morphological priming paradigm Beyersman et al. (2015a) found, that the suffix frequency effect was modulated by grade, with decreasing suffix effects as reading proficiency increase. Using the same paradigm, Beyersman et al. (2015b) failed to find a significant effect for suffix frequency in university students. The lack of significance of a suffix frequency effect in expert readers and the modulation of the effect by grade in children is a somewhat different pattern from that observed in Spanish, despite the fact that both French and Spanish are Romance languages: the diminished orthographic transparency of French may lead to a coarse coding of lexical entries and to a greater competition between lexical candidates simultaneously active in word recognition, specifically as vocabulary increases and whole-word recognition becomes automatic. This greater competition could make the expert reader rely on whole-word lexical access, thus obscuring the suffix frequency effect in adults and older children.

With the same rationale, it could be expected that in opaque languages such as English, these effects should be negligible from the early years of reading instruction. There are two reasons to this. On one hand, Ford, Davis and Marslen-Wilson (2010) found in adults that complex words with high frequency suffixes generated faster responses than complex words with low frequency suffixes (Ford, Davis & Marslen-Wilson, 2010, exp. 2; see also Baayen et al., 2007). On the other hand, reading training in English is mostly aimed at presenting words as logographic patterns (in clear contrast to training in transparent languages). This explains why French and English speaking children reach reading and spelling expertise later than children of completely transparent orthographies (Nunes & Bryant, 2009). Morphological decomposition in English may be, in fact, a late acquisition (Beyersman et al., 2012; Carlisle & Feling, 2009), secondary to the acquisition of an extended vocabulary (Venezky, 2006). However, with respect to children, to our knowledge there is no direct evidence of the suffix frequency effect in this language. It seems clear, therefore, that regarding children's reading development, results in English would not match the Spanish data.

This idea however does not fit evidence found in Italian, a similar language to Spanish in terms of morphology and orthographic transparency. For example, Burani and Thornton (2003) found in adults that stem frequency facilitated word recognition, but they did not find suffix frequency effects, in contrast to Spanish data. However, as seen in the introduction, Traficante et al. (2011) and Burani et al. (2002) found that children were sensitive to suffixes at a very early age. To the best of our knowledge, there are no specific data concerning the suffix frequency effect in children in Italian, but the previously mentioned results clearly show different results for Italian and for Spanish in adult reading. Although Italian uses transparent orthography, stems seem to benefit lexical access more than suffixes. Methodological differences make any further comparisons difficult.

In Finnish, evidence collected with children aged 9.6 years shows that in a definition task, complex words with frequent suffixes obtained better definitions than complex words with infrequent suffixes (Bertram, Lainne, & Virkkala, 2000a). The results for Finnish, a transparent language, could indeed be similar to ours, even given the fact that Finnish is a rich morphological language (derivation is very productive and only 3 % of the words are simple, see Järvikivi, Bertram, & Niemi, 2006), a variable that could enhance early development of efficient morphological processing. As we have seen, methodological discrepancies, the different nature of the tasks, and the vague definition of the variables used to measure morphological processing (presence or absence of suffix, type frequency, token frequency, allomorphy) do not allow any generalization of conclusions. In fact, this seems to be the major challenge, to create a unified model of the role of suffixes and the development of suffix frequency across languages, according to their transparency and morphological nature.

In summary, our study provides clear evidence for the first time of a suffix frequency effect in Spanish children. Our results show that young readers process complex words morphologically and benefit from the frequency of suffixes at an early stage of reading development. The emergence of a suffix frequency effect, as shown by the reviewed literature depends on linguistic properties of the concerned

language. Cross-linguistic and longitudinal studies should be done to examine the nature and development of suffix frequency effects by equating methods, procedures, and tasks in all the relevant respects. New evidence will give us a better understanding of the role of morphological processing and its impact on reading development and rehabilitation (Traficante 2012).

