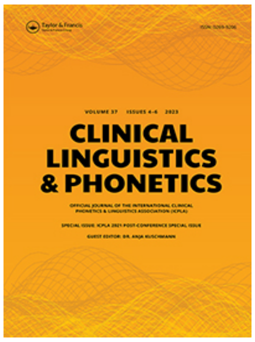

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Exploring word production in three-year-old monolingual French-speaking children

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ABSTRACT

There is a general need for more knowledge on the development of French phonology, and little information is currently available for typically developing French-speaking three-year-old children. This study took place in Belgium and explores the accuracy of speech production of 34 typically developing French-speaking children using a picture naming task. Measures of speech accuracy revealed lower performance than previously seen in the literature. We investigated speech accuracy across different phonological contexts in light of characteristics of target words that are known to have an influence on speech production, namely the condition of production (spontaneous vs. imitated), the length of the word (in number of syllables), syllable complexity (singleton vs. cluster) and positional complexity (onset vs. coda). Results indicate that the accuracy of words produced spontaneously did not differ from imitated words. The presence of consonant clusters in the target word was associated with lower performance on measures of Percentage of Consonants Correct and Whole Word Proximity for both 1- and 4-syllable words. Singleton codas were produced less accurately than onsets in 1-syllable words. Word-internal singleton codas were produced less accurately than final codas. In our sample, 1-syllable words showed surprisingly low levels of performance which we can explain by an over-representation of phonologically complex properties in the target words used in the present study. These results highlight the importance of assessing various aspects of phonological complexity in French speech tasks in order to detect developmental errors in typically developing children and, ultimately, help identify children with speech sound disorders.

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Speech sound development; consonant accuracy; French; preschool children

Background

Few studies have reported on speech development in French-speaking[1] children, and French speech production continues to be assessed in light of normative studies based on English (Brosseau-Lapré et al., 2018). This practice is especially questionable given that phonological characteristics of the two languages differ in terms of the number and nature of the speech sounds present in these two languages, in addition to prosodic factors such as syllable structure and stress (Brosseau-Lapré et al., 2018; MacLeod et al., 2014; Rvachew

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

[1]For a comprehensive overview of the adult phonological system in French and its differences with English phonology, see, Bérubé et al. (2013), MacLeod et al. (2011), and Rose and Wauquier-Gravelines (2007) and Rvachew et al. (2013).

et al., 2013). Limited data not only hinder the understanding of speech sound disorders (SSD) in French-speaking children, they limit our ability to study children's phonological development cross-linguistically. In the past, a few studies consisting mainly of case studies have provided a starting point for understanding speech production in French-speaking children (Aicart-De Falco & Vion, 1987; Demuth & McCullough, 2009; Dos Santos, 2007; Maillart & Parisse, 2006; Rose, 2000, 2003; Vinter, 2001; Yamaguchi, 2012). During the last 10 years, Canadian researchers have brought a significant contribution to the knowledge of typical Canadian-French speech development (Bérubé et al., 2020; Brosseau-Lapré, 2013; MacLeod et al., 2011; Rvachew et al., 2013). More recently, studies have provided additional observations on phonological and phonetic development in French, also in connection to lexical development and bilingualism (Kehoe & Cretton, 2021; Kehoe & Girardier, 2020; Kehoe & Havy, 2019; Kehoe et al., 2021).

An understanding of typical speech production development is crucial to the early identification of children with atypical speech development. Early identification often involves comparing children with reduced intelligibility to typically developing peers (Rvachew et al., 2013; Sylvestre et al., 2020). Achieving accurate and consistent production of speech sounds is a progressive process that begins first with babble and extends well into adolescence (Glaspey et al., 2022; Rvachew & Brosseau-Lapré, 2018). Speech by three-year-olds is particularly prone to variability (Kehoe & Cretton, 2021; MacLeod, 2019) and displays errors that are considered to be part of typical development (Brosseau-Lapré et al., 2018; McLeod & Crowe, 2018). This period is also a key age at which parents start to consult with speech-language therapists (Wankoff, 2011). Hence the need to study this key age group.

Concerning the analysis of children's productions, most metrics consider the adult productions as the perceptual referent. The Whole Word Proximity (WWP) measure considers both the phonological mean length of utterance (PMLU) and the accuracy of consonants as produced by the child compared to an adult target (Ingram, 2002). By taking into account the complexity of the adult target, this measure goes beyond segmental measures to explain variability. Specifically, WWP attributes a point to each phoneme the child has produced and an additional point to the correct production of each consonant. The child's production is then compared to the adult target to obtain a percentage. In contrast, the Percentage of Consonants Correct (PCC) is a measure used in both research and clinical contexts to provide information on the perceived accuracy of consonants (Shriberg et al., 1997). It is based on a traditional segmental perspective, irrespective of word characteristics or inherent complexity. Specifically, each correctly produced consonant is attributed a point, and the child's production is compared to the adult target. WWP and PCC offer different outlooks on speech production, so these measures complement each another.

Phonological factors influencing accuracy in French development

To our knowledge, five published studies (listed in Table 1) document the accuracy of speech production in three-year-old typically developing monolingual French-speaking children. These studies included between 6 and 99 children from this age group and relied on picture naming tasks to elicit between 20 and 111 words. The tasks however differ between studies concerning the proportion of words of different lengths, or the types of

Table 1. Studies on French-speaking 3-year-old children and characteristics of words used for assessment.

