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Emergence of a consonant bias during the first year of life: New evidence from own-name recognition

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Abstract
Recent evidence suggests that during the first year of life, a preference for consonant information during lexical processing (consonant bias) emerges, at least for some languages like French. Our study investigated the factors involved in this emergence as well as the developmental consequences for variation in consonant bias emergence. In a series of experiments, we measured 5-, 8-, and 11-month-old French-learning infants orientation times to a consonant or vowel mispronunciation of their own name, which is one of the few word forms familiar to infants at this young age. Both 5- and 8-month-olds oriented longer to vowel mispronunciations, but 11-month-olds showed a different pattern, initially orienting longer to consonant mispronunciations. We interpret these results as further evidence of an initial vowel bias, with consonant bias emergence by 11 months. Neither acoustic-phonetic nor lexical factors predicted preferences in 8- and 11-month-olds. Finally, counter to our predictions, a vowel bias at the time of test for 11-month-olds was related to later productive vocabulary outcomes.

1 | INTRODUCTION

Adult native speakers of a variety of languages typically have a bias for consonant over vocalic information during lexical processing (consonant bias; for a review see Nazzi & Cutler, 2018), although this may not be the case in tonal languages (Gómez, Mok, Ordin, Mehler, & Nespor, 2018; Poltrock, Chen, Kwok, Cheung, & Nazzi, 2018; Wiener & Turnbull, 2016). For example, English, Dutch, and Spanish listeners are more likely to change the pseudoword *kebra* into the real word *cobra*, conserving consonantal information, than changing it into *zebra*, conserving vocalic information (Cutler, Sebastián-Gallés, Soler-Vilageliu, & Ooijen, 2000; Ooijen, 1996). Such evidence of a consonant bias in lexical processing is thought to reflect the underlying structure of speech and although originally proposed as innate (Nespor, Peña, & Mehler, 2003), recent evidence suggests that infants initially have a bias for vocalic over consonant information during lexical processing (vowel bias; for a review of cross-linguistic evidence see Nazzi, Poltrock, & Von Holzen, 2016). The emergence of the consonant bias may therefore reflect development of a sophisticated understanding of the speech in an infants' native language and has been proposed as a bootstrapping mechanism for early language acquisition. For children learning French, the language where this has been most studied and also the language we focus on in the current study, evidence for the consonant bias in older infants and toddlers has been robust (Havy & Nazzi, 2009; Havy, Serres, & Nazzi, 2014; Nazzi, 2005; Nazzi & Bertoncini, 2009; Nazzi, Floccia, Moquet, & Butler, 2009; Nazzi & New, 2007; Zesiger & Jöhr, 2011) and has been extended to the first year of life, in infants as young as 8 months in word segmentation (Nishibayashi & Nazzi, 2016; Von Holzen, Nishibayashi, & Nazzi, 2018) and 11 months in familiar word form recognition (Poltrock & Nazzi, 2015). By examining younger infants, however, two studies have established that for French-learning infants, an initial vowel bias remains until at least 5 months for own-name recognition (Bouchon, Floccia, Fux, Adda-Decker, & Nazzi, 2015) and 6 months for word form segmentation (Nishibayashi & Nazzi, 2016). This switch from a vowel to consonant bias is also reflected in the developmental trajectory of infant's native sound category acquisition, which shows that vowel categories (6 months; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992) are learned earlier than consonant categories (10–12 months; Werker & Tees, 1984). Yet, little is known about the factors driving the differential processing of consonants and vowels during lexical processing or those modulating infants' switch from an initial bias for vowels to a consonant bias or how the timing of this switch relates to other aspects of language acquisition. The focus of the current manuscript is to shed light on these issues by examining the developmental trajectory of consonant bias emergence in French-learning infants' word form recognition.

Thus far, only one study has directly examined the timing of consonant bias emergence using the exact same stimuli and method. In a series of word form segmentation experiments, Nishibayashi and Nazzi (2016) examined the emergence of the consonant bias with 6- and 8-month-old French-learning infants, finding a vowel bias in 6-month-olds but a consonant bias in 8-month-olds (see Von Holzen et al., 2018 for similar ERP results with 8-month-olds). Other indirect evidence comes from another type of lexical processing, familiar word form recognition. While word form segmentation requires short-term maintenance of a newly segmented word's phonological form, word form recognition requires the long-term retention of the phonological form of a familiar word. French-learning infants as young as 11 months exhibit a consonant bias (Poltrock & Nazzi, 2015). The number of words that even younger infants recognize is comparably smaller, rendering the study of word form recognition challenging. Yet, given that 5-month-olds recognize their own name (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Mandel, Jusczyk, & Pisoni, 1995), Bouchon et al. (2015) used the Head-turn Preference Procedure (HPP) to study phonological bias in own-name recognition by French-learning 5-month-olds, establishing a vowel bias at this age. Combined, these studies provide additional evidence that the consonant bias emerges during the latter half of the first year of life, although the gap in age between 5- and 11-month-olds is rather large and the words used in both studies are very different (own name vs. familiar names not referring to the infant).

The first goal of the present study, in line with Bouchon et al. (2015), is to extend the developmental trajectory of the vowel to consonant bias shift, to infant's processing of their own name. We begin our investigation with two ages where a vowel to consonant bias shift has been previously found for unfamiliar words or pseudowords (Hochmann, Benavides-Varela, Nespor, & Mehler, 2011; Hochmann, Benavides-Varela, Nespor, Mehler, & Flo, 2017; Nishibayashi & Nazzi, 2016), at 5 and 8 months (Experiment 1). This investigation is then extended to 11 months of age in Experiment 2, since a consonant bias has been found at that age for familiar words by Poltrock and Nazzi (2015).

A second goal of the present study is to better understand the factors that support consonant bias emergence. According to the acoustic-phonetic hypothesis (Floccia, Nazzi, Luche, Poltrock, & Goslin, 2014), a vowel change interrupts lexical processing because vowels are more salient than consonants. Bouchon et al. (2015) found that French-learning 5-month-old infants' early vowel bias may be driven by acoustic factors such as spectral distance, and to a lesser extent duration difference, between the correct and mispronounced vowel of their name. As development continues, however, the saliency of vowels loses importance to consonants, which are processed more categorically (Fry, Abramson, Eimas, & Liberman, 1962) and therefore provide a more reliable cue to lexical processing. Variation in acoustic/phonetic properties, such as lexical stress which leads to vowel reduction in English or the large number of vowels in Danish, has been suggested to account for the cross-linguistic variation found in evidence for the consonant bias (Delle Luche, Floccia, Granjeon, & Nazzi, 2016; Floccia et al., 2014; Højen & Nazzi, 2015; see Nazzi et al., 2016 for a review).

In contrast to the acoustic-phonetic hypothesis, the lexical hypothesis was originally proposed to account for the presence of a consonant bias in adults (Keidel, Jenison, Kluender, & Seidenberg, 2007). According to Keidel and colleagues, it is the experience with the French lexicon that leads French adults to discover that consonant information is more informative for lexical processing than vowel information. Keidel et al. (2007) analyzed the consonant and vowel structure of French CVCVCV words from the Lexique database (New, Pallier, Brysbaert, & Ferrand, 2004). They found that a given word (e.g., numéro,/nymeʁo/) is almost 40% more likely to be identified given only its consonant tier information (/n.m.ʁ/) than its vowel tier information (y.e.o). For a consonant bias to emerge, an infant's exposure to their native language must reach some unknown threshold whereby the informativeness of consonants compared with vowels for word identity becomes clear. This may come through a certain lexical size or more specifically the structure of the early infant lexicon that cues infants into the usefulness of consonants for lexical processing. Yet, in the few studies where vocabulary scores have been collected, there has been no evidence for a relationship between overall lexicon size and magnitude of the consonant bias (Poltrock & Nazzi, 2015) and even evidence that a larger lexicon is related to greater sensitivity tovowel mispronunciations (vMP) in English-learning 12-month-olds (Mani & Plunkett, 2011), a finding that runs counter to the predictions of a lexically based consonant bias emergence. However, the lexical hypothesis is not based on the number of words known, but instead the statistical information provided by consonants and vowels across known words. To better capture this consonant and vowel structure, Hochmann et al. (2011) examined the words French- and Italian-learning infants are likely to know at this early stage (using CDI norming data), revealing that already at 8 months, infants typically know a greater proportion of words that have unique consonant compared with vowel tiers (e.g., canapé /kanape/: /k.n.p/ vs. /a.a.e/). Yet, this analysis does not account for the wide variation in the early infant lexicon (Frank, Braginsky, Yurovsky, & Marchman, 2017), nor does it connect early lexical structure to the consonant bias in individual infants, which will be explored in the present study.

