A sociophonetic analysis of rhotic variation in Italian schoolchildren

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Abstract.

This paper investigates the production of Italian rhotics in the speech of 75 schoolchildren (6-10 years old) in the area of Biella, in the northwest of Italy. As rhotics are subject to a high degree of variation in Italian, their distribution and phonetic realisations were taken into account to test the influence of linguistic and sociolinguistic variables, i.e., phonological context, age and migratory background of the children's families. Results show that children's production varies across contexts and ages, as older subjects' patterns of variation seem to be approaching the distribution and the characteristics described in the literature for Italian adult speakers. Moreover, we propose that the migratory backgrounds and, in particular, the different heritage languages present in the children's repertoires, might be explanatory to the high degree of variability observed, e.g., in subjects of the same age.

Keywords: Rhotics; Italian; sociophonetic variation; phonological acquisition; child language; heritage language; majority language.

Abstract. Un'analisi sociofonetica della variazione dei suoni rotici in bambini italiani d'età scolare.

Il presente lavoro indaga la variazione dei foni rotici dell'italiano nelle produzioni di 75 bambini in età scolare (6-10 anni) dell'area di Biella, nel nord-ovest dell'Italia. Essendo i suoni rotici soggetti a un alto grado di variazione, in italiano come in altre lingue, la loro distribuzione e le loro caratteristiche fonetiche sono state prese in considerazione per testare l'influenza di variabili linguistiche e sociolinguistiche, come il contesto fonologico, l'età e il background migratorio delle famiglie dei bambini. I risultati indicano un effetto significativo del contesto e dell'età. In particolare, i pattern di variazione osservati nei bambini più grandi si avvicinano maggiormente a quelli descritti in letteratura per l'italiano di parlanti adulti. Inoltre, i background migratori e, in particolare, le diverse lingue ereditarie (*heritage languages*) presenti nei repertori dei bambini offrono, nei nostri risultati, una possibile spiegazione per l'alto grado di variabilità osservato, ad esempio, tra soggetti della stessa età.

Parole chiave: Rotiche; italiano; variazione sociofonetica; acquisizione fonologica; lingua infantile; lingue ereditarie; lingua maggioritaria.

Resum. Una anàlisi sociofonètica de la variació ròtica en escolars italians.

Aquest treball investiga la producció dels sons ròtics italians en la parla de 75 escolars (de 6 a 10 anys) de la zona de Biella, al nord-oest d'Itàlia. Atès que en italià els sons ròtics estan subjectes a un alt grau de variació, se'n van tenir en compte la distribució i les característiques fonètiques per comprovar la influència de variables lingüístiques i sociolingüístiques; és a dir, el context fonològic, l'edat i l'origen migratori de les famílies dels nens. Els resultats demostren que la producció dels nens varia en funció dels contextos i les edats, ja que els patrons de variació dels subjectes de més edat semblen aproximar-se a la distribució i les característiques que caldria esperar en els parlants adults. A més, proposem que els antecedents migratoris i, en particular, les diferents llengües patrimonials presents en els repertoris dels nens, podrien ser explicatius de l'alt grau de variabilitat observat, per exemple, en subjectes de la mateixa edat.

Paraules clau: Italià; variació sociofonètica; escolars; sons ròtics; llengües patrimonials.

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1. Language and migration in the northwest of Italy

The present investigation has been developed as a part of a bigger research project aimed at documenting and analysing the linguistic landscape of the area of Biella, a small town in the Alpine area of Piedmont, in the northwest of Italy. The interest in Biella's linguistic background stems from the many immigration waves after WWII that its territory was subjected to, as the region was famous for its textile industries. The first two waves, in the 1950s and 1970s, saw the arrival in the area of workers from other regions of Italy. At first, farmers moved up to find an occupation, most of them being uneducated and dialect-speaking people, while in the 1970s the area became particularly popular among specialised workers (e.g. nurses, teachers) who could speak not only their regional dialect but also regional Italian, which still made them sound "foreign-accented" to the people in the area (Meluzzi, 2019). More recently, from 1990 to 2013, the area, as well as the rest of the Italian territory, was the destination of a new migratory wave from non-European countries. The *Corpus of Language, Identity and Migration* (CoLIMBI; Meluzzi, 2019; Meluzzi, Sbacco, Rossi, & Betti, 2021), from which the data for the current study are taken, was collected as a part of the project *Lingua, identità e migrazione nel Biellese* (*Language, Identity and Migration in the Biellese Area*), which aims at documenting these migratory waves by creating an oral archive and investigating to what extent some of the most peculiar features of the dialects, Italian regional varieties and languages of migrants were and still are maintained throughout the 2nd and 3rd generations of immigrants. This study focuses on the speech of schoolchildren in the Biellese area – particularly on the distributional and phonetic features of their production of rhotics in Italian, to identify which linguistic and sociolinguistic factors play a role in their variation. Moreover, by including children with diverse migratory backgrounds, who are speakers of different heritage languages (HLs), the present investigation also aims at informing theories on heritage speakers' (HSs) phonologies.

2. Phonetics and phonology of rhotics

Rhotics are a complex and wide class of sounds (Maddieson, 1989) that exhibits a great range of manners and places of articulation (Ladefoged & Maddieson, 1996). Rhotics can in fact be characterised by an uvular, retroflex or alveolar place of articulation and by one of the five possible manners (tap, trill, fricative, approximant and lateral flap) (Ladefoged & Maddieson, 1996; Wiese, 2011). Researchers agree that such a varied and vast class is better defined in both articulatory and acoustic terms (Wiese, 2011), as many r-sounds across languages show a lowered third formant, whereas in others the same value is extremely high (Lindau, 1985). On the spectrogram, trills show as a

multiphase phone, characterised by a sequence of two or more apical contacts (Ladefoged, 2001; Celata, Vietti, & Spreafico, 2018). They are articulatory complex sounds and are naturally inclined towards variation and change (Romano, 2013). As the vibration required for the articulation of this class of sounds is physically demanding, the most spread variants are either taps, approximants or fricatives (Solé, 2002; Celata, 2014; Wiese, 2011).