Authors	MacLeod et al., 2011	Sylvestre et al., 2020	Bérubé et al., 2020	Kehoe & Girardier, 2020	Kehoe et al., 2021
Age (months)	36 to 41	36	36 to 47	35 to 47	35 to 47
Monolingual participants	25	99	6	7	8
Test's name	ESPP	ESPP	TPFC	/	DRAP
Number of words	40	40	111	78	20
Percentage of 1-syllable words	42	42	44	42	65
Percentage of 2-syllable words	50	50	41	44	25
Percentage of 3-syllable words	8	8	14	12	10
Percentage of 4-syllable words	0	0	1	1	0
Percentage of words including tautosyllabic cluster(s)	18	18	23	32	55
Percentage of syllables including singleton coda	39	39	37	40	48
• Word-final coda	35	35	33	35	38
• Word-internal coda	5	5	5	7	10
PCC (*M* – *SD*)	87.8–7.7	78.4–13.4	-	92.3–5.6	85.2–11.6
WWP (*M* – *SD*)	94.5–3.7	-	-	-	-

syllable structures that these words present. Due to this variability across the tasks, a careful analysis of factors that influence speech accuracy should shed light on early speech development within this age group. This is consistent with the general observation that error patterns in developmental speech production should be assessed based on a variety of complexity characteristics (Bérubé et al., 2020). Exploring the phonological properties of words in their various combinations thus provides a sound foundation to better understand developmental speech patterns. The inclusion of words combining different levels of complexity help avoid ceiling effects in typical speech assessments. According to non-linear models of phonology, segmental and prosodic characteristics of word forms are organised in a hierarchical fashion and interact with one another, which can yield combined effects of complexity (Brosseau-Lapré et al., 2018). In the following paragraphs, we review how accuracy in young children is influenced by imitation, word length, syllable complexity and positional complexity.

First, irrespective of the particular characteristics of word forms, accuracy in speech production can be influenced by the condition of production, specifically whether the word is produced spontaneously or in imitation. Imitation has been hypothesised to artificially improve accurate production by correcting unstable representation, thanks to the provision of an adult model (MacLeod et al., 2011). The scoring of some picture naming tasks in French even take this factor into consideration (Chevrie-Müller & Plaza, 2001). However, this effect is not observed consistently (Goldstein et al., 2004) and recent data on French yielded no significant difference between spontaneous and imitated productions (Kehoe & Havy, 2019).

Moving to phonological characteristics at the word level, the number of syllables (word length) is thought to influence speech accuracy (Masso et al., 2017, 2016). The inclusion of polysyllabic words (understood as words of three or more syllables) is centrally relevant to speech assessment protocols, not only for the differential diagnosis and the profiling of SSD (Meloni et al., 2020), but also given that these words are more likely to elicit speech errors and reveal issues in phonological representations (Mason et al., 2015). Bérubé et al. (2020) indeed revealed a significant interaction between word length and accuracy on singleton consonants in the speech of children at risk of SSD, but failed to show a similar effect in typically developing children. This latter result may in fact relate to the issue that children are typically not assessed based on polysyllabic word forms; words of 4-syllables have traditionally been poorly represented in French speech assessments, even though these words are relatively common within the language (Bérubé et al., 2020; MacLeod et al., 2011). As it can be seen in Table 1, this is especially true of 4-syllable words. The underrepresentation of polysyllabic words in French picture naming assessment could also be one of the reasons why high PCC scores were obtained by the children aged four and half studied by MacLeod et al. (2011).

In addition to word length, factors related to syllable structure may influence speech accuracy. The presence of a consonant cluster in the target word in French is a well-known challenge (Kehoe, 2021; MacLeod et al., 2011), especially in word-final position (Demuth & McCullough, 2009; MacLeod et al., 2011). More generally, consonants in syllable codas are particularly prone to errors. Codas are thought to involve more phonological complexity, or be more marked, than onsets. Further, word-internal codas appear to be particularly challenging, as they tend to be acquired later than similar codas in word-final position in French (Rose, 2000). This observation is also in line with the argument that word-final codas in French can be syllabified as syllable onsets (Rose, 2003, for a review of the arguments). Syllable complexity can add up between levels of representations, especially in polysyllabic words, which remain a challenge even for older children (Rvachew et al., 2013). Accuracy of codas production in French might indeed be influenced by word length (Hilaire-Debove & Kehoe, 2004).

In sum, speech patterns displayed by typically developing French-speaking are still relatively under-documented. Current studies generally under-represent words with high levels of phonological complexity (e.g. 4-syllable words with consonant clusters and/or syllable codas). Yet, we know that different areas of phonological complexity may conspire to yield error patterns in developmental speech productions (Bérubé et al., 2020). A task that does incorporate different elements of phonological complexity should thus offer more compelling grounds for our understanding of phonological development in French-speaking children (Bérubé & Macleod, 2022).

Current research

The present study aimed to describe the accuracy of consonant production in typically developing three-year-old children who are monolingual speakers of French. Their consonant accuracy was measured through PCC and WWP based on speech from a picture naming task designed for clinical applications. We interpreted our results in light of different markers of phonological complexity as well as the possible combination of complexity effects, as per the following hypotheses:

(1) Condition of production: PCC and WWP scores should be higher for imitated words than for words that are produced spontaneously by the children (MacLeod et al., 2011).
(2) Word length: PCC and WWP should be lower for polysyllabic words as compared to mono- and bisyllabic words (Mason et al., 2015).
(3) Syllable complexity: PCC and WWP scores should be lower for words that contain tautosyllabic consonant clusters (Kehoe, 2021; MacLeod et al., 2011) as compared to words that contain only singleton consonants.