The final goal of this study is to examine the relationship between early variation in the consonant bias and later vocabulary outcomes over the second year of life. Both the acoustic/phonetic and lexical hypotheses predict emergence of the consonant bias resulting from accumulating linguistic input over the first year of life. Considering that linguistic input varies across infants and that variability in individual performance in laboratory tasks is often large (Kuhl et al., 2006), there is reasonable expectation of variation in the evidence of the consonant bias in a given age group. This variation may be related to the acoustic/phonetic and/or lexical factors described above, highlighting how differences in the input may contribute to earlier or later emergence of the consonant bias in individual infants. Furthermore, this variation in consonant bias emergence may have consequences for subsequent linguistic development. One may thus expect that word learning and recognition may be facilitated in infants developing an earlier or stronger consonant bias, leading to better vocabulary outcomes later in development.

2 | EXPERIMENT 1:5- AND 8-MONTH-OLDS

In Experiment 1, we sought to extend previous evidence of a switch from vowel to consonant bias during the first year of life in unfamiliar words (Hochmann et al., 2011, 2017; Nishibayashi & Nazzi, 2016) to familiar words, specifically own-name recognition. Although the experiment was inspired by Bouchon et al. (2015), it differs from it because, rather than comparing correct pronunciations (CPs) with consonant or vowel mispronunciations (cMPs; vMPs) in two separate experiments, we used a conflict task (Nishibayashi & Nazzi, 2016) and directly compared how long infants' attend to a cMP or vMP of their own name within a single experiment. If infants process consonant and vowel information differently during lexical processing, we expect them to differentially orient to the two kinds of mispronunciations. Related tasks with French-learning infants find that infants orient longer to word forms that best match the word form they are familiar or have been familiarized with (Bouchon et al., 2015; Nishibayashi & Nazzi, 2016). For example, orienting longer to a vowel compared with a consonant mispronunciation (cMP) would indicate a consonant bias, as the vMP conserves consonant information. Our study differs from these in that we use the infants' own names (contrary to Nishibayashi & Nazzi, 2016) and familiarize infants with the CP of their name (contrary to Bouchon et al., 2015). As a consequence of either or both of these differences, we may change the difficulty of the present task, which may reverse the effects as predicted by the model of Hunter and Ames (1988). The results of the 5-month-olds, for which we expect a vowel bias as found for own-name recognition by Bouchon et al. (2015) should clarify this issue.

Based on previous evidence from word segmentation (Nishibayashi & Nazzi, 2016; Von Holzen et al., 2018), we may expect 8-month-olds to show a consonant bias during own-name recognition. However, word form segmentation only requires the short-term retention of a word form, whereas word form recognition requires the long-term maintenance of a word form. Furthermore, infant's own names are among some of the earliest word forms recognized, with evidence for recognition as young as 4.5 months (Mandel et al., 1995). As a result, these words are heard in a variety of intonational contexts. Considering that intonation is carried by vowels, this may render the processing of the infant's own-name more resistant to the emergence of the consonant bias. If this is the case, we may find that 8-month-olds do not exhibit a consonant bias in own-name recognition.

In addition to examining the differential processing of consonants and vowels in these two age groups, we also examined whether this processing is modulated by acoustic-phonetic and/or lexical factors. Similar to Bouchon et al. (2015), we measured the duration, intensity, and spectral distance between correct and mispronounced phonemes (both consonant and vowel) in the own-name stimuli presented to infants. Unlike Bouchon et al. (2015), however, we present each infant with both cMPs and vMPs (test phase) and CPs (pre-test phase). In addition to demonstrating the CP to the infant, this also allowed for an examination of performance in relation to acoustic/phonetic factors of both consonants and vowels within each infant. We also measured the overall lexicon size as well as the number of unique consonant and vowel tiers in known words of each of the 8-month-old infants we tested. This could not be done for 5-month-olds since these inventories are not used before 8 months, due to parental difficulties in identifying, with reliability, the few words their infants might know.

Finally, to capture the developmental consequences of individual variation in the emergence of the consonant bias, we sent follow-up vocabulary questionnaires to the 8-month-old infant participants when they were 13, 16, and 24 months of age. Sensitivity to both vMPs and cMPs in word segmentation at 8 months has been found to predict growth in word production over these ages (Von Holzen et al., 2018). In the current study, however, we measure the preference for consonant compared with vowel information, which may provide a more accurate assessment of whether consonant bias emergence is related to later vocabulary outcomes.

2.1 | Methods

2.1.1 | Participants

Twenty-seven monolingual, French-learning 5-month-old infants (mean age = 165.85 days, age range = 156–179 days, 13 females) and 27 monolingual French-learning 8-month-old infants (mean age = 260.41 days, age range = 248–274 days, 15 females) were included in the analysis. The name and amount of exposure to the name for each infant were determined in a pre-visit telephone conversation, which ensured that the correct, individual name was noted. Only infants who had at least 80% exposure to French and to an individual name were included. All parents reported that their infant was born to term and healthy, with no reports of cognitive, visual, or hearing impairment. The present study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent or guardian for each infant before any assessment or data collection. All procedures involving human subjects in this study were approved by the Ethics Committee of CERES (No. 2011-14, 18 October 2011) at the Paris Descartes University. An additional fourteen 5-month-old infants were tested but excluded from the final data set due to fussiness (8), having two consecutive trials with insufficient orientation times (OTs; 2), three or more insufficient OTs overall (2), or being an outlier (three; difference between cMPs and vMPs two *SD* below or above the group mean, as in Bouchon et al., 2015). An additional eight 8-month-old infants were tested but excluded from the final data set due to fussiness (1), having two consecutive trials with insufficient OTs (3; see below), three or more insufficient OTs overall (2), or being an outlier (2; see below). Families were recruited from Paris, France, a large metropolitan city, using addresses obtained by the public birth registry and letters were sent to eligible parents inviting them to participate. The socio-economic status of families participating in studies in this laboratory is typically upper-middle class.[1] Families were compensated by a participation diploma with their child's picture.

2.1.2 | Stimuli

A set of stimuli recordings was prepared for each infant, corresponding to a CP, cMP, and vMP of their own name. Twenty-one of the 5-month-old and 23 of the 8-month-old infants had names beginning

[1]As pointed out by an anonymous reviewer, the homogeneous socio-economic status of our samples in Experiments 1 and 2 limits their generalizability to the broader population. Future studies should consider the potential impact that socio-economic status may have on the developmental trajectory of consonant bias emergence.

with a consonant; for these infants, the cMP was the initial consonant and the vMP was the first vowel to occur in the name. The remaining six 5-month-olds and four 8-month-olds had names beginning with a vowel; for these infants the vMP was the initial vowel and the cMP was the first consonant to occur in the name. A table of infant names and cMPs and vMPs can be found in Appendix A. The cMPs and vMPs of the names always consisted of a 1-feature change, with the three possible feature changes for consonants (place, manner, voicing) and for vowels (place, height, roundness) counterbalanced across infants in each age group for a total of nine possible combinations, with three infants per combination. For each name, a female, native French speaker recorded 15 tokens each of the cMP and vMP names and 10 tokens of the CP. For each MP, two 24-s files of all 15 tokens were created using the same tokens in reverse order of one another for the two files. For each CP, two 16-s files of all 10 tokens were created using the same tokens in reverse order of one another for the two files.