2.1 Rhotic variation across languages

Due to this tendency to variation, rhotics are great sociolinguistic markers and have a wide range of realisations across several languages and dialectal varieties of the same language (Labov, 1966; Scobbie, 2006). Works by Maddieson (1984) show how the vast majority of languages in the world have rhotic phonemes within their repertoires. Languages that do not often showcase rhotic allophones of some other phoneme, or in a peripheral area (Wiese, 2011). Typically, languages have two rhotic phonemes in their repertoires, e.g., Spanish and Catalan, whereas languages with three or more rhotic phonemes are extremely rare, e.g., Irish Gaelic and some Australian languages (Wiese, 2011). Following Maddieson's accounts (1984), around 40% of all languages have a dental and/or alveolar voiced trill, while only 20% of the languages display a voiced alveolar flap. Only four languages show a uvular trill – French and German being two of them. Yet, the predominance of dental-alveolar trills remains somewhat a mystery, given the effort required to produce them. According to Bertinetto and Loporcaro (2005), the apical alveolar trill is the unmarked allophone of the rhotic phoneme in Italian. As singletons, trills are produced with a maximum of two apical contacts, whereas the geminate variant is produced with up to seven contacts (Maddieson & Ladefoged, 1996). In spontaneous speech, the singleton intervocalic /r/ is realised as a tap, while a biphasic tap is frequent before or after a consonant (Bertinetto & Loporcaro, 2005). However, the manner and place of articulation of Italian rhotics are subject to a high degree of diatopic variability. For instance, in northern regions of Italy, the majority of r-sounds tend to be produced as single-phase or a biphasic tap, while uvularised realisations are reported for trills (Rohlfs, 1966; Romano, 2013); alveolar approximant variants are also observed in northern regions, in particular in the northeast of Italy (Romano, 2013; Canepari, 1980). Moreover, in southern varieties, as in Sicilian and Calabrian, word-initial trills might be produced as cacuminal or retroflex fricatives, and clusters like -tr- and -dr- tend to be affricated (Romano, 2013). Nevertheless, rhotic sounds display a high degree of individual variation. In fact, as it has been observed in studies on different Italian varieties, like Tuscan (Celata, 2014), Tyrolean (Spreafico & Vietti, 2010, 2013) Sicilian (Celata, Meluzzi, & Ricci, 2016), and Rome Italian (Nodari & Meluzzi, 2020), rhotic realisation varies greatly depending on factors like speech style, social background and identity, and can convey socio-indexical meanings or communicative-interactional functions.

3. Acquisition of rhotics

Because of their articulatory complexity, rhotics are late-acquired sounds. Studies have shown that children start producing rhotic sounds at 27 months, regardless of their linguistic and familiar background (Zmarich & Bonifacio, 2004). By the age of 3, children have matured the ability to produce rhotics but would still prefer marked geminate sounds within that class, as they are easily controlled in their articulation – variants like these are usually not deemed coherent with the variety the children's community speaks (Nagy & Gadanidis, 2022). Such over-extensions in children's production disappear as their vocabulary reaches 50 items and start to be moulded on the input they receive from adults (Velleman & Vihman, 2007). More generally, children will substitute rhotics with the closest sound class (mostly liquids) in their repertoire if rhotics haven't been fully acquired yet (Bortolini & Leonard, 1991). Research on monolingual children shows how these phonemic categories will continue to develop up until early adolescence and that the variability they show more in children's early speech will inevitably reduce with age (McCarthy, Rosen, & Evans, 2014).

3.1 Acquisition by Heritage Language speakers

HSs are by definition speakers of a HL, i.e., a language or a variety they were exposed to since birth, that they either acquired by living in the area where it is spoken or by being exposed to it through parenthood or relatives (Montrul, 2013), and that is different from the dominant language of the community they live in. Although HSs are by broader definition bilingual speakers, they are neither considered canonical bilinguals nor L2 learners (Chang, 2016). In fact, HSs are less proficient in the language they acquired first (HL) and share some limitations with late-acquired L2s in their Majority Language (ML), i.e., the dominant language of the community, such as a smaller expressive vocabulary or a slower speech rate (Chang, 2016; Flege, 1995; Major, 2001). Even with a later onset of exposure, HSs' L2, which is the ML, can become their dominant language, reducing any HL effect (McCarthy, 2013). In fact, children that speak a HL at home can become dominant in the ML by the time they are introduced to the schooling system, regardless of when they started being exposed to it. The enormous amount of ML input outside of home could potentially reduce any HL effect in their production. In their study on the acquisition of the English voicing contrast by children of immigrant families, McCarthy et al. (2014) found that their subjects' perceptual abilities and production skills reflected the phonetic properties of the HL to which they were exposed to at home at 4;4 years of age; however, one year later, at 5;4, after the start of full-time education in English, their abilities matched those of their monolingual peers. Thus, the start of schooling has been identified as a crucial period for the development

of the ML, with consequent attrition on the HL (McCarthy et al., 2014). Lloyd-Smith, Einfeldt and Kupisch (2020) argue that considering an early onset of exposure to the ML as a predictor for foreign-accented production in the HL later on is strongly supported by the fact that phonological acquisition is not completed as early as thought. Research in phonology shows that there are some early and late acquired properties to a language and that acquisitional patterns are language specific. This means that by the time the child is introduced to the ML and massively exposed to its input, some early acquired properties may be completely set, while late acquired ones are still being developed (Lloyd-Smith et al., 2020). This might interfere with the development of complex categories, like rhotics. However, bilinguals (whether canonical ones or HSs) that have such variants in their L1's phonological repertoire manage to produce it as a result of positive transfer phenomena (Kopečková, 2016). These children's repertoire however appears to be conditioned by their networks as well, e.g. parents and relatives, with them being exposed to local variants through their parents' input (Selas & Neteland, 2019). As kids acquire linguistic features without necessarily acquiring their social value altogether (Selas & Neteland, 2019), the phonological context within which these variants appear is way more relevant and influential in these sounds' acquisition than social cues (Chevrot, Beaud & Varga, 2000). Studies have also shown that HSs (and sequential bilinguals together with them) are really sensitive to highly variable speech and, consequently, to accented variants (McCarthy et al., 2014). Some kids might in fact be exposed to neutralised phonetic contrasts of the ML by immigrant parents or late-L2 learner relatives, and might acquire the accented variant instead of the expected L2 contrast (McCarty et al., 2014). Based on these premises, we hypothesise that the eldest children accounted for within our sample have matured the ability of producing rhotics as a result of becoming dominant in the ML, regardless of the phonetic repertoire of their HL. Thus, children whose HL does not include some rhotic variant, have acquired it nevertheless, due to the constant and dominant exposure to the ML. However, some instances of HL influence could still be found in their production.

4. Research questions

This study thus sets out to investigate Italian rhotics in the speech of elementary school children between the ages of 6-10 with diverse migratory backgrounds, and to assess which factors might influence the pattern of distribution of different variants, as well as their acoustic form. In particular, the research questions that guided the study are the following:

1. What rhotic variants can be observed in the speech of elementary school children with diverse migration backgrounds?

2. Do the phonetic form and distribution of rhotics in the speech of the children in our dataset vary based on phonological context, age, and migratory background of the subjects?