(4) Positional complexity: the percentage of singleton codas correct (PCoC) should be lower than the percentage of singleton onsets correct (POC; Kehoe, 2021). Specifically, word-internal codas are predicted to be less accurately produced than word-final codas (Rose, 2000).

(5) Combination of complexity: PCC and WWP scores should be lower in words combining at least two complexity factors (previously revealed by our results) as compared to words containing no or only one complexity factor.

Method

The research was approved by the Research Ethics Committee at the University of Liège, Belgium (protocol B707201940403). All participants were part of a larger longitudinal research project aiming at studying the potential link between orofacial myofunctional development and speech development in children from 3 years to 5 years old. This present study focuses on the first data collection on speech, but includes information from the longitudinal study.

Participants

All children were recruited from 27 regular schools in the Liège area, Wallonia, Belgium. Parents returned consent forms and background questionnaires when they agreed to their child's participation. As shown in Figure 1, 34 typically developing French-speaking Belgian children were included in the analysis from an initial sample of 64 children. Children in the study mostly came from families with high levels of maternal education (median of 2), ranging from 1 to 5 on a scale of 1 to 7 (Genoud, 2011). The sample included 18 girls and 16 boys aged 35 to 39 months (mean 37.29 ± 1.19). Only children speaking exclusively French at home were included in the current set. To exclude atypical development, information from the larger

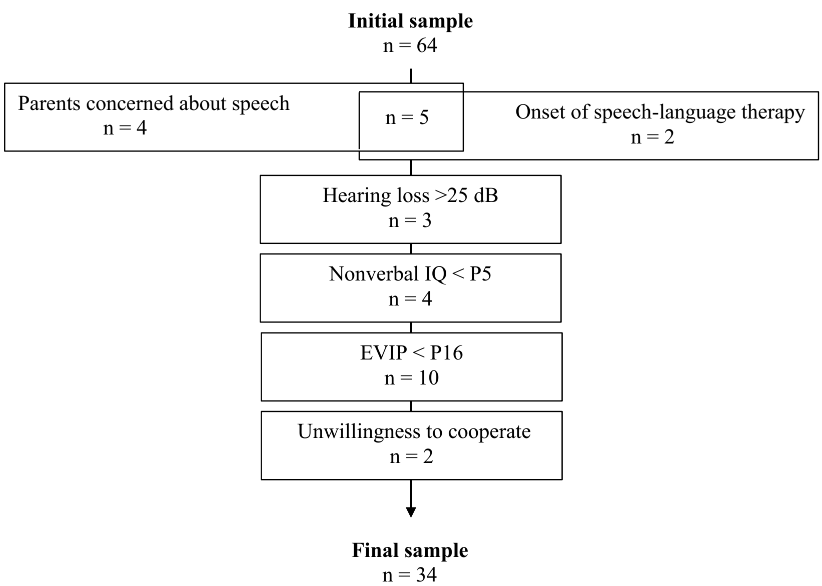

Figure 1. Flowchart describing selection of study sample.

longitudinal study was considered, which included parental questionnaires collected every six months between 3 and 4; 6 years of age; children were retroactively excluded when parents expressed concerns about language or speech development (n = 9), or if the children had already begun speech-language therapy (n = 7). Children who failed the hearing screening with a threshold at 25 dB were excluded (n = 3). Lastly, children were excluded if they obtained a nonverbal intelligence below the normal range (< P5) measured at 4;6 years old through the nonverbal Wechsler (Wechsler & Naglieri, 2006; n = 4) or a low standardised score on the receptive vocabulary task "Échelle de Vocabulaire en Images de Peabody" (Dunn et al., 1993; < P15), following Sylvestre et al. (2020).

Stimuli

EULALIES is a battery for phonological assessment which includes a picture naming task (Meloni et al., 2017). We used a version of this task adapted for young children. This adaptation included 43 words, which provided an opportunity to produce all French phonemes across all positions (listed in Appendix 1). We chose EULALIES because the stimulus set includes a diverse range of inherent complexities, providing a representative overview of the developmental trajectory of speech which addresses limitations such as ceiling effect found in other tasks (MacLeod et al., 2011). Indeed, the stimulus set includes words of three and four syllables, and eleven consonant clusters present across words of different lengths. In addition, EULALIES is a clinically appropriate task consisting mainly of words (36 out of 43) that can be found in the *Développement du langage de production en français (DLPF) version 3 (31–36 mois;* Bassano et al., 2005). The remaining items were likely to be familiar to three-years-olds, although specific words such as *oreiller* (pillow), *locomotive* (locomotive) and *uniforme* (uniform) often required a model from the experimenter. We summarise the relevant characteristics of the 43 words we used in Table 2.

Task administration

Speech productions were collected at the children's schools. Children were tested individually by two native French speakers. Pictures were shown on a computer placed in front of the child and were interspersed with a reinforcer to encourage the child to continue the task. The child was asked to name each picture. If the child did not name a given picture, the experimenter first provided a semantic cue. If the child still did not name the target word, the experimenter gave the first phoneme of the item (phonemic cue). As a last resort, the experimenter gave a model and requested an immediate imitation, e.g. "*Peux-tu répéter: locomotive*" (*Can you repeat: locomotive*). Children's productions were recorded with professional microphone Zoom H4nPro placed at 30 cm from the child. The session took approximately 20 minutes to complete.

Table 2. Characteristics of the words used in the picture naming task EULALIES (adapted version).