2.1.3 | Behavioral task

The HPP used in the current study was similar to that of Bouchon et al. (2015). Each session started with two CP pre-test trials, one for each flashing red light on the sides of the booth, which allowed the infants an opportunity to practice one head turn to each side. The purpose of these pre-test trials was to demonstrate to the infants the CP of their name, as pronounced by our speaker; it was not intended to habituate the infants. Furthermore, these trials provided the correct phonemes with which to compare the acoustic characteristics of the mispronounced phonemes (see below). Once infants had listened to 20 repetitions of the CP of their name (10 in each of the two pre-test trials), the test phase began.

The test phase consisted of two blocks of four trials each (eight trials total). Each block presented the two sound files for each cMP and vMP and order of the sound files within each block was randomized. In total, therefore, infants heard four cMP trials and four vMP trials (side of presentation was counterbalanced within blocks). Stimuli played continuously until completion or stopped immediately if the infant failed to maintain the head turn for two consecutive seconds. If the infant turned away from the target flashing light by 30° in any direction for less than 2 seconds, the trial continued without interruption, but the time spent orienting away from the target flashing light (as determined by the experimenter's release of the corresponding button on the response box) was automatically calculated and subtracted from the total OT by the computer program. The maximum OT for a given trial was the duration of the entire speech sample (24 s). If a trial lasted less than 1.5 seconds (defined as insufficient OT), the trial was repeated and the original OT was discarded. The dependent variable was mean OT for each trial. Infants with a mean difference score (cMP − vMP) greater or less than two standard deviations from the group mean were removed as outliers (Bouchon et al., 2015).

2.1.4 | Acoustic analysis of the stimuli

Similar to Bouchon et al. (2015), to capture acoustic/phonetic distance, we measured three acoustic dimensions of the contrasted phonemes (correct vs. mispronunciation for both consonants and vowels) in order to characterize their differences: duration, intensity, and Mel Frequency Cepstral Coefficients (MFCCs; measure of spectral distance). Contrasted phonemes were manually segmented using Praat (Boersma & Weenink, 2016) for the first token in the set of tokens for CP (correct consonant, correct vowel), cMP (mispronounced consonant), and vMP (mispronounced vowel) words. The remaining contrasted phonemes in each set of tokens were then automatically located using dynamic time

TABLE 1 A summary of the number of vocabulary questionnaires returned and words comprehended and produced by 8-month-olds (Experiment 1) and 11-month-olds (Experiment 2) at each age measured. Note that vocabulary questionnaires were not collected for the 5-month-olds tested in Experiment 1

			Comprehension			Production		
Age	**Age measured**	***n***	**Mean**	***SD***	**Range**	**Mean**	***SD***	**Range**
8	8	21	22.9	35.09	0–122	1.19	4.04	0–19
	13	22	68.91	59.5	0–181	5.41	13.69	0–66
	16	19				11.47	11.34	0–39
	24	20				177.45	108.86	0–375
11	8	27	61.67	70.08	0–282	2.19	3.32	0–11
	13	25	70.71	67.67	0–309	3.8	5.37	0–19
	16	23				42.83	102.86	0–511
	24	25				239.72	173.99	4–618

warping (DTW; Sakoe & Chiba, 1978) in a custom MATLAB ("MATLAB and Statistics Toolbox Release 2014b," 2014) script. DTW is a speech comparison method that automatically determines the optimal temporal matching between two speech patterns (detecting segment similarities) independently of duration and speech rate.

Duration and intensity of each contrasting phoneme were measured using a custom Praat (Boersma & Weenink, 2016) script, which calculated a normalized difference score for both consonant and vowel contrasts. For example, the mean intensity of the contrasting consonant in the cMP was subtracted from the mean intensity of the contrasting consonant in the CP, and divided by their mean (*Cdiff.intensity*). The same procedure was done for the contrasting vowel intensity (*Vdiff.intensity*), and duration (*Cdiff.duration*, *Vdiff.duration*). A positive difference score indicates that the CP was more intense, or longer than the mispronunciation. MFCCs were measured for each contrasting phoneme using a custom Matlab script (for details on the procedure, see Bouchon et al., 2015). The ratio of the mean cross-category distance between the 10 CPs and the 15 MPs (Dcross) of a given pair and the mean internal variability within the 10 CPs (DwithinCP) and within the 15 MPs (DwithinMP) was calculated for both consonants (*Cdiff.spectral*) and vowels (*Vdiff.spectral*). For these measurements, a larger difference score indicates that the distance between the two pronunciations was spectrally larger.

2.1.5 | Vocabulary questionnaire (8-month-old infants)

At the time of their visit, parents of the 8-month-old infants were asked to complete the French Communicative Developmental Inventory: Words and Gestures for ages 8–16 months (Kern & Géraldine, 2003). Parents completed the questionnaire at home on paper and brought it to their appointment, mailed it back, filled out a pdf and sent it by email, or filled out the questionnaire online. To examine how infants' vocabulary scores grew with time, parents were asked to complete the same questionnaire when their child was 13 months, as well as the French CDI: Words and Phrases for ages 16–30 months (Kern, 2003) when their child was 16 and 24 months. Parents were sent a reminder by email to fill out the questionnaire at each target age (13, 16, 24). The top half of Table 1 includes a summary of the number of vocabulary questionnaires returned and reported words comprehended and produced.

To assess whether the consonant and/or vowel structure of an individual infant's lexicon is related to their preference for cMPs or vMPs, we calculated the number of words comprehended as well as a

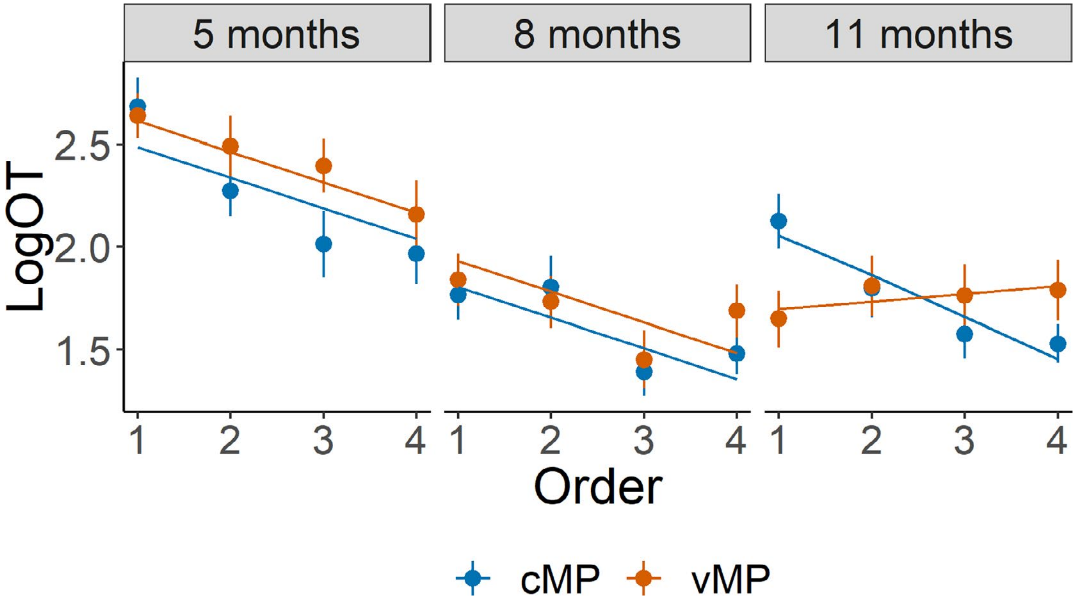

FIGURE 1 The mean and *SE* range of log-transformed orientation times (LogOT) is plotted against Order separately with model fits from Experiment 1 for 5-month-olds (left panel) and 8-month-olds (middle panel) and Experiment 2 for 11-month-olds (left panel). The color blue indicates consonant mispronunciations (cMPs) and orange indicates vowel mispronunciations (vMPs)