5. Methods

To investigate these research questions, we analysed the speech of 75 schoolchildren (6-10 years old) from the CoLIMBI. Pupils were recorded carrying out two picture-naming tasks in which 18 target words containing a rhotic sound were represented by a picture and its orthographic transcription. In particular, the stimuli were presented on a page and were connected by arrows forming a path. Participants were instructed to name each image while creating a narrative based on their observations of the images on the page. The words constituting the stimuli were real Italian disyllabic initial-stress words with the rhotic always occurring words-internally, in the unstressed syllable. Rhotics were presented as intervocalic singletons (5 words) or geminates (3 words), and preceding (5 words) or following a plosive consonant (5 words). Intervocalically, the rhotic was preceded by either central (e.g., "sbarra", bar), front ("ghiri", dormice) or back vowel ("muro", wall). The vowel for the pre- and post-consonant contexts was always the central "a" (e.g., "capra", goat; "carta", paper). Children's production data in the CoLIMBi was collected in 1st, 2nd, 4th and 5th grades (3rd grade classes were not available for the data collection) within two elementary schools in the Biellese area. Each subject was individually recorded while carrying out the tasks under one researcher's supervision. Recordings have been carried out during school hours in empty and quiet school rooms, using a Tascam DR-40 with an external Sony microphone with a 44.1kHz sampling rate and a 16-bit depth. Information about the children and their families, about a possible migratory background, as well as the language(s) and/or the dialect(s) spoken at home with the child, was collected through sociolinguistic questionnaires filled out by the children in class, under the researchers' and the teachers' close supervision. Before data collection could start, children's parents signed a consent form containing all the information about the research. All subjects have been anonymised for privacy protection.

5.1 Annotation

Audio recordings were saved in .wav format and labelled using Praat (Boersma & Weenink, 2022) following the annotation protocols developed by Meluzzi (2020) and by Celata et al. (2016). Rhotics were isolated in the TextGrids and labelled based on the realisation type of the rhotic, i.e., its manner of articulation – tap, trill, approximant or fricative. The realisation type was assessed visually from the spectrogram, as well the aperture and constriction phases of taps and trill, which were also isolated on an additional tier (an

example of the annotation in Praat can be seen in Fig. 5). Such phases were also used to discriminate between a tap and a trill, with trills having more than one constriction phase, i.e., one tap of the tongue (cfr. Ladefoged, 2001). Approximants are spectrally characterised by well-defined and uninterrupted formant structure, similarly to vowels, due to the tongue not making contact with the roof of the mouth, while fricatives are recognizable by the high-frequency noise energy caused by the turbulence of the air passing through a narrow constriction in the vocal tract. A team of 8 expert annotators performed the annotation, with files equally divided between them. Doubtful cases were flagged and double-checked by another expert annotator. If unclassifiable, occurrences were excluded. All labels, as well as the duration of the phone and the phase count, were extracted using a Praat script coded by the authors.

6. Analysis

As previously mentioned (see § 5), the phonological contexts were the intervocalic singleton ("sing"), intervocalic geminate ("gem"), preceding a plosive consonant ("pre") and following a plosive consonant ("post"). The speakers' age has been operationalised using the pupils' school grade, i.e., "first", "second", "fourth" and "fifth". The variable associated with the migratory background is "generation", referring to the migratory generation the pupils belong to, that was assessed through the information about their parents' and grandparents' places of birth. This way we were able to obtain three groups of children, based on their background: the "LOC", i.e., the locals, whose families are originally from the area, and the "IMM2" and "IMM3", whose parents or grandparents, respectively, have migrated to the Biellese area and settled down there. In line with the migratory history of the area, the great majority of the pupils in "IMM2" group have parents that have migrated from non-European countries, while "IMM3" consists of children whose grandparents migrated to the area from another Italian region. Moreover, the languages and language varieties spoken by the families of the children with a migratory background are several, and very diversified, as shown below in Tab. 1. The variable "languages" was used in the analysis to indicate the language(s) spoken at home. The labels within this variable correspond to the reported language(s), such as "Italian" for Italian or "Filipino+English" when both languages were reported. The labels "Sardinian", "Venetian", etc., refer to the Romance variety spoken in the respective Italian region.

	first	second	fourth	fifth	total
LOC	Italian (5) Piedmontese (1)	Italian (3)	Italian (3)	Italian (4) Piedmontese (3)	20
IMM2	Pugliese (1)	Italian (4) Arabic (1) English + Venetian (1) French + Swahili (2)	Italian (8) Arabic (1) French (1) Sardinian (2) Sicilian (1)	Piedmontese (1) Albanese (1) Moroccan[1] (1) Filipino + English (1) Pugliese (1)	27
IMM3	Italian (8) Piedmontese (1) Sardinian (1)	Italian (5) Sicilian (1)	Italian (5)	Italian (5) Friulian + Neapolitan + Piedmontese (1)	28
total	17	17	21	20	75

Table 1. Languages and varieties to which the children are exposed at home, with the number of subjects who provided the answer. Pupils are divided both by school grade and by migratory generation. Some subjects reported that more than one language was spoken at home, and these instances are indicated with a "+" symbol.

The analysis was carried out in R (R Core Team, 2021). The distribution of the different realisations of the rhotics within the subject groups was tested using $\chi 2$ tests. Linear mixed-effects regression models were fitted using the lmer() function in the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2017) to examine the effects of the phonological context, school grade, and migratory generation on duration. Post-hoc tests were conducted using the emmeans package (Lenth, 2022) to examine the differences between the levels of significant fixed effects. The effects package (Fox & Weisberg, 2019) and the sjPlot package (Lüdecke, 2023) were used to visualise the models. Summaries of the models are reported in full in the Appendix.

7. Results

The dataset analysed for the current study consists of 1531 segments produced by the 75 Italian schoolchildren in the picture-naming tasks. Tokens

1. The term "Moroccan" is employed in the study to indicate the subject's reported HL based on the response provided in our questionnaire regarding the family's background and languages spoken at home. However, it is worth noting that the use of the label "Moroccan" may introduce a certain degree of ambiguity or confusion due to its broad nature, encompassing the different languages and varieties spoken in the region, such as Classical Arabic, Standard Arabic, Moroccan Arabic and Berber (Ennaji, 2007). Even though further private information about the subject might help us connect the given label "Moroccan" with Moroccan Arabic, we decided to report the answer as it was provided in the questionnaire, while acknowledging the limitations of using a generic term without further linguistic specification.

that were not possible to annotate due to recording issues, or those that were produced in a way that was completely divergent from the target, were excluded from the dataset. Repetitions of the same words over the course of the task were kept in the final dataset. In total, the analysis includes 307 segments for the children in the 1st grade, 364 for those in the 2nd, 436 for those in the 4th and 424 for the pupils of the 5th grade.

7.1 Distribution

We have observed all the expected realisation types, i.e., trills (n=562), taps (n=868), approximants (n=88) and fricatives (n=13). The distribution of the realisation type appears to be significatively connected to the children's age. In fact, a $\chi 2$ test assessing the relationship between "realisation" and "grade", with p-values estimated using the Monte Carlo simulation (Hope, 1968) since 3 out of 16 cells (18%) have values <5, results to be significant ($\chi 2$ = 164.82, df = NA, p < .0001). The Pearson residuals for the test show that approximant and fricative realisations occur significantly more frequently in the speakers from 1st and 2nd grade, while taps are observed more frequently in 5th grade and trills in 4th (see Tab. 2).

	first	second	fourth	fifth
approximant	27 (2.22)	35 (3.07)	3 (-4-40)	23 (-0.27)
fricative	6 (2.10)	7 (2.22)	0 (-1.92)	0 (-1.89)
tap	170 (-0.30)	230 (1.64)	178 (-4.40)	290 (3.19)
trill	104 (-0.81)	92 (-3.60)	255 (7.50)	111 (-3.57)

Table 2. Observations (and Pearson residuals) for the $\chi 2$ test assessing the relationship between "realisation" and "grade".