	1-syllable	2-syllable	3-syllable	4-syllable	Total
Number of words (% of total words)	13 (30%)	12 (30%)	12 (26%)	6 (14%)	43 (100%)
Number of words including tautosyllabic cluster (% of words)	5 (38%)	3 (25%)	2 (17%)	1 (17%)	11 (26%)
Number of syllables including singleton codas (% of syllables)	8 (62%)	7 (29%)	5 (14%)	8 (33%)	28 (29%)
• word-final coda	8 (62%)	6 (25%)	2 (6%)	6 (25%)	22 (23%)
• word-internal coda	-	1 (4%)	3 (8%)	2 (8%)	6 (6%)

Transcriptions

We used Phon, a software program specifically designed for the analysis of phonological data (Rose & MacWhinney, 2014). The first author (transcriber 1) and a trained Master's student (transcriber 2) who did the data collection were responsible for transcribing the children's productions. A first phase was carried out on 10 sessions considered the most complex to transcribe: these sessions were transcribed independently by the transcribers 1 and 2, and by the last author, then pooled to reach ultimate agreed transcriptions. This first phase allowed us to establish rules for transcribing. After this, transcribers 1 and 2 transcribed all remaining sessions following the same process. The total reliability between the two was over 85%. Transcribers 1 and 2 then pooled the transcriptions to reach consensus on the transcribed forms from which the analyses will be made. To ensure that those ultimate transcriptions were valid, the second author re-transcribed 20% of the sample. Agreement reached 92.91%. Intra-judge reliability was calculated on 20% of the total samples for both transcribers 1 and 2 and reached over 85%.

Analyses

We used the PCC (Shriberg et al., 1997) and the WWP (Ingram, 2002) to describe global accuracy of consonants within words, whereas PCoC and POC described accuracy of singleton consonant codas and onsets. Pre-vocalic glides (e.g. *voiture* [vw̠atur] "car") were not considered consonants, given that they are arguably syllabified as part of (nuclear) rising diphthongs in French (e.g. Kaye & Lowenstamm, 1984) or, in the case of a vocalic hiatus, result from coarticulatory pressures (e.g. *bibliothèque* [biblijɔtɛk] "library"). However, syllable-final glides (e.g. *grenouille* [gʀənuj] "frog" were incorporated in the analysis, given that French does not standardly display falling-sonority diphthongs (Casagrande, 1984), also in line with the relevant clinical literature (Kehoe & Girardier, 2020).

Two-way ANOVAs for repeated measurements (RM) were used for analyses and a square root and Greenhouse-Geisser correction were applied when assumptions were violated. Effect size was determined by partial eta squared, where $\eta_p^2 = 0.01$ is considered as a small, 0.06 as moderate and 0.14 as large. We performed a Scheffe post-hoc for multiple comparisons. When a RM ANOVA could not fit because of missing data, we used a paired sample student's t-test. For the last hypothesis, we took words as the independent variable, instead of children, meaning that the compared samples are not considered as dependent anymore. This allowed us to use an independent sample t-test. Statistical analyses were carried out using Jamovi version 1.6.23.

Results

Overall results

Our global results show an average PCC value of 64.98% (SD = 16.49), ranging from 26.66% to 88.63%. Average WWP is 82.38% (SD = 10.53), ranging from 52.37% to 95.82%. A total of 50% of the words were produced spontaneously. For non-spontaneous word productions, children were first provided with a semantic cue (leading to a production for 6% of the words), then a phonetic cue (leading another 6% of word productions) and, finally, for the remaining 38%, children were asked to imitate the target. Given the small percentage of words produced

Table 3. PPC and WWP performance for spontaneous compared to imitated production.

Measure	Spontaneous			Imitated			Comparison		
	Mean	SD	Range	Mean	SD	Range	t	df	*p*
PCC	65.26	19.19	13.57–89.88	64.29	17.69	27.14–90.91	−0.51	33	0.62
WWP	82.51	9.85	60.08–95.67	82.22	12.20	44.02–96.30	−2.79	33	0.78

with cues, we included these words as spontaneous productions in the analyses. However, condition of production (spontaneous, semantic cues, phonetic cues or imitation) could not be incorporated into the ANOVA model because some 4-syllable words were never produced spontaneously. As illustrated in Table 3, student t-test showed no differences between spontaneous and imitated productions for either PCC or WWP performances. In the absence of significant differences, we grouped these categories together for the following analyses.

Descriptive data for accuracy of production according to word length, syllable complexity and positional complexity are presented in Table 4. Overall, variation based on standard deviation was high across all types of complexity, especially for PCC. Details of performance by word are available in Appendix 2.

We explored interactions between word length, syllable complexity and positional complexity through RM ANOVAs below. We present descriptive data in Table 5 and statistical results of main effects and interactions in Table 6.

Effects of word length (number of syllables) and syllable complexity (singleton vs cluster)

The RM ANOVA reveals a large main effect of both syllable complexity and word length, and a moderate but significant interaction (Table 6). Words containing a tautosyllabic consonant cluster had significantly lower PCC than words containing only singleton consonants, $F(1, 33) = 29.30$, $p < 0.001$. The number of syllables present in the word also influenced the PCC, $F(2.57, 84.69) = 27.3$, $p < 0.001$, but the performance on words with 2 and 3 syllables did not differ, $t(33) = 0.47$, $p_{scheffe} = 0.97$, and showed significantly higher scores than 1- and 4-syllable word, $t(33) = 0.98$, $p_{scheffe} = 0.81$. The post-hoc analysis of the interaction effect showed that the syllable complexity effect is only present for 1-syllable words, $t(33) = 4.54$, $p_{scheffe} = 0.017$. The interaction is illustrated in Figure 2.