consonant and a vowel proportion score for each infant. We use comprehension as opposed to production because infants at this age are more likely to comprehend than produce words, allowing for more individual variability in the calculation. After determining the number of words comprehended for each infant, we calculated the number of unique consonant and vowel tiers in these known words using the phonetic transcriptions from the Lexique database (New et al., 2004). For example, an infant who knows the words bain (/bɛ̃/), chien (/ʃjɛ̃/), and merci (/mɛʁsi/) would have three unique consonant tiers, as all three words contain different consonant sequences (/b/; /ʃ.j/; /m.ʁ.s/), but two unique vowel tiers, as bain and chien share the same vowel sequence (/ɛ̃/), which is different than merci (/ɛ.i/). To achieve consonant and vowel proportion scores, we then divided the number of unique (consonant or vowel) tiers by the number of known words. In our example, the infant would have a consonant tier proportion score of 1 (3/3) and a vowel tier proportion score of 0.667 (2/3). The number of words comprehended, consonant proportion score, and vowel proportion score were included to evaluate the role of lexical factors in the consonant bias.

Finally, to evaluate the role of early consonant bias emergence on later vocabulary outcomes, we calculated total number of words produced at each age measured (8, 13, 16, and 24 months). We use production because this measurement was available at all four ages, whereas comprehension was only available at ages 8 and 13 months.

2.2 | Results

2.2.1 | Orientation time

The raw OTs were not normally distributed and were therefore log-transformed (logOT; Csibra, Hernik, Mascaro, Tatone, & Lengyel, 2016). LogOTs were analyzed with linear mixed-effects

TABLE 2 A summary of the means and standard deviations of the intensity and duration measurements, as well as the normalized difference scores for intensity, duration, and spectral measurements for correct pronunciations (CP) and mispronunciations (MP) presented to 5- and 8-month-olds (Experiment 1) and 11-month-olds (Experiment 2)

		Vowels			Consonants		
		Mean (*SD*)			Mean (*SD*)		
Experiment	**Acoustic measurement**	**CP**	**MP**	**Difference**	**CP**	**MP**	**Difference**
1	Duration	85.08 (27.35)	86.67 (30.08)	−0.03 (0.21)	65.97 (21.19)	73.2 (27.39)	−0.16 (0.43)
	Intensity	69.91 (6.79)	70.34 (5.02)	−0.01 (0.06)	53.75 (8.37)	53.76 (7.63)	−0.01 (0.16)
	Spectral			1.64 (0.24)			1.66 (0.32)
2	Duration	91.62 (48.28)	99.83 (42.32)	−0.2 (0.34)	65.72 (18.03)	64.19 (25.41)	0.01 (0.29)
	Intensity	69.63 (7.63)	69.76 (5.93)	−0.01 (0.06)	57.02 (8.61)	55.19 (9.09)	0.03 (0.11)
	Spectral			1.72 (0.39)			1.68 (0.31)

models, using R (R Core Team, 2018) and the package lme4 (Bates, Maechler, Bolker, & Walker, 2015). Fixed effects were Type of mispronunciation (cMP, vMP), Age (5, 8 months), and Order (whether the test trial was the 1st, 2nd, 3rd, or 4th instance of that mispronunciation). Random intercepts for Trial number (1–8) and for participant, including a random slope by Type, were included. All fixed effects were coded with contrast coding and the fixed effect of Trial was mean centered. The full equation was as follows: logOT ~ Age × Type × Order + (1 + Type | Participant) + (1 | Tri al). Significance was assessed via model comparison with an alpha of 0.05 using the drop1 function (Chambers, 1992). The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix B (Table B1).

The two left panels of Figure 1 plot infants' orientation times (logOT) for cMP and vMPs over all Orders separately for 5- and 8-month-old infants. The results of the model revealed a significant main effect of Order (χ^2 (1) = 21.24, $p < .001$), showing that as the experiment progressed, OTs decreased ($\beta = -0.15$, $SE = 0.03$). The effect of Age was also significant (χ^2 (1) = 30.47, $p < .001$), showing that overall 5-month-olds oriented longer than 8-month-olds ($\beta = -0.68$, $SE = 0.11$). Critically, the effect of Type was significant (χ^2 (1) = 5.06, $p = .02$), showing that infants oriented longer for vMPs compared with cMPs ($\beta = -0.13$, $SE = 0.06$). There were no significant interactions between Age, Type, and Order.

2.2.2 | Acoustic measurements

A summary of the means and standard deviations of the intensity and duration measurements, as well as the difference scores for intensity, duration, and spectral measurements, is given in Table 2 Below, we report a series of linear mixed-effects models that analyzed whether these measurements differed for the consonants and vowels in the recording stimuli.

2.2.2.1 | Duration and intensity measurements

To quantify any saliency difference in the recorded stimuli, mean values for duration and intensity for each contrasted phoneme were analyzed using separate linear mixed-effects models with the fixed effects Pronunciation (CP, MP) and Type of contrast (vowel, consonant) and participant as a random intercept. Type of contrast was significant for both duration ($\beta = -19.11$, $SE = 4.5$, $p < .001$) and intensity ($\beta = -16.17$, $SE = 1.35$, $p < .001$), indicating that consonants were significantly shorter and softer than vowels. This pattern is similar to that of Bouchon et al. (2015) and suggests that vowels were more salient than consonants. The lack of an effect of Pronunciation or an interaction between Pronunciation and Type of contrast for both duration and intensity, however, suggests that cMPs and vMPs could not be discriminated from their respective CPs based on duration and intensity differences.

2.2.2.2 | Spectral measurements

In contrast to duration and intensity, the normalized acoustic/phonetic distance (MFCCs) assesses the acoustic distinctiveness of the contrasted phonemes. *Diff.spectral* for each contrasted phoneme pair (CP vs. MP) was analyzed using a linear mixed-effects model with the fixed effect Type of contrast (vowel, consonant) and participant as a random intercept. Type of contrast was not significant ($\beta = 0.02$, $SE = 0.05$, $p = .73$). Spectral distance of consonant and vowel contrasts was not overall distinct from one another in the recordings presented to infants in Experiment 1, contrary to Bouchon et al. (2015) who found greater spectral distinctiveness for consonant contrasts.

2.2.3 | Acoustic predictors of orientation time

To assess the influence of acoustic characteristics on OT for cMPs or vMPs, a linear mixed-effects model was computed. To reduce the number of estimated effects, the fixed effect of Order was removed. Mean difference scores (CP − MP) for each acoustic measurement were calculated for both consonants and vowels (*Cdiff.Intensity*, *Vdiff.Intensity*, *Cdiff.Duration*, *Vdiff.Duration*, *Cdiff.Spectral*, *Vdiff.Spectral*). Fixed factors included Age (5, 8 months), Type of mispronunciation (cMP, vMP), and the 6 acoustic measurements. In the full model, each acoustic difference score was allowed to interact with each possible combination of Age and Type (e.g., *Cdiff.Intensity* X Age, *Cdiff.Intensity* X Type, *Cdiff.Intensity* X Age X Type). Random intercepts for Trial (1–8) and for participant, including a random slope by Type, were included. Significance was assessed via model comparison with an alpha of 0.05 using the drop1 function (Chambers, 1992). The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix B (Table B2).

The resulting best-fitting model included main effects of Age and *Vdiff.Spectral*. The effect of Age was significant (χ^2 (1) = 31.56, $p < .001$), reflecting the previous result showing that 5-month-olds had longer OTs than 8-month-olds ($\beta = -0.72$, $SE = 0.11$). The effect *Vdiff.Spectral* was also significant (χ^2 (1) = 5.96, $p = .01$), showing that infants with a smaller spectral difference between the MP and CP vowel in their name had longer OTs overall, regardless of whether the trial presented a vMP or a cMP. Without a significant interaction between any of the acoustic measurements and Type, this model provides no evidence for a role of acoustic characteristics in the preference for vMPs compared to cMPs.