Moreover, a $\chi 2$ test indicates the existence of a relation also between the realisation type and the phonological context in which the rhotic occurs ($\chi 2$ = 261.16, df = NA, p < .0001). In particular, the residuals for the test indicate that taps tend to occur significantly more often in the "post" (n. observations: 302; residual: 2.89) and in the "sing" (280; 4.30) contexts, while the trills occur significantly more in the "gem" (140; 9.30) and "pre" (233; 3.01) contexts. Such distribution, with more trills occurring in the geminate and pre-consonant context, and more taps occurring in the intervocalic singleton and post-consonant context, can be observed in all grades, with the exception of the 4th. In fact, as can be seen in Fig.1, in 4th grade the percentages of trills are very high in all the controlled contexts.

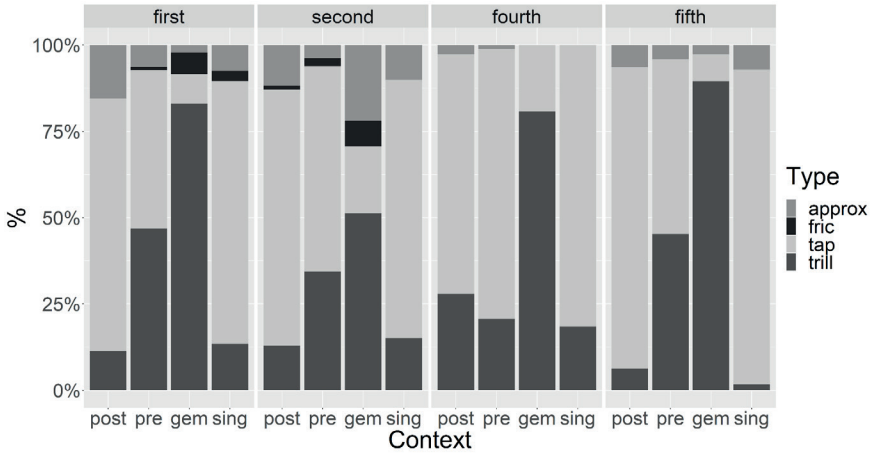

Figure 1. Percentage of realisation types (approximant, fricative, tap, trill) in each context (post-consonant, pre-consonant, geminate, intervocalic singleton) produced by subjects in each grade.

The distribution of the realisations appears to be also significantly related to the children's migratory generation, as a second $\chi 2$ test with simulated p-values reveals ($\chi 2$ = 39.116, df = NA, p < .001). The residuals for this test indicate that Italian rhotics are realised as approximants significantly more frequently by the "LOC" and, even though this is not significantly related to the migratory generation, a higher number of trills is observed in the "IMM2" group, followed by "IMM3" (see Tab. 3).

	IMM2	IMM3	LOC
approximant	29 (-0.36)	14 (-3.32)	45 (4.34)
fricative	4 (-0.27)	5 (0.04)	4 (0.25)
tap	285 (-1.20)	346 (1.04)	237 (0.14)
trill	222 (1.68)	212 (0.01)	128 (-1.94)

Table 3: Observations (and Pearson residuals) for the $\chi 2$ test assessing the relationship between "realisation" and "generation".

A more detailed observation of rhotic realisation by the children in each generation group, considering also the individual languages spoken at home, reveals, however, very different distributional situations. For instance, in the "IMM2", 5 subjects did not produce any taps, but showed an evident preference for trills (e.g., "Arabic", "French", "Sardinian", all in grade 4th). The distribution is different for the subjects in the "IMM3" group, with more cases which are closer to the target distribution ("Friulian+Neapolitan+Piedmontese" and "Venetian+Piedmontese", both in grade 5th), even though with a high degree of variation. Finally, in the "LOC" group, in which subjects'

caregivers only speak (the Piedmont variety of) Italian and the local dialect (Piedmontese), we are able to observe the general distribution pointed out earlier, with a higher number of trills in the "gem" and "pre" context, and more taps in the "sing" and "post" context, along with several approximant realisations. The following figures (Fig. 2, 3, 4) are provided to offer a comprehensive understanding of the composition of the groups and the realisations they produced. However, it is important to note that in Fig. 2 and 3, certain entries pertain to only one or two subjects (e.g., Filipino+English, Moroccan), and therefore do not represent an average across subjects.

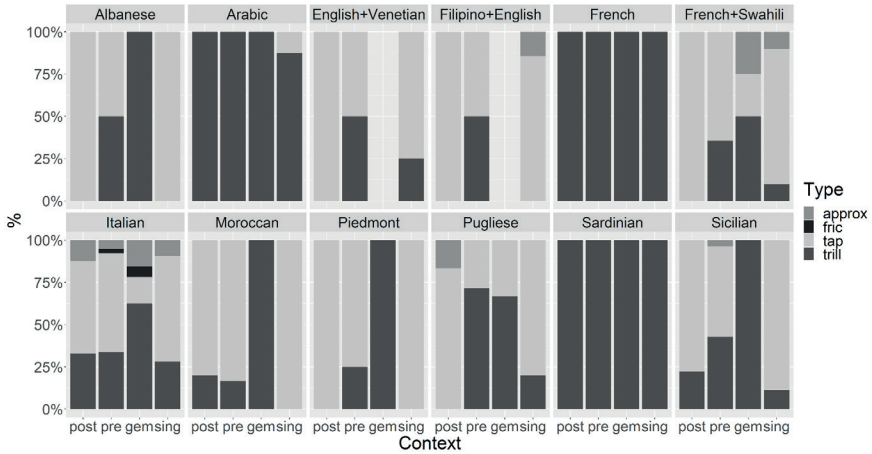

Figure 2. Distribution of realisation types for the languages and/or varieties children in the "IMM2" group are spoken to at home.