The RM ANOVA analyses on WWP show a main effect of syllable complexity and of word length as well as a significant interaction (Table 6). Our results show analogous results of simple effect compared to PCC for syllable complexity, $F(1, 33) = 42.50$, $p < 0.001$. Simple effect of word length, $F(2.14, 70.50) = 39.60$, $p < 0.001$, reveals that 2- and 3-syllable also form a plateau $t(33) = 1.94$, $p_{scheffe} = 0.31$, but here 1- and 4-syllable words were significantly different $t(33) = -2.99$, $p_{scheffe} = 0.046$. A post-hoc analysis of the interaction effect shows noticeably different results than with the PCC, as the effect of word length can be seen throughout all categories except for 4-syllable words $t(33) = 0.72$, $p_{scheffe} = 0.99$, as displayed in Figure 3.

Effects of word length (number of syllables) and positional complexity (onset vs. coda)

It was not possible to include this model in the previous analyses because positional analyses of accuracy required segmental analyses, making the word level PCC and WWP measures unsuitable. A main effect was found for both singleton position and word length. The

Table 4. Descriptive data for word length, syllable complexity and positional complexity.

Measures of accuracy based on word			Mean	SD
Word length	PCC	Words of 1 syllable	61.5	18.7
		Words of 2 syllables	71.8	16.2
		Words of 3 syllables	71.1	16.1
		Words of 4 syllables	59.6	18.2
	WWP	Words of 1 syllable	82.2	10.5
		Words of 2 syllables	87.7	8.5
		Words of 3 syllables	86.2	10.3
		Words of 4 syllables	75.3	13.9
Syllable complexity	PCC	Words including tautosyllabic cluster	59.3	19.8
		Words including only singletons	68.7	15.5
	WWP	Words including tautosyllabic cluster	77.9	13.2
		Words including only singletons	85.9	8.9
Measures of accuracy based on phonemes			**Mean**	**SD**
Positional complexity	PCoC	Singleton coda	55.1	22.4
		• Word-final coda	60.36	19.63
		• Word-internal coda	41.31	28.89
	POC	Singleton onset	68.9	15.5

Table 5. Descriptive data for syllable complexity and positional complexity according to word length.

		Syllable complexity				Positional complexity	
		Singleton		Cluster		Coda	Onset
Word length		PCC	WWP	PCC	WWP	PCoc	POC
1-syllable	Mean	66.1	86.3	54.1	75.5	43.3	68.9
	SD	17.4	7.7	24.3	16.5	23	16
2-syllable	Mean	73.7	89.5	66.2	82.1	72.3	73.3
	SD	16.8	8	20.2	12.9	18.2	15.9
3-syllable	Mean	71.5	87.4	69.2	79.5	59.4	73.7
	SD	16.7	10.2	19.3	13.6	32.9	16.7
4-syllable	Mean	59.9	75.5	57.7	74.2	54.1	63.6
	SD	19	14.3	22.2	16.3	21.5	19

Table 6. Main effects and interactions of two-way RM ANOVA.

Effect	Measures	F	df	p	η_p^2
Syllable complexity	PCC	18.88	1–33	< 0.001*	0.36
Word length		18.95	2.27–74.95	< 0.001*	0.37
Interaction		3.13	2.52–83	< 0.038*	0.09
Positional complexity	PCoC, POC	29.54	1–33	< 0.001*	0.47
Word length	PCC	11.20	2.72–89.92	< 0.001*	0.25
Interaction	PCC, PCoC, POC	6.47	2.66–87.87	< 0.001*	0.16
Syllable complexity		48.59	1–33	< 0.001*	0.60
Word length	WWP	22.54	2.19–72.30	< 0.001*	0.41
Interaction		4.79	2.40–79.22	< 0.004*	0.13

* Effect statistically significant

interaction was statistically significant (Table 6). Singleton consonants in syllable codas were less accurate than singleton consonants in onsets $F(1, 33) = 28.1$, $p < 0.001$. A simple main effect of length, $F(2.57, 84.69) = 27.3$, $p < 0.001$, showed a similar pattern as above. Post-hoc analysis of the interaction effect revealed that singleton consonants in coda position were less accurate than singleton onsets only for 1-syllable words $t(33) = 7.50$, $p_{scheffe} < 0.001$, as illustrated in Figure 4.

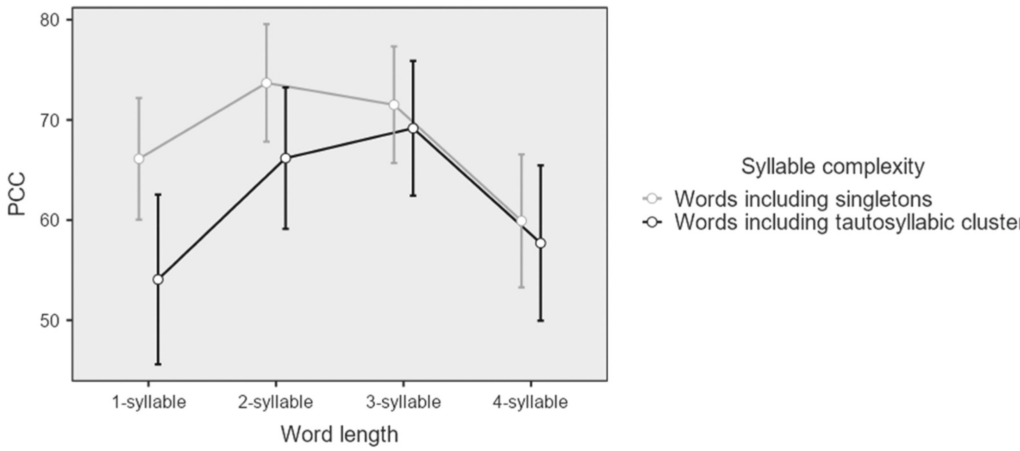

Figure 2. Interaction between word length and syllable complexity for speech accuracy.