2.2.4 | Lexical predictors of orientation time

The 21 8-month-old infants for whom vocabulary questionnaires were returned at 8 months knew on average 22.90 words ($SD = 35.85$) at this age, which consisted of an average of 20.43 unique consonant tiers ($SD = 30.42$) and 15.57 unique vowel tiers ($SD = 19.83$). The proportion of unique consonant tiers ($M = 0.95$; $SD = 0.06$) was significantly greater than the proportion of unique vowel tiers ($M = 0.88$; $SD = 0.16$), $t(17) = 2.66$, $p = .02$ (three infants reportedly knew no words at age 8 months, their data were removed to conduct this *t* test).

To assess the influence of lexical factors at 8 months, derived from vocabulary scores, on preference for vMPs or cMPs, a linear mixed-effects model was computed. We included the fixed effect Type of mispronunciation (cMP, vMP), but not Order, to reduce the number of estimated effects, or Age, as this model was only fit to data from 8-month-olds (from whom we collected vocabulary scores). We also added fixed effects of the log-transformed total number of words comprehended (Comp), proportion of known words with unique consonant tiers (Cprop), and proportion of known words with unique vowel tiers (Vprop). All fixed effects were coded with contrast coding and the lexical scores were mean centered. Random intercepts for Trial (1–8) and for participant, including a random slope by Type, were included. The full equation was as follows: logOT ~ Type + Comp + Cprop + Vprop + Type:Comp + Type:Cprop + Type:Vprop + (1 + Type | Participant) + (1 | Trial). Significance was assessed via model comparison with an alpha of 0.05. The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix B (Table B3).

Model comparison revealed no significant effects, all effects and interactions being eliminated. This fails to provide evidence that the measured lexical factors influenced infants' OTs for vMPs or cMPs.

TABLE 3 A summary of the number of questionnaires returned and mean words produced at each age measured for 8- (Experiment 1) and 11-month-old (Experiment 2) infants with either longer orientation times (preference) for consonant (cMP) or vowel mispronunciations (vMP)

		cMP preference			vMP preference		
Age	**Age measured**	***n***	***M***	***SD***	***n***	***M***	***SD***
8	8	8	2.88	6.56	13	0.15	0.55
	13	8	11.88	22.33	14	1.71	2.49
	16	8	14.62	12.58	11	9.18	10.88
	24	7	175.71	128.11	13	178.38	106.86
11	8	15	2.27	3.97	12	2.08	2.61
	13	13	3.38	5.64	12	4.25	5.48
	16	12	65.83	142.71	11	17.73	21.71
	24	14	217.07	179.49	11	268.55	178.29

2.2.5 | Relationship between CV preference and later vocabulary

We next examined the relationship between infants' OTs for vMPs or cMPs and word production at 8, 13, 16, and 24 months. Of the 27 infants included in the final sample, 24 completed a vocabulary questionnaire for at least one age. Each infants' productive vocabulary score (Prod.z; *z*-score transformed) was submitted to a mixed-effects model. To capture whether later productive vocabulary was related to longer OTs for vMPs or cMPs at 8 months, the mean OT for vMPs was subtracted from cMPs, creating a difference score (*OT.diff*). The effect of *OT.diff* as well as the interaction between *OT.diff* and Age of vocabulary measurement (8, 13, 16, 24) was included as fixed factors and a random intercept for participant. The full equation was as follows: Prod.z ~ Age × *OT.diff* + (1 | Participant). The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix B (Table B4). Only effects of *OT.diff* or interactions with *OT.diff* will be interpreted.

The results of the model revealed no significant main effect of or interaction with *OT.diff*. A summary of the vocabulary scores for infants with a positive *OT.diff* score (cMP preference) and a negative *OT.diff* score (vMP preference) is given in Table 3.

2.3 | Discussion

Experiment 1 measured 5- and 8-month-old infants' OTs for consonant (cMPs) and vMPs of their own-name. Previous studies showed evidence of a vowel bias at 5/6 months (Bouchon et al., 2015; Nishibayashi & Nazzi, 2016) while 8-month-olds exhibit a consonant bias (Nishibayashi & Nazzi, 2016), and we expected a similar change if the timing of emergence of the consonant bias is the same for familiar and unfamiliar words. Yet, the results of Experiment 1 show that both 5- and 8-month-olds show the same pattern of results, with log-transformed OTs (logOT) longer to vowel compared to cMPs. This unexpected lack of a difference between 5- and 8-month-olds makes an interpretation of these results difficult. Given previous evidence that French-learning infants orient longer to novel word forms that are similar to more familiar or familiarized word forms, then orienting longer to a vowel compared with a cMP would indicate a consonant bias because the vMP conserves the consonant information of the name. If this is the case, then Experiment 1 would provide evidence of a consonant bias at the youngest age tested to-date, 5 months.

Interpretation of the results of Experiment 1 to indicate a consonant bias at 5 months, however, would be in conflict with Bouchon et al. (2015) who found a vowel bias at the same age of 5 months for the same kind of words (own-name). An alternative explanation for the results would be that infants attend more to a novel word form with a more novel change, listening longer to mispronunciations that change the identity of the word form according to their bias. If this is the case, listening longer to a vMP would indicate a vowel bias. However, this interpretation suggests that 8-month-olds maintain a vowel bias longer than suggested by previous studies examining unfamiliar words (Nishibayashi & Nazzi, 2016; Von Holzen et al., 2018), at least in the current testing conditions.

According to Hunter and Ames (1988), longer familiarization times and low task difficulty are likely to elicit longer looks toward stimuli that present a novel change. Unlike Bouchon et al. (2015), we familiarized infants with a CP of their name (not measuring their OT to the CP) and tested infants on their preference for cMPs and vMPs. Familiarizing with the CP of infants' names may have increased infants interest in stimuli with a more novel change whereas testing infants on both consonant and vowel mispronunciations may have raised task difficulty, as it requires comparison of two changes instead of one. Based on the results of Experiment 1, it is not possible to determine which alternative is the case.

The results of Experiment 1 therefore leave us with two puzzles to solve. First, which conclusion should we draw from these results, a consonant bias (attending longer to words that are more similar to familiar stimuli) or a vowel bias (attending longer to words that are more novel in comparison to familiar stimuli)? Second, when does a switch from a vowel to consonant bias occur when processing one's own name? Previously, 11-month-olds have shown a consonant bias when tested on recognition of familiar word forms (Poltrock & Nazzi, 2015) and we therefore expect them to also exhibit a consonant bias in own-name recognition. By testing 11-month-olds on the same task as the infants tested in Experiment 1, their responses should help us solve the above two questions. If 11-month-old infants show the same pattern of results as those infants tested in Experiment 1, listening longer to vowel compared with cMPs, this would indicate that all three age groups exhibit a consonant bias. If 11-month-olds show an different pattern, however, it would indicate that the 5- and 8-month-olds tested in Experiment 1 exhibited a vowel bias and establish that the switch from a vowel to consonant bias occurs between 8 and 11 months for own-name recognition.

Finally, acoustic/phonetic as well as lexical factors were not found to modulate OTs to consonant or vMPs in 5- and 8-month-olds. These null results run counter to the predictions of both the acoustic/phonetic (Floccia et al., 2014) and lexical (Keidel et al., 2007) hypotheses and do not replicate the findings of Bouchon et al. (2015). We also failed to reveal a link between OTs for consonant or vMPs at 8 months and later vocabulary outcomes. In Experiment 2, we examine these factors in 11-month-olds' OTs for cMPs and vMPs and discuss the full results in the General Discussion.