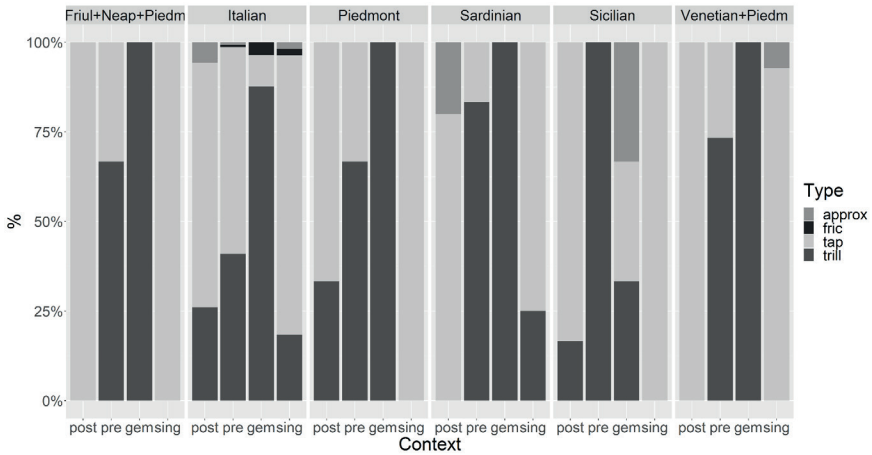

Figure 3. Distribution of realisation types for the languages and/or varieties children in the "IMM3" group are spoken to at home.

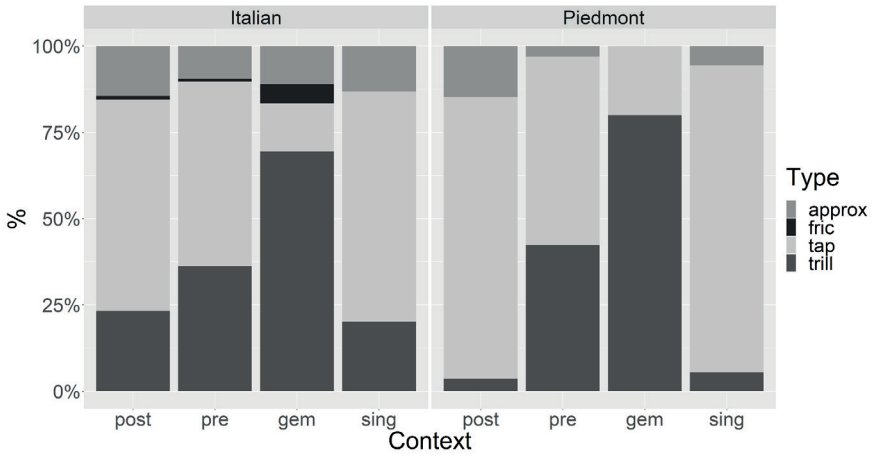

Figure 4. Distribution of realisation types for the languages and/or varieties children in the "LOC" group are spoken to at home.

7.2 Phases and duration

In general, in our dataset 60% of taps are biphasic and 40% monophasic. Trills are most commonly produced with either 3 (30%) or 4 phases (19%), although there is considerable variability in their phase number depending on the phonological context and the grade of the children. For instance, the average number of phases is 2 for the "pre" and "post" contexts, 1,5 for the "sing" context, and 5,5 for the "gem" context. As for the age variation, trills produced by children in the first and second grade have a higher number of phases than children in the higher grades, with some outliers even reaching the 10, 13 or 15 phases for the geminate context (see Fig. 5) in the first grade (the peculiarity of these forms will be addressed in the Discussion section, § 8). Although several outliers can be observed, the fourth grade shows a decrease in the number of trill phases. In contrast, by the fifth grade, taps become predominantly monophasic, and trills become more distinct due to a higher number of phases, typically around four, with only a few outliers.

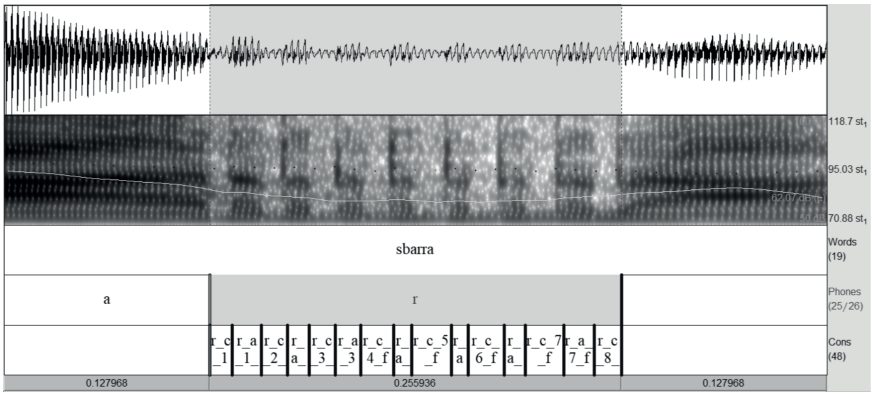

Figure 5. Trill in the geminate context produced with a total of 15 aperture-constriction phases with the relative annotation in Praat.

To assess whether taps and trill are not only distinguished by the number of phases but also by their segmental duration, we fitted a linear mixed model (see Fig. 6 and Model 1 in Appendix) to predict duration with realisation and grade (formula: duration ~ realisation + grade). The model included speaker as random effect (formula: ~1 | speaker). The model's total explanatory power is substantial (conditional R2 = 0.41) and the part related to the fixed effects alone (marginal R2) is of 0.29.

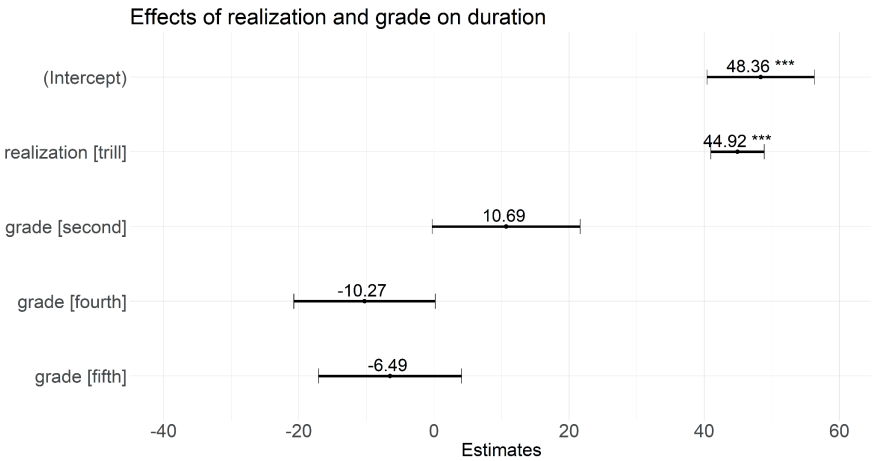

Figure 6. Effects of the model duration ~ realisation + grade + (1|subject).

The effect of realisation was found to be statistically significant and positive. Specifically, an increase in realisation from tap to trill was associated with a significant estimated increase in duration by 44.92 (95% CI [40.98, 48.87]). Lastly, the effects of grades second, fourth, and fifth were not found to be statistically significant, suggesting no different trends in duration variation related to grade. In fact, the post-hoc Tukey pairwise comparison test indicates that tap and trills are significantly differentiated between each other in terms of duration in each grade.