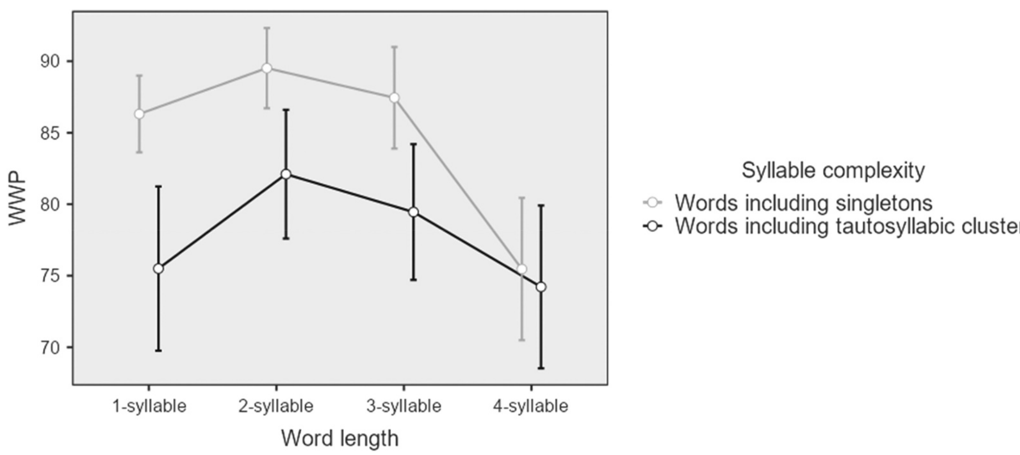

Figure 3. Interaction between word length and syllable complexity for speech accuracy.

Lastly, the comparison between word-internal and final codas could not fit in the previous model including word length since word-internal codas are not possible in 1-syllable words. The paired sample t-test, $t(33) = -3.99$, $p = < 0.001$, shows that word-internal singleton codas are not as accurate ($M = 40.20$, $SD = 40.02$) as final ones ($M = 60.36$, $SD = 19.63$).

Effect of the combination of complexity factors

Twelve words (see Appendix 1) combined more than one complexity factor revealed by our previous results, namely presence of cluster and/or final coda and/or internal coda and/or four syllables. We did not consider 1-syllable words in this analysis (see below). WWP score was significantly lower for words combining complexity factors ($M = 77.44$, $SD = 6.51$) than words with no or one complexity factor ($M = 86.32$, $SD = 7.21$), $t(41) = 3.72$, $p = < 0.001$. This was not the case for PCC, $t(41) = 1.28$, $p = 0.10$, for which no differences were found between combination ($M = 62.78$, $SD = 11.89$) vs. no combination ($M = 68.33$, $SD = 13.07$).

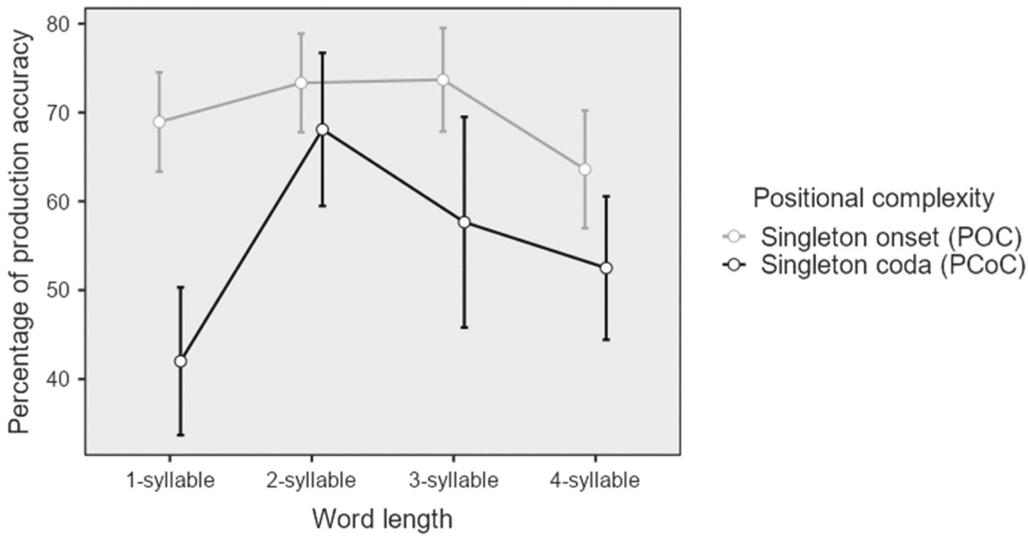

Figure 4. Interaction between word length and positional complexity for speech accuracy.