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Appendix 1: Stimuli of the experiment

Words with HF suffixes	Words with LF suffixes	Simple words	Simple words
Perdedor (looser)	Isleño (islander)	Torneo (tourament)	Dinastía (dynasty)
Secador (dryer)	Hogareño (homelike)	Gacela (gazelle)	Acertijo (riddle)
Nadador (swimmer)	Navideño (Christmas)	Canela (cinnamon)	Almendra (almond)
Jugador (player)	Zarpazo (zarpazo)	Pupila (pupil)	Mazmorra (dungeon)
Aviador (aviator)	Chispazo (spark)	Garrafa (carafe)	Cerámica (ceramics)
Caluroso (warm)	Golpazo (wallop)	Enchufe (plug)	Apéndice (appendix)
Miedoso (scary)	Cochazo (nice car)	Azafrán (saffron)	Libélula (dragon-fly)
Aceitoso (oily)	Pinchazo (prick)	Emblema (emblem)	Cómplice (shill)
Venenosa (poisoning)	Hallazgo (finding)	Meñique (pinky)	Flamenco (flamenco)
Velero (sailing ship)	Noviazgo (engagement)	Maratón (marathon)	Cisterna (tank)
Escudero (squire)	Ligereza (lightness)	Anfibio (amphibian)	Avispa (wasp)
Guerrero (warrior)	Simpleza (simplicity)	Paladar (palate)	Jungla (jungle)
Barbero (barber)	Aspereza (roughtness)	Supremo (suprem)	Talisman (talisman)
Bromista (joker)	Firmeza (firmness)	Penalti (penalty)	Asfalto (asphalt)
Modista (modist)	Belleza (beauty)	Catarro (catarrh)	Calamar (squit)
Taxista (taxi driver)	Tipejo (despicable person)	Nuclear (nuclear)	huracán (hurricane)
Tenista (tennis player)	Bichejo (insect)	Trapecio (trapeze)	Alergia (allergy)
Tubería (pipe)	Melenudo (hairy)	Gamberro (thug)	Bellota (acorn)
Joyería (jewelry)	Forzudo (strong men)	Aguacate (avocado)	Borrego (lamb)
Bollería (pastries)	Orejudo (big-eared)	Polémica (controversy)	Calibre (caliber)

Pseudwords with HF suffixes	Pseudowords with LF suffixes	Simple pseudowords	
Lerfedor	Esfeño	Porneo	Dinaspia
Semador	Cojareño	Racela	Afertijo
Nasador	Nariseño	Cabela	Aldendra
Lujador	Zartazo	Putila	Maztorra
Amiador	Chisfazo	Gatafa	Cefamica
Taculoso	Golmazo	Enfuge	Alendice
Liecoso	Corrazo	Asatran	Litedula
Aveidoso	Rintazo	Emplema	Contrice

Pseudwords with HF suffixes	Pseudowords with LF suffixes	Simple pseudowords	
Belenosa	Hañazgo	Metique	Fladenco
Tefero	Vosiazgo	Magaten	Cisperna
Esdutero	Limereza	Antigio	Afista
Guetero	Sintreza	Patalar	Cungla
Barfero	Asdeleza	Sutreno	Tadistan
Troñista	Tirneza	Pefalti	Asdalfo
Nofista	Teñeza	Cadarro	Racamal
Tagista	Pilejo	Nuselar	Hutatan
Teyista	Biyejo	Tratesio	Agergia
Luvería	Neletudo	Gampeto	Betocha
Gojería	Tortuzo	Asuatate	Sorrego
Tolería	Ofejudo	Polejica	Rapibre

Appendix 2: Summary of the statistical output

Reaction time data

Group reference: second graders

Random effects:

Groups	Name	Variance	SD
Participant	(Intercept)	3.119e−02	0.176595
SuffixFreq		6.935e−05	0.008328
Words	(Intercept)	1.539e−02	0.124038
Residual		6.269e−02	0.250386

Fixed effects:

	Estimate	SE	*df*	*t* value	Pr(>|t|)
(Intercept)	7.551e+00	8.133e−02	8.890e+01	92.846	<2e−16***
Group2 (4th)	−2.438e−01	6.522e−02	1.950e+02	−3.738	0.000243***
Group3 (6th)	−3.353e−01	6.403e−02	1.851e+02	−5.236	4.43e−07***
SuffixFreq	−6.279e−02	2.910e−02	7.000e+01	−2.158	0.034399*
Group2: suffixfreq	−1.778e−04	1.944e−02	2.350e+03	−0.009	0.992702
Group3: suffixfreq	−4.049e−03	1.892e−02	2.344e+03	−0.214	0.830553