3 | EXPERIMENT 2:11-MONTH-OLDS

In Experiment 2, we examined the emergence of a consonant bias in French-learning 11-month-olds using the same task as Experiment 1. The purpose of this experiment was to specify the correct interpretation of the results for Experiment 1 as well as test whether the switch from vowel to consonant bias occurs between 8 and 11 months for own-name recognition. Similar to Experiment 1, we also examined the role of acoustic and lexical factors in OTs for cMPs and vMPs for 11-month-olds, as well as whether the OTs for cMPs and vMPs at this age predicts later vocabulary outcomes.

3.1 | Methods

3.1.1 | Participants

For Experiment 2, 27 monolingual, French-learning 11-month-old infants were included in the analysis (mean age = 352.56 days, age range = 336–363 days, 18 females). Participants were recruited in the same way as Experiment 1. Only infants who had at least 80% exposure to French and to an individual name were included (determined in a pre-visit telephone conversation). All parents reported that their infant was born to term and healthy, with no reports of cognitive, visual, or hearing impairment. An additional 12 infants were tested but excluded from the final data set due to fussiness (4), having two consecutive trials with insufficient OTs (1), three or more insufficient OTs overall (5), or being an outlier (2; difference between cMPs and vMPs 2 *SD* below or above the group mean, as in Bouchon et al., 2015).

3.1.2 | Stimuli, behavioral task, and acoustic analysis of the stimuli

Stimuli preparation, the behavioral task, and acoustic analyses for Experiment 2 were identical to that of Experiment 1. Twenty-one of the infants had names beginning with a consonant and 6 beginning with a vowel. Two infants shared the same name and mispronunciation, leading to a total of 25 names used in Experiment 2. A table of infant names (CP) and consonant (cMP) and vowel (vMP) mispronunciations can be found in Appendix C.

3.1.3 | Vocabulary questionnaire

As with 8-month-olds in Experiment 1, at the time of their visit and at 13 months, parents were asked to complete the French Communicative Developmental Inventory: Words and Gestures for ages 8–16 months (Kern & Géraldine, 2003) and the French CDI: Words and Phrases for ages 16–30 months (Kern, 2003) at 16 and 24 months. As in Experiment 1, parents of infants tested in Experiment 2 had the option of completing the questionnaire on paper and bringing it to their appointment or mailing it back, filling out a PDF form and returning it by email, or filling out the questionnaire online. A reminder was sent to parents by email to fill out the questionnaire at each target age (13, 16, 24). The bottom of Table 1 includes a summary of the number of vocabulary questionnaires returned and words comprehended and produced.

3.2 | Results

3.2.1 | Orientation time

The raw OTs were not normally distributed and were therefore log-transformed (logOT; Csibra et al., 2016). Similar to Experiment 1, logOTs were analyzed with linear mixed-effects models, including the fixed effects of Type of mispronunciation (cMP, vMP) and Order (whether the test trial was the 1st, 2nd, 3rd, or 4th instance of that mispronunciation). The full equation was as follows: logOT ~ Type × Order + (1 + Type | Participant) + (1 | Trial). As in Experiment 1, significance was assessed via model comparison with an alpha of 0.05 using the drop1 function (Chambers, 1992). The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix D (Table D1).

The rightmost panel of Figure 1 plots infants OTs (logOT) for cMP and vMPs over all Trials for the 11-month-old infants. The results of the best-fitting model revealed a significant main effect of Type (χ^2 (1) = 8.75, p < .01), showing infants oriented longer for cMPs compared with vMPs (β = 0.61, SE = 0.2). The interaction Type by Order was also significant (χ^2 (1) = 10.56, p < .01). At the beginning of the experiment, infants oriented longer to cMPs, but OTs declined rapidly as the experiment progressed while OTs to vMPs stayed fairly level throughout the experiment (β = −0.24, SE = 0.07). The main effect of Order was not significant.

3.2.2 | Acoustic measurements

A summary of the means and standard deviations of the intensity and duration measurements, as well as the difference scores for intensity, duration, and spectral measurements, is given in Table 2. Below, we report a series of linear mixed-effects models that analyzed whether these measurements differed for the consonants and vowels in the recording stimuli.

3.2.2.1 | Duration and intensity measurements

As in Experiment 1, mean for duration and intensity for each contrasted phoneme were analyzed using separate linear mixed-effects models with the fixed effects Pronunciation (CP, MP) and Type of contrast (vowel, consonant) and participant as a random intercept. Type of contrast was significant for both duration (β = −25.9, SE = 8.54, p < .01) and intensity (β = −12.61, SE = 2.11, p < .001), indicating that consonants were significantly shorter and softer than vowels. There were no effects of Pronunciation or interactions between Type and Pronunciation, indicating that cMPs and vMPs could not be discriminated based on duration and intensity differences. This pattern is similar to that of Bouchon et al. (2015) and suggests that vowels were more salient than consonants.

3.2.2.2 | Spectral measurements

As in Experiment 1, *Diff.spectral* for each contrasted phoneme pair (CP vs. MP) was analyzed using a linear mixed-effects model with the fixed effect Type of contrast (vowel, consonant) and participant as a random intercept. Type of contrast was not significant (β = −0.04, SE = 0.09, p = .73). Consonant and vowel contrasts were not acoustically distinct from one another in the recordings presented to infants in Experiment 2. Although this is similar to the results of the spectral measurements of Experiment 1, it is different than Bouchon et al. (2015) who found greater spectral distinctiveness for consonant contrasts.

3.2.3 | Acoustic predictors of orientation time

To assess the influence of acoustic characteristics of consonant and vowels on OT, a linear mixed-effects model was computed as in Experiment 1. The only deviation was the removal of the fixed factor Age, as only the data from 11-month-olds were included in this analysis. Significance was assessed via model comparison with an alpha of 0.05 using the drop1 function (Chambers, 1992). The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix D (Table D2).

Model comparison revealed no significant effects, all effects and interactions being eliminated. This fails to provide evidence that the measured acoustic characteristics influenced infants' OTs for vMPs or cMPs.

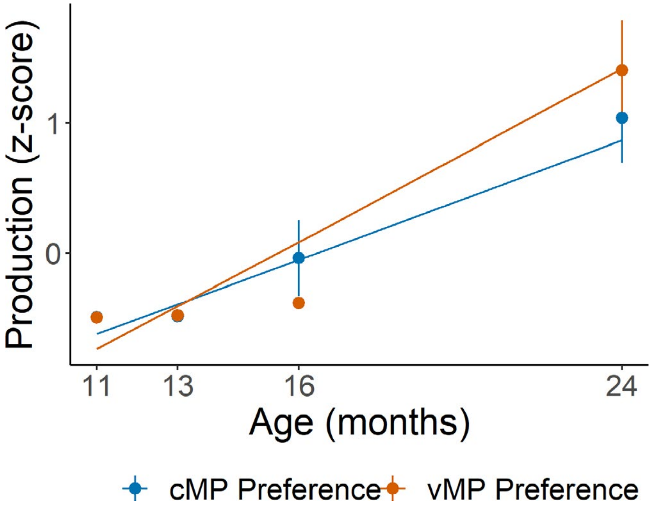

FIGURE 2 Total word production (z-score) for the 11-month-olds tested in Experiment 2 at the four ages measures (11, 13, 16, 24 months) for infants with either longer orientation times for vowel (vMP preference) or consonant mispronunciations (cMP preference). Lines indicate the fit of the model, and whiskers indicate a standard error of 1

3.2.4 | Lexical predictors of orientation time

The 27 11-month-old infants for whom vocabulary questionnaires were returned at 11 months knew on average 61.67 words ($SD = 71.25$) at this age, with an average of 51.26 unique consonant tiers ($SD = 54.10$) and 34.89 unique vowel tiers ($SD = 30.32$). The proportion of unique consonant tiers ($M = 0.89$; $SD = 0.07$) was significantly greater than the proportion of unique vowel tiers ($M = 0.70$; $SD = 0.15$), $t(24) = 9.56$, $p < .001$.