Discussion

This study aimed to describe consonant accuracy in typically developing three-year old children who were monolingual speakers of French. Consonant accuracy was further investigated in light of issues in phonological complexity. We focused on consonant accuracy according to condition of production (spontaneous vs. imitated), word length (number of syllables), syllable complexity (singleton vs. cluster) and positional complexity (onset vs. coda).

Our results revealed a mean PCC score of 64.98% and a mean WWP score of 82.38%, suggesting lower levels of accuracy than what has been found in previous studies. MacLeod et al. (2011) found a mean PCC of 87.8% (*SD* = 7.7) and a mean WWP of 94.5% (*SD* = 3.7) with very little variability for children from 36 to 41 months of age. The present study also considered slightly younger, 35-month-old children. In this regard, the results for children aged 30 to 35 month in MacLeod et al.'s original study showed greater variability for the WWP measure which better aligns with our results (*M* = 89.3, *SD* = 10.8). On the other hand, PCC scores were still much higher in that study than for the current one (*M* = 81.5, *SD* = 12.7). Kehoe et al. (2021) found a mean PCC of 85.17 with more variability (SD 11.64) in a sample of 29 bilingual children. In another study of monolingual children, Kehoe and Girardier (2020) however found near-ceiling results (*M* = 92.3, *SD* = 5.6). Sylvestre et al. (2020), based on a larger sample, obtained results more similar to ours, with a mean PCC of 78.4% (SD 13.4) for 99 monolingual Québec French children.

The current study found large inter-individual variability, even in this homogenous sample where gender, SES, audition, receptive vocabulary and nonverbal IQ were taken into consideration. Specifically, PCC ranged from 26.66% to 88.63% and WWP ranged from 52.37% to 95.82%. This reinforces the need to use data elicitation tasks that reduce floor or ceiling effects in order to better reflect the variability in speech development during the most critical developmental periods (Bérubé & Macleod, 2022).

Before exploring the influence of inherent word characteristics on these performances, we first considered the condition of production. The proportion of words which were imitated (38%) is similar to previous research (e.g. 40% of words in MacLeod et al., 2011). Performance on the PCC and the WWP did not differ statistically when words were produced spontaneously (including cues) or when imitated. While some research suggests that imitated words are potentially more accurate (Chevrie-Müller & Plaza, 2001; MacLeod et al., 2011), the present findings align with recent findings that they may not be different than spontaneously produced words (Kehoe & Havy, 2019). Since we have included words produced with cues in the spontaneous group, it decreases the possibility that imitated words are words whose phonological representation is temporarily inaccessible. In that case, the absence of differences between spontaneous and imitated productions could hypothetically be explained by a balanced effect between two very different underlying processes. Imitation may involve a short-term memory effects for words unknown to the child, for which phonological representations are either non-existent or incomplete (e.g. *oreiller* was produced spontaneously in only 8% of cases and showed a score of 75% for PCC and 90% for WWP). In contrast to this, words produced spontaneously or with a cue, even if not accurate, are likely words known by the child that also involve more complete phonological representations (e.g. *chocolat* was produced spontaneously in 97% of cases and showed a score of 76% for PCC and 92% for WWP). In sum, the absence of difference in the results suggests that speech-language pathologists should consider both spontaneous and imitated productions in their assessment (Goldstein et al., 2004).

Our main analyses revealed, as expected, significant effects of word length, syllable complexity, and positional complexity within the syllable. PCC showed the lowest scores for 1- and 4-syllable words, with significantly higher scores for 2- and 3-syllable words. WWP also showed a plateau for 2- and 3-syllable words. However, 4-syllable words were produced significantly less accurately than 1-syllable words. From the outset, low accuracy for 1-syllable words was unexpected, given previous research on polysyllable words in French (Bérubé et al., 2020; Mason et al., 2015). Several factors may explain these results for 1-syllable words. First, words including tautosyllabic consonant cluster were produced less accurately than words with singleton consonants only. Clusters were more frequent in 1-syllable words than in words of two or more syllables. Second, there was a high prevalence of singleton consonants in coda position in 1-syllable words (i.e. 62% of syllables), while singleton codas were relatively less prominent in words of two or more syllable (i.e. 33% of syllables at the most). In parallel, the process of word-final devoicing also impacted accuracy, even if it was expected given that it is a well-known speech feature of the Liège region in Belgium. However, this process is typically restricted to continuous speech in adults, as opposed to isolated word productions. A very common example would be the adult production [nɛʃ] rather than [nɛʒ] for the word *neige* (snow) in a coarticulated context, but not when the word is produced in isolation. This observation supports the hypothesis that children extract information from continuous adult speech of perceptual exemplars that will become more precise later in development (McAllister Byun et al., 2016; Menn et al., 2012; Redford, 2019). The group of 1-syllable words used in our study thus incorporated a number of pitfalls, such as clusters and codas, which did not occur as prominently in the longer words. Lower performance on 1-syllable words can thus be attributed to a task effect.

None of these explanations, however, can be extended to the lower accuracy scores obtained from 4-syllable words. These longer words were significantly less accurate than the 2- and 3-syllable words, although no effects of syllable complexity and positional complexity were present in 4-syllable words. The challenge of producing longer words may therefore underlie a true developmental effect (Bérubé & Macleod, 2022; Mason et al., 2015). These are preliminary results and it is important to highlight the need for both a replication of our results and a consideration of additional factors (e.g. the distribution of complexity factors between words or the relative frequency in usage of the words included in the test materials) to further understand all the potential issues at play.