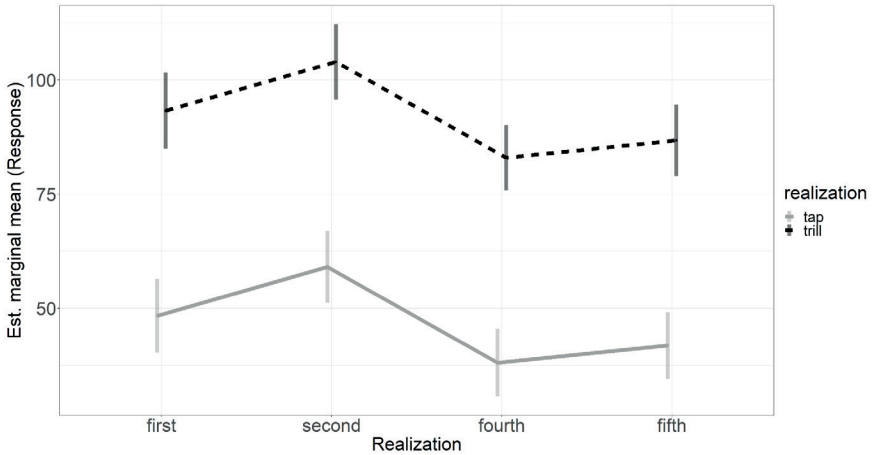

Figure 7. Post-hoc Comparisons of Estimated Marginal Means for the model duration ~ realisation + grade + (1|subject).

To explore whether there is a relationship between age and the phonetic form of rhotics in different phonological contexts, we fitted a linear mixed model (see Fig. 8 and Model 2 in Appendix) to predict duration with grade and context (formula: duration ~ grade * context). The model included speaker as random effect (formula: ~1 | speaker). The model's total explanatory power is substantial (conditional R2 = 0.55) and the part related to the fixed effects alone (marginal R2) is 0.46. We find significant interaction effects between context and grade, indicating that children's pronunciation of rhotics develops with age in specific phonological contexts.

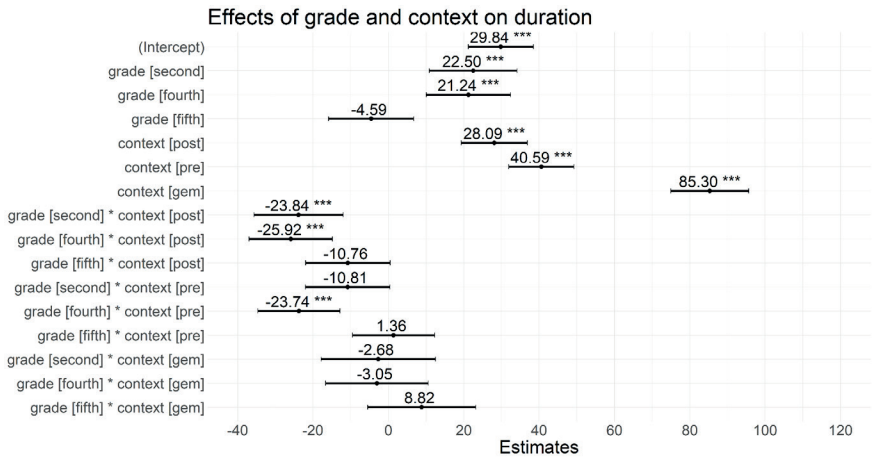

Figure 8. Effects of the model duration ~ grade * context + (1|subject).

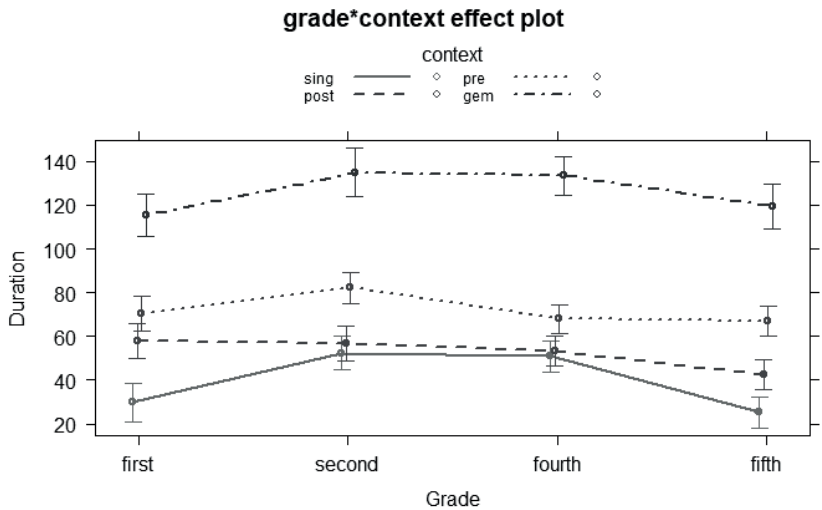

Figure 9. Effects plot of the model duration ~ grade * context + (1|subject).

Each age group significantly distinguishes different contexts in terms of duration. When comparing grades within each context, complexities arise. In the "post" context, duration decreases in the 5th grade, indicating shorter taps and trills without significant group differences. In the "pre" context, duration decreases with higher grades, and there's a significant difference between the 2nd and 4th grades (β = -14.192, t ratio = -2.840, p = .01). Geminates also shorten from the 2nd to 5th grade, but without significant group differences. In the "sing" context, rhotics lengthen after the 1st grade and shorten after the 4th, with significant changes between the 1st and 2nd grades (β = 22.497, t ratio = 3.794, p = .0006) and between the 4th and 5th grades (β = -25.829, t ratio = -4.988, p < .0001).

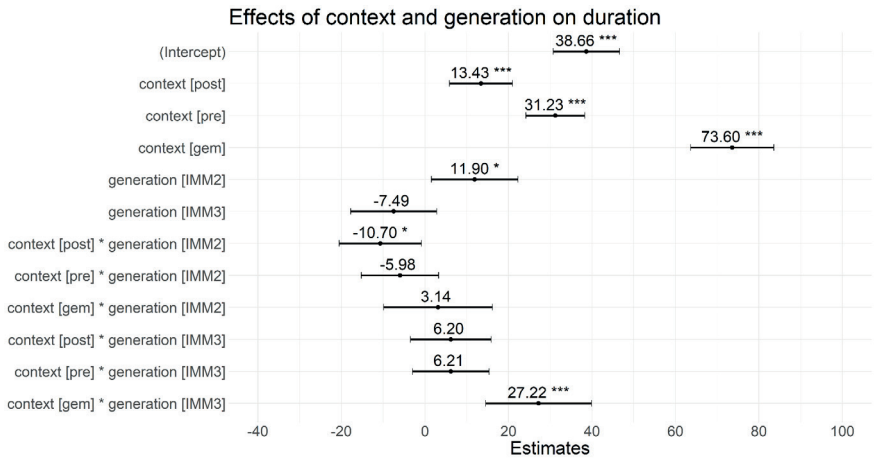

Figure 10. Effects of the model duration ~ context * generation + (1|subject).