To assess the influence of lexical factors at 11 months, derived from vocabulary scores, on orientation behavior, a linear mixed-effects model was computed and analyzed using the same procedure as Experiment 1. The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix D (Table D3).

The resulting best-fitting model included the effects of Cprop (χ^2 (1) = 5.66, $p = .02$) and Vprop (χ^2 (1) = 4.48, $p = .03$) which were both significant, showing that *LogOT* was longer for infants with a lower proportion of unique consonant tiers ($\beta = -4.02$, $SE = 1.53$) but a higher proportion of unique vowel tiers ($\beta = 1.68$, $SE = 0.75$). Similar to Experiment 1, the lack of an interaction between any of the measured lexical factors and Type fails to provide evidence that the measured lexical factors influenced infants' OTs for vMPs or cMPs.

3.2.5 | Relationship between CV preference and later vocabulary

To examine the relationship between infants' preference for vMPs or cMPs and the growth of word production at 11, 13, 16, and 24 months, a linear mixed-effects model was computed and analyzed using the same procedure as Experiment 1. The resulting best-fitting model is interpreted here and a table of these results can be found in Appendix D (Table D4). Only effects of *OT.diff* or interactions with *OT.diff* will be interpreted.

Figure 2 depicts word production with model fits for the effect of *OT.diff* at each age measured. The results of the model revealed a significant interaction between *OT.diff* and Age ($\beta = -0.01$, $SE = 0$, $p = .03$), indicating that children who had a negative *OT.diff* (vMP preference) at 11 months had a greater increase in productive vocabulary over the ages of 11, 13, 16, and 24 months. A summary of the vocabulary scores for infants with a positive *OT.diff* score (cMP preference) and a negative *OT.diff* score (vMP preference) are given in Table 1.

3.3 | Discussion

Experiment 2 tested 11-month-old infants on their OTs for consonant (cMP) and vowel (vMP) mispronunciations of their own name. Overall, infants had longer logOT to consonant compared with vMPs, especially at the beginning of the experiment, showing a different pattern of results than the 5- and 8-month-olds in Experiment 1. Considering the existing evidence showing that French-learning infants initially exhibit a vowel bias at 5/6 months and only later at 8 or 11 months does a consonant bias emerge (Bouchon et al., 2015; Nishibayashi & Nazzi, 2016; Poltrock & Nazzi, 2015), it is unlikely that the pattern of results in this study show a switch from a consonant to a vowel bias. Instead, these results indicate that the switch from a vowel to a consonant bias occurs between 8 and 11 months for own-name recognition. Although both the cMPs and vMPs are novel word forms to the infants tested, this interpretation implies that infants attend longer to the mispronunciation that contains a more novel change. If vowels are a greater cue to the identity of a word (vowel bias), then infants should attend longer to words where vowels are mispronounced, and vice versa, when they are tested under the conditions of the current study.

Similar to Experiment 1, there was no relationship between the measured acoustic or lexical factors and OTs to cMPs and vMPs, suggesting that these factors do not explain 11-month-olds' differential processing of consonant and vowel information. Orienting longer to vMPs, which we now interpret as a consonant bias, was related to a smaller growth in productive vocabulary over the second year of life. This runs counter to our predictions and will be discussed in the General Discussion.

4 | GENERAL DISCUSSION

Our results provide evidence of a vowel bias at 5 and 8 months, and emergence of a consonant bias by 11 months. In two experiments, we investigated the developmental trajectory of the consonant bias when recognizing a familiar word, their own name. Infants aged 5, 8, and 11 months were tested on their orientation times (OTs) for consonant (cMP) vs. vowel (vMP) mispronunciations of their own name. In Experiment 1, 5-, and 8-month-olds had longer logOTs for vMPs compared with cMPs, whereas in Experiment 2, 11-month-olds show a different pattern, orienting initially longer to cMPs. Based on evidence for the vowel and consonant bias in lexical processing found by previous studies (Bouchon et al., 2015; Poltrock & Nazzi, 2015), we interpret the pattern of infants' OTs as an indication that under the conditions of the current study, infants attend longer to the mispronunciation that contains a more novel change.

There are several possible explanations for why our task elicits longer looks to a mispronunciation that contains a more novel change, whereas previously infants have been found to attend longer to stimuli that are more similar to familiar words. According to Hunter and Ames (1988), this pattern of looking preference is found when the difficulty of the task is low or familiarization times are longer. Task difficulty in our study was arguably high, as infants were tested on mispronounced word forms that differed minimally from their CP as well as from one another. This would set our task difficulty as similar to that of other studies that have used a conflict task (Nishibayashi & Nazzi, 2016; Poltrock & Nazzi, 2015). Instead, the greater difference between our study and previous studies was the inclusion of a familiarization phase. Our study has arguably longer familiarization times than previous studies, which either contained no familiarization (Bouchon et al., 2015; Poltrock & Nazzi, 2015) or presented the target word embedded in a familiarization passage (Nishibayashi & Nazzi, 2016). We argue that infants in our study attended longer to mispronunciations containing a more novel change because we included a familiarization phase that presented infants with the CP of their name.

These results support evidence for consonant bias emergence between 5/6 months (Bouchon et al., 2015; Nishibayashi & Nazzi, 2016) and 11 months (Poltrock & Nazzi, 2015) in French-learning infants. Results differ, however, in the timing of the switch from a vowel to a consonant bias. Whereas our results suggest that a vowel bias is maintained at 8 months, studies investigating segmentation abilities have found a consonant bias at 8 months (Nishibayashi & Nazzi, 2016; Von Holzen et al., 2018). We examined word form recognition, which requires the infants to access an existing representation, whereas word segmentation tasks (Nishibayashi & Nazzi, 2016) require the infant to build a representation for the newly segmented word form during the experiment. Sensitivity to the phonological form of newly segmented words requires short-term retention whereas own-name recognition tested in the current study requires infants to access an existing word form representation in long-term memory. The difference in timing of the vowel to consonant bias shift for unfamiliar (Nishibayashi & Nazzi, 2016) and familiar (present study; Bouchon et al., 2015; Poltrock & Nazzi, 2015) word forms may therefore be due to differences in the cognitive processes involved in familiar word form recognition and unfamiliar word form segmentation. The representation or processing of the infant's own name may be more resistant to the emergence of the consonant bias, which could be due to the specificity of recognition of familiar word form representations. This could also be due to early establishment of the word form at a younger age when vowel information played a greater role in lexical processing, a vowel bias. Future research will have to determine whether this delayed switch extends to other early familiar names or is specific to the infant's own name, which is highly frequent, uttered in many different situations, arguably produced with widely varying intonation and pronunciation, and probably one of the first words learned.

4.1 | Factors modulating the consonant bias: testing the acoustic and lexical hypotheses

Our second goal was to examine the role of different factors in consonant bias emergence. We found no evidence for an influence of acoustic or lexical factors on OTs for vMPs and cMPs. This runs counter to the predictions of the acoustic/phonetic hypothesis (Floccia et al., 2014), which attribute infants' early vowel bias to vowels greater saliency over consonants, and infants' later consonant bias to consonants' greater categorical perception, as well as the lexical hypothesis (Keidel et al., 2007), which attributes emergence of a consonant bias to discovery that consonants are more informative than vowels in lexical processing.

Bouchon et al. (2015) found that infants' vowel bias at 5 months was driven by spectral distance differences between the individual correct and mispronounced vowel stimuli presented to infants during the experiment. In a direct replication of this study with British-English-learning infants, Delle Luche et al. (2016) found no evidence for a consonant or vowel bias and weak evidence that infants' processing of consonants and vowels is driven by acoustic cues, specifically energy information in consonants. Taken together with the results of the current study, we suggest that the inconsistent findings in terms of the role of acoustic/phonetic factors may result from the type of stimuli used. In own-name recognition studies, the acoustic properties of CPs and mispronunciations are not controlled for during recording (although the mispronounced consonants and vowels are counterbalanced by feature type). For example, our lack of replication of Bouchon et al.'s (2015) spectral property differences between cMPs and vMPs might also partly explain why we did not find a link between acoustic properties and OTs for cMPs and vMPs in the current study.