As far as metrics are concerned, the WWP appears, on the one hand, to better identify interactions between syllable complexity and word length than the PCC and, on the other hand, to take into account the combination of complexity factors in the target word. This suggests that the WPP is a better indicator of the child's productive abilities across different phonological contexts. Indeed, WWP calculation is based on PMLU which takes into account the presence of phonemes and therefore the word length (Ingram, 2002). WWP consequently considers the overall word shape. The PCC scores were clearly influenced by the task effect identified above, especially with regard to the phonological complexity of 1-syllable words. The fact that PCC scores are impacted by word complexity characteristics brings into question the use of general PCC norms (Shriberg et al., 1997); PCC scores should indeed be considered with reference to the specific task(s) at hand. In comparison, the PCoC and POC allowed more precise analyses showing that singleton word-internal codas are less accurately produced than final ones. Although these results are consistent with the literature (Kehoe, 2021; Rose, 2000), our sample only includes the phonemes [s] and [ʀ], also in relatively low numbers. This further calls for a systematic replication of the current study. While both the WWP and the PCC are very useful in research, their respective limitations confirm the need to use different measures, as well as going further in the assessment of the functional and clinical impact of the child's speech abilities (Glaspey et al., 2022; Mason et al., 2015).

Although the consonant inventories of different varieties of French tend to resemble one another, important differences may be found with regard to allophonic processes, vowel production, or prosody (Rose & Wauquier-Gravelines, 2007). It is therefore not possible to exclude a regional effect on performance in the current data. Studies comparing performance across different dialects of French, including the Belgian variety, are thus in order as well.

Conclusion

The results of this study support the importance of assessing various word complexity characteristics in French speech tests – not only word length but also the presence of a cluster, word internal or final codas. The low accuracy found for one-syllable words in the current study may be task-specific. The picture-naming task that was used also included 4-syllable words, clusters and singleton codas. As such, we were able to document developmental errors in typically developing children speech production that impact their accuracy. This research contributes to our broader understanding of speech development in typically-developing children, but also towards the identification of children with speech sound disorders who speak French.

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Data availability statement

Data underlying the study are available on https://phon.talkbank.org in the French corpora.

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Appendices

Appendix 1. Target words of EULALIES picture naming task (adapted version)

Orthographic	Phonetic	Number of syllables	Tauto-syllabic clusters	Word-final codas	Word-internal codas	Syllabic structure
Oreiller	ɔʀeje	3				V.VC.GV
Locomotive*	lɔkɔmɔtiv	4		v		CV.CV.CV.CVC
Hippopotame*	ipɔpɔtam	4		m		V.CV.CV.CVC
Indien	ɛ̃djɛ̃	2				V.CGV
Jambe	ʒɑ̃b	1		b		CVC
Huile	ɥil	1		l		GVC
Pyjama	piʒama	3				CV.CV.CV
Œuf	œf	1		f		VC
Fourchette*	fuʀʃɛt	2		t	ʀ	CVC.CVC
Hibou	ibu	2				C.CV
Escargot*	ɛskaʀgɔ	3			s, ʀ	VC.CVC.CV
Uniforme	ynifɔʀm	3	ʀm			V.CV.CVCC
Neige	nɛʒ	1		ʒ		CVC
Capuche	kapyʃ	2		ʃ		CV.CVC
Parapluie	paʀaplɥi	3	pl			CV.CV.CCGV
Grenouille*	gʀənuj	2	gʀ	j		CCV.CVC
Éléphant	elefɑ̃	3				V.CVC.V
Aspirateur*	aspiʀatœʀ	4		ʀ	s	VC.CV.CV.CVC
Yaourt	jauʀt	2	ʀt			GV.VCC
Langue	lɑ̃g	1		g		CVC
Zèbre	zɛbʀ	1	bʀ			CVCC
Euro	øʀɔ	2				CVC
Couverture*	kuvɛʀtyʀ	3		ʀ	ʀ	CV.CVC.CVC
Rhinocéros*	ʀinɔseʀɔs	4		s		CV.CV.CV.CVC
Dentiste	dɑ̃tist	2	st			CV.CVCC
Ours	uʀs	1	ʀs			VCC
Gare	gaʀ	1		ʀ		CVC
Ordinateur*	ɔʀdinatœʀ	4		ʀ	ʀ	VC.CV.CV.CVC
Bibliothèque*	biblijɔtɛk	4	bl	k		CV.CCV.GV. CVC
Téléphone	telefɔn	3		n		CV.CV.CVC
Enveloppe**	ɑ̃v(ə)lɔp	2 (3)		p		V.CCVC
Stade*	stad	1	st	d		CCVC
Toboggan	tɔbɔgɑ̃	3				CV.CV.CV
Cinéma	sinema	3				CV.CV.CV
Ongle	ɔ̃gl	1	gl			VCC
Chocolat	ʃɔkɔla	3				CV.CV.CV
Montagne	mɔ̃taɲ	2		ɲ		CV.CVC
Voiture	vwatyʀ	2		ʀ		CGV.CVC
Fraise*	fʀɛz	1	fʀ	z		CCVC
Feu	fø	1				CV
Oiseau	wazo	2				CV.CV
Rue	ʀy	1				CV
Champignon	ʃɑ̃piɲɔ̃	3				CV.CV.CV

* Words combining more than one complexity factor

** As the vast majority of children produced [ɑ̃vlɔp], we categorised the word into 2 syllables. However, in this case the structure of [vl] consonants being ambiguous, we did not consider these two consonants in any of the analyses.

Appendix 2. Performance for PCC and WWP by words according to word length. Note: Words including a cluster are represented by an empty bar