In order to determine whether different migratory backgrounds have a significant effect on the phonetic form of rhotics in children's speech, we fitted a linear mixed model (see Fig. 10 and Model 3 in Appendix) to predict duration with context and generation (formula:duration ~ context * generation). The model included speaker as random effect (formula: ~1 | speaker). The model's total explanatory power is substantial (conditional R2 = 0.54) and the part related to the fixed effects alone (marginal R2) is of 0.43. The specific generation does not have a significant effect on duration. However, there are significant interaction effects between generation and context, suggesting that the relationship between generation and duration depends on the specific context. In fact, in the post-hoc contrasts, we observe significant differences in the duration of taps between "IMM2" and "IMM3" in the intervocalic context (IMM3 - IMM2: β = -16.195, t ratio = -3.124, p = .0041), with taps being shorter for "IMM3" speakers. We also observed significant differences

in the duration of trills between "IMM3" and "LOC" in the geminate context (LOC - IMM3: β = -20.046, t ratio = -2.941, p = .0068), with trills being longer for "IMM3".

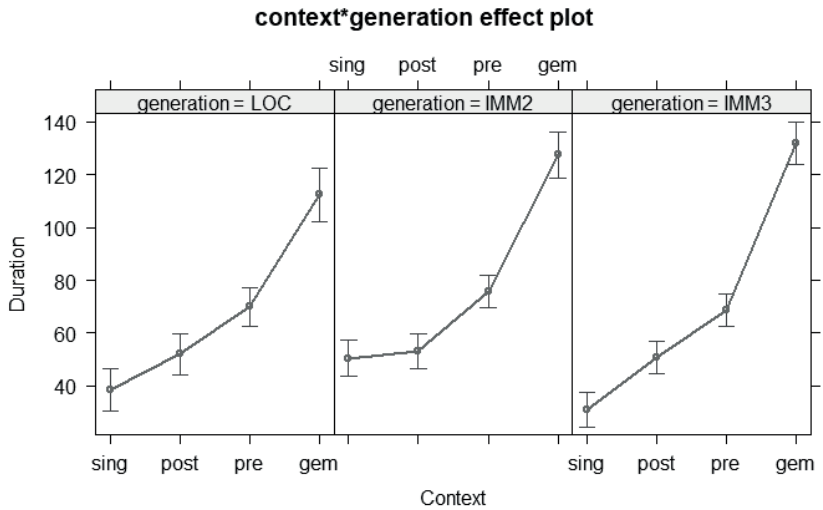

Figure 11. Effects plot of the model duration ~ context * generation + (1|subject).

8. Discussion

From the analysis of schoolchildren's speech, we have observed that both Italian rhotic variants, i.e., the tap and the trill, are well represented in our dataset. The alveolar trill, i.e., an articulatory and aerodynamically challenging segment (Solé, 2002), is present already in the productions of our 1st grade subjects. This indicates that 6 years old Italian children have already learned how to produce a rhotic sound consisting of multiple and rapid contacts of the tongue tip with the alveolar ridge. This is in line with the research L1 phonological acquisition, both on Italian and several other languages, which indicates that the trills are acquired around the ages 3-5 (Orsolini, 2002; McLeod & Crowe, 2018), and are among the last to be mastered (Vihmann, 1996).

Moreover, we have observed some realisations of the rhotic as either a fricative or an approximant. The replacement of taps and trills with segments that have a different manner of articulation and are easier to produce articulatorily has been observed not only in children, but also in teenagers and adults, as reported by Jaworski and Gillian (2011). The authors explain this phenomenon as the result of an incomplete closure between the tongue tip and the alveolar ridge due to articulatory undershoot, which leads to the production of lenited

variants of the rhotic, such as a fricative or an approximant. In our data, the frequency of the fricative is very low and limited to younger children, in particular those in the 1st and 2nd grade, especially in the geminate context, where a long trill would be expected. From an acquisitional perspective, this might suggest some remaining imprecision and difficulties in the articulation of a proper vibratory movement for younger children. The approximant variant, instead, was also observed in higher grades. In fact, we find that the distribution of the approximant realisation, besides being related to the children's age, is also connected to their families' background. In fact, approximants are most frequent in the group whose families are from the Piedmont area (cfr. Table 3, § 7.1), where the pronunciation of rhotics as approximants is common (Canepari, 1980).

Taps and trills are distinguished by children of all ages in terms of their number of phases and duration, i.e., the main features contrasting the two types of realisations (Willis & Bradley, 2008; Menke, 2018), even though there is a lot of variation in the distribution of both realisations and in the phonetic form of the segments, even in the 5th grade. As we have observed both in the analysis of the distribution and that of the segmental duration of rhotic realisations, in the contexts where more taps would be expected there are still a lot of trills, even if some development can be observed in the higher grades. For instance, such development appears to be particularly evident for the intervocalic singleton ("sing") context, where the number of tap realisations increases and the segmental duration decreases with age, a pattern which was also observed for Spanish acquisition by bilingual and by monolingual children, by Menke (2018) and by Carballo and Mendoza (2000) respectively, and is connected with an increase in articulatory control. A similar explanation could be at the base of the very high number of distinct phases observed in the early grades for trills, which decreases for older children. Another factor which might be contributing to the high number of phases in trills could be connected to the perceived formality of the task that the subjects had to carry out. Stylistic variation has been observed in children as early as 3-4 years old (Nardy, 2008). Chevrot et al. (2000) investigated the production of post-consonantal word-final /R/ in French speakers of 6-7 and 10-12 years of age and find that children seem to have acquired "a hyper-articulatory ability, which comes to the fore when attentional resources are directed towards speech" (Chevrot et al., 2000, p. 316) in response to formal situations, which does not take into consideration which one is the correct variable to use in the standard. Thus, in our case, children might hyperarticulate the trills and substitute taps with trills, even in higher grades, as a response to a situation that they perceive as formal.