Group reference: fourth graders

Random effects:

Groups	Name	Variance	SD
Participant	(Intercept)	3.119e−02	0.176595
SuffixFreq		6.935e−05	0.008328
Words	(Intercept)	1.539e−02	0.124038
Residual		6.269e−02	0.250386

Fixed effects:

	Estimate	SE	*df*	t value	Pr(>|t|)
(Intercept)	7.307e+00	7.568e−02	6.780e+01	96.560	<2e−16***
Group2 (2nd)	2.438e−01	6.522e−02	1.950e+02	3.738	0.000243***
Group3 (6th)	−9.144e−02	5.715e−02	1.343e+02	−1.600	0.111927
SuffixFreq	−6.297e−02	2.692e−02	5.160e+01	−2.339	0.023221*
Gruop2: SuffixFreq	1.778e−04	1.944e−02	2.350e+03	0.009	0.992702
Gruop3: SuffixFreq	−3.871e−03	1.554e−02	2.221e+03	−0.249	0.803220

Group reference: sixth graders

Random effects:

Groups	Name	Variance	SD
Participant	(Intercept)	3.119e−02	0.176595
SuffixFreq		6.935e−05	0.008328
Words	(Intercept)	1.539e−02	0.124038
Residual		6.269e−02	0.250386

Fixed effects:

	Estimate	SE	*df*	t value	Pr(>|t|)
(Intercept)	7.216e+00	7.364e−02	6.110e+01	97.988	<2e−16***
Group 2 (4th)	9.144e−02	5.715e−02	1.343e+02	1.600	0.112
Group 3 (2nd)	3.353e−01	6.403e−02	1.851e+02	5.236	4.43e−07***
SuffixFreq	−6.684e−02	2.615e−02	4.610e+01	−2.556	0.014*

	Estimate	SE	*df*	t value	Pr(>|t|)
Group 2: SuffixFreq	3.872e−03	1.554e−02	2.221e+03	0.249	0.803
Group 3: SuffixFreq	4.049e−03	1.892e−02	2.344e+03	0.214	0.831

Error data

Group reference: second graders

Random effects:

Groups	Name	Variance	SD
Participant	(Intercept)	0.783	0.8849
Word	(Intercept)	1.844	1.3579

Fixed effects:

	Estimate	SE	z value	Pr(>|z|)
(Intercept)	−0.58837	0.54996	−1.070	0.284691
Group 2 (4th)	1.26751	0.33476	3.786	0.000153***
Group 3 (6th)	2.35935	0.34807	6.778	1.22e−11***
SuffixFreq	0.53434	0.20353	2.625	0.008656**
Group 2: SuffixFreq	0.19421	0.09877	1.866	0.062576
Group 3: SuffixFreq	0.10984	0.10716	1.025	0.305386

Group reference: fourth graders

Random effects:

Groups	Name	Variance	SD
Participant	(Intercept)	0.7829	0.8848
Word	(Intercept)	1.8439	1.3579

Fixed effects:

	Estimate	SE	z value	Pr(>|z|)
(Intercept)	0.67914	0.55056	1.234	0.217375
Group 2 (2nd)	−1.26748	0.33478	−3.786	0.000153***

	Estimate	SE	z value	Pr(>|z|)
Group 3 (6th)	1.09181	0.33851	3.225	0.001258**
SuffixFreq	0.72856	0.20615	3.534	0.000409***
Group 2: SuffixFreq	−0.19422	0.09878	−1.866	0.062576
Group 3: SuffixFreq	−0.08437	0.10668	−0.791	0.429026

Group reference: sixth graders

Random effects:

Groups	Name	Variance	SD
Participant	(Intercept)	0.783	0.8849
Word	(Intercept)	1.844	1.3579

Fixed effects:

	Estimate	SE	z value	Pr(>|z|)
(Intercept)	1.77102	0.55749	3.177	0.00149**
Group 2 (4th)	−1.09188	0.33849	−3.226	0.00126**
Group 3 (2nd)	−2.35936	0.34808	−6.778	1.22e−11***
SuffixFreq	0.64416	0.20992	3.069	0.00215**
Group 2: SuffixFreq	0.08437	0.10667	0.791	0.42900
Group 3: SuffixFreq	−0.10984	0.10717	−1.025	0.30537

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