Finally, even if the sample is very diverse in terms of origins and HLs, the children's migratory background seems to have some influence on their production of Italian rhotics. For instance, our results revealed notable variations

in trill and tap duration and distribution. Among children from the third migratory generation, taps are considerably shorter and their distribution is more consistent with the phonotactic expectations of Italian compared to those from the second migratory generation. As the parents of the "IMM3" group were already born into the ML community, their children's speech patterns are more aligned with the anticipated distribution of rhotics. On the other hand, the "IMM2" group showed distinct patterns of realisation, and the group also exhibited a considerable degree of variability among its subjects, suggesting the possibility of very diverse acquisitional patterns. This could be due to the many different HLs to which the children in this group are exposed at home. For instance, children whose HL's phonological inventory does not include a tap-trill contrast, but only a trill, are producing trills in each phonotactic contexts, e.g., Arabic, Sardinian and French HSs in 4th grade. The two subjects who have English as HL are not producing geminate segments, at 7- and 10-year olds respectively, and 10-year-old subjects with HLs which have both taps and trills (e.g., Moroccan Arabic and Albanian) produce such contrast in Italian as well, probably starting from the intervocalic position, i.e., where the contrast is realised, and then moving on to other contexts (Colantoni, Steele, & Escudero, 2015). Even if the start of schooling in the ML should greatly support the development in the ML, i.e., Italian (cfr. § 3.1), it is possible that our subjects' HLs, or also a foreign-accented version of the ML spoken at home (McCarty et al., 2014), might still be influencing the production of difficult sounds in Italian, such as rhotics, even in the higher grades. Moreover, the very different patterns of acquisition that we observe in HSs of all grades could also be heavily influenced not only by the characteristics of the HLs, but also by many other factors about which we do not have information at this stage of the project, such as the children's amount of exposure to the HL at home, their attitudes towards and connections to the HL community, and the age of onset for Italian.

9. Limitations of the study

Although our study provides valuable insights into phonetic variation in the speech of schoolchildren with different ages and migratory backgrounds, there are several limitations that should be noted. Firstly, as previously mentioned in § 5, our experimental materials included not only the target word image but also its orthographic transcription, allowing children to read the word aloud if they were uncertain. This could have influenced the way children produced more difficult words, with younger children potentially experiencing greater difficulty. Furthermore, in the current analysis we did not distinguish between read and spontaneous speech, nor did we control for speech rate, both of which could have impacted the duration of the rhotic segments produced by the children. Additionally, our study was unable to collect

data from third-grade classes, limiting our ability to present a comprehensive picture of the development of rhotic pronunciation with age. Lastly, as already mentioned above (see § 8), detailed sociolinguistic information about the language history and use of the children and their families was not collected, which limited our understanding of the influence of their heritage languages on their Italian speech production.

10. Conclusions

In this paper we analysed the variation of Italian rhotics in the speech of 75 children in elementary school. In particular, we tested if the distribution of different types of realisations attested for the Italian /r/, as well as the phonetic form of taps and trills, are influenced by factors such as the phonological context in which the sound is produced, the speakers' age, the family's migratory generation and languages spoken at home. In general, we observed that older children are able to produce overall shorter segments, even if a high degree of variability remains up to the higher grades. The family's migratory background and the children's exposure to HLs appears to be the cause at the base of such variability. For instance, we addressed the case of the 4th grade in our sample, in which the very high rate of trills production came down to a few children not producing any taps, possibly because of the influence of their HLs' phonological features. Despite its limitations, our study provides evidence that exposure to an HL at home may have a lasting impact on the ML acquisition during the elementary school years. These findings underscore the need for further research in this area to better understand the role of HLs in shaping children's linguistic development.

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Author contributions

Conceptualisation: all authors; data processing and annotation: all authors (with project P.I. and collaborators); statistical analysis: all authors; data visualisation: M. Rossi; writing (original draft): L. Sbacco (§§ 1, 2, 2.1, 3, 3.1, 4), M. Rossi (§§ 4, 5, 5.1, 6, 7, 7.1, 7.2, 8, 9, 10); review and editing: all authors.

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Appendix

Model 1

Formula: duration ~ realisation + grade + (1|speaker)
Data: subset including only tap and trill realizations (approximants and fricatives excluded from the model)

	duration		
Predictors	Estimates	CI	p
(Intercept)	48.36	40.42 – 56.31	<0.001
realization [trill]	44.92	40.98 – 48.87	<0.001
grade [second]	10.69	-0.26 – 21.65	0.056
grade [fourth]	-10.27	-20.73 – 0.19	0.054
grade [fifth]	-6.49	-17.07 – 4.08	0.229
	Random Effects		
σ^2	976.04		
$\tau_{00\ speaker}$	204.86		
ICC	0.17		
$N_{speaker}$	75		
Observations	1430		
Marginal R^2 / Conditional R^2	0.292 / 0.415		

Model 2

Formula: duration ~ grade * context + (1|speaker)
Data: subset including only tap and trill realizations (approximants and fricatives excluded from the model)

	duration		
Predictors	Estimates	CI	p
(Intercept)	29.84	21.19 – 38.49	<0.001
grade [second]	22.50	10.87 – 34.13	<0.001
grade [fourth]	21.24	10.05 – 32.43	<0.001
grade [fifth]	-4.59	-15.88 – 6.70	0.425
context [post]	28.09	19.33 – 36.86	<0.001
context [pre]	40.59	31.96 – 49.23	<0.001
context [gem]	85.30	74.96 – 95.64	<0.001
grade [second] * context [post]	-23.84	-35.67 – -12.02	<0.001
grade [fourth] * context [post]	-25.92	-36.98 – -14.86	<0.001
grade [fifth] * context [post]	-10.76	-21.98 – 0.45	0.060
grade [second] * context [pre]	-10.81	-22.05 – 0.43	0.059
grade [fourth] * context [pre]	-23.74	-34.64 – -12.85	<0.001
grade [fifth] * context [pre]	1.36	-9.54 – 12.27	0.806
grade [second] * context [gem]	-2.68	-17.87 – 12.52	0.730
grade [fourth] * context [gem]	-3.05	-16.65 – 10.55	0.660
grade [fifth] * context [gem]	8.82	-5.52 – 23.15	0.228
Random Effects			
σ^2	684.98		
$\tau_{00\ speaker}$	133.04		
ICC	0.16		
$N_{speaker}$	75		
Observations	1430		
Marginal R^2 / Conditional R^2	0.460 / 0.548		

Model 3

Formula: duration ~ context * generation+ (1|speaker)
Data: subset including only tap and trill realizations (approximants and fricatives excluded from the model)

	duration		
Predictors	Estimates	CI	p
(Intercept)	38.66	30.71 – 46.61	<0.001
context [post]	13.43	5.86 – 20.99	0.001
context [pre]	31.23	24.17 – 38.30	<0.001
context [gem]	73.60	63.65 – 83.56	<0.001
generation [IMM2]	11.90	1.54 – 22.27	0.024
generation [IMM3]	-7.49	-17.80 – 2.83	0.155
context [post] * generation [IMM2]	-10.70	-20.53 – -0.87	0.033
context [pre] * generation [IMM2]	-5.98	-15.23 – 3.28	0.205
context [gem] * generation [IMM2]	3.14	-9.90 – 16.19	0.637
context [post] * generation [IMM3]	6.20	-3.45 – 15.86	0.208
context [pre] * generation [IMM3]	6.21	-2.98 – 15.40	0.185
context [gem] * generation [IMM3]	27.22	14.54 – 39.90	<0.001
Random Effects			
σ^2	693.05		
$\tau_{00\ speaker}$	164.51		
ICC	0.19		
$N_{speaker}$	75		
Observations	1430		
Marginal R^2 / Conditional R^2	0.433 / 0.542		