A complementary approach to studying the role of acoustic characteristics would be to explicitly manipulate acoustic characteristics and the type of feature changed and then measure the resulting influence on OTs. To do so, it might be preferable to use the same stimuli across infants, and thus other highly frequent and early recognized words such as Mommy and Daddy (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 1999, 2012) rather than infants' own names. Note, however, that a relationship between differential processing of consonants and vowels and acoustic factors might only be found early in development, possibly only before the consonant bias is acquired, since there is some evidence suggesting that consonants and vowels are differentially processed by adults independently of their acoustic properties (Toro, Shukla, Nespor, & Endress, 2008).

Lexical factors were also not found to modulate OTs to cMPs and vMPs in 8- and 11-month-olds. This lack of evidence for a role of lexicon size is congruent with previous evidence (Poltrock & Nazzi, 2015; but see Mani & Plunkett, 2011). Yet, our analyses of the structure of the early lexicons of the infants of the present study showed that in their early lexicons, there are more unique consonant than vowel sequences (20.43 vs. 15.57 respectively at 8 months; 51.26 vs. 34.89, respectively, at 11 months), which is one argument that has been invoked to link the emergence of the consonant bias to early lexical acquisition. This finding has so far only been found in normed French and Italian CDI data (Hochmann et al., 2011, Supplementary Material), and is thus demonstrated here for the first time for individual infant data.

The null result for evidence of an influence of lexical factors may reflect a true lack of effect, but may also be due to our measurement. Comprehension lexicon size and the proportion of unique consonant and vowel tiers based on this measurement reflect what the infant reportedly *knows*, not what they are *exposed* to. If the consonant bias emerges from statistics computed on the input as opposed to comprehended words, then ours and previous measurements (Hochmann et al., 2011; Poltrock & Nazzi, 2015) are insufficient to capture this variation. Further investigation is needed to determine whether this is the appropriate metric to assess the statistical structure of the early lexicon, which is proposed by the lexical hypothesis to support emergence of the consonant bias (Keidel et al., 2007).

Poltrock and Nazzi (2015) proposed that instead of a strict division between the acoustic-phonetic and lexical hypotheses, both may play a role in consonant bias emergence (see also Nazzi et al., 2016). Development of speech perception and word learning skills occur at the same time and likely influence one another (Werker, 2018). Infants must first have some knowledge that consonants and vowels are distinct phonological categories and different from one another, which likely would emerge from their acoustic-phonetic properties. Yet, this experience comes with exposure to word forms that contrast on these properties and therefore on the distribution of consonants and vowels in an infant's first words. Studying the influence of acoustic-phonetic and lexical factors simultaneously using the approaches proposed above will hopefully clarify this issue.

4.2 | Consonant bias and later vocabulary outcome

Although there was no evidence of a relationship at 8 months, a consonant bias at 11 months resulted in a relative disadvantage in productive vocabulary at 24 months compared with infants that showed a vowel bias at 11 months. This runs counter to our predictions that a greater consonant bias at 8 or 11 months would predict greater productive vocabulary growth over the second year of life. Considering that studies with adult speakers of a variety of languages have shown consistent evidence for a consonant bias (Nazzi & Cutler, 2018; but see studies with tonal languages, Gómez et al., 2018; Poltrock et al., 2018; Wiener & Turnbull, 2016), we had predicted that infants that exhibit early consonant bias emergence may have an advantage in vocabulary acquisition because consonants are more informative in the French lexicon (Hochmann et al., 2011; Keidel et al., 2007). The only study to examine this relationship found that sensitivity to mispronunciations in general, but not specifically consonant or vowel changes, predicted overall vocabulary growth at 24 months of age (Von Holzen et al., 2018). Thus, the evidence to-date suggests that a vowel preference or sensitivity to phonological alterations in general is beneficial to vocabulary growth. This stands in contrast to our predictions, but we emphasize that sensitivity to both consonant and vowel information is essential to successfully acquiring a native language. We note that the current study as well as that of Von Holzen et al. (2018) measured later outcomes in productive vocabulary as opposed to comprehension, because this was the only measure available at all four ages. There was little variation in the few words produced by infants in the early ages measured (8/11 and 13 months), as infants produce few words at these ages. If more measurements are made at younger ages and comprehension as opposed to production is measured, an initial instead of long-term advantage in acquisition may be uncovered.

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APPENDIX A

TABLE A1 Details of the individual stimuli presented to 5-month-olds in Experiment 1

5-month-olds							
		Consonant			Vowel		
	Infant name	CP	MP	Feature	CP	MP	Feature
1	Loïs	l	r	Place	o	ø	Place
2	Joann	ʒ	ʃ	Voicing	o	ø	Place
3	Mathis	m	b	Manner	a		Height
4	Maxime	m	n	Place	a	ɛ	Height
5	Luce	l	d	Manner	y	i	Roundness
6	Iris	r	l	Place	i	y	Roundness
7	Léonie	l	r	Place	e	ø	Roundness
8	Lison	l	z	Manner	i	e	Height
9	Vadim	v	f	Voicing	a	ɛ	Height
10	Manon	m	n	Place	a	ɛ	Height
11	Charlotte	ʃ	ʒ	Voicing	a	ɛ	Height
12	Nael	n	z	Manner	a	ɛ	Height
13	Léopold	l	r	Place	e	ø	Roundness
14	Noemie	n	l	Manner	o	ø	Place
15	Lalo	l	r	Place	a	ɛ	Height
16	Kalissou	k	g	Voicing	a	ɛ	Height
17	Choubi	ʃ	s	Place	u	y	Place
18	Louann	l	d	Manner	u	y	Place
19	Léo	l	d	Manner	e	ø	Roundness
20	Elliot	l	d	Manner	e	ø	Roundness
21	Tim	t	d	Voicing	i	y	Roundness
22	Edgar	d	t	Voicing	e	ø	Roundness
23	Corentin	k	g	Voicing	o	ø	Place
24	Julie	ʒ	j	Manner	y	u	Place
25	Joséphine	ʒ	z	Place	o	ø	Place
26	Octave	k	g	Voicing	o	ø	Place
27	Estelle	s	z	Voicing	e	ø	Roundness

Note: Information is given for each infant included in the final sample, including infants' name, correct (CP), and mispronounced (MP) consonants and vowels (in International Phonetic Alphabet), and the feature changed from correct to mispronunciation.

TABLE A2 Details of the individual stimuli presented to 8-month-olds in Experiment 1

5-month-olds							
		Consonant			**Vowel**		
	Infant name	**CP**	**MP**	**Feature**	**CP**	**MP**	**Feature**
1	Bérénice	b	p	Voicing	ɛ	œ	Roundness
2	Malcom	m	n	Place	a	ɛ	Height
3	Benoît	b	m	Manner	ø	o	Place
4	Charlie	ʃ	ʒ	Voicing	a	ɛ	Height
5	Maceo	m	b	Manner	a	ɛ	Height
6	Jade	ʒ	z	Place	a	ɛ	Height
7	Silas	s	t	Manner	i	y	Roundness
8	Flora	f	s	Place	o	ø	PLACE
9	Émilie	m	b	Manner	e	ø	Roundness
10	Mia	m	b	Manner	i	y	Roundness
11	Auguste	g	k	Voicing	o	ø	Place
12	Pierre	p	t	Place	i	y	Roundness
13	Milo	m	n	Place	i	e	Height
14	Elisa	l	r	Place	e	ø	Roundness
15	Tristan	t	k	Place	i	y	Roundness
16	Zoé	z	v	Place	o	ø	Place
17	Clément	k	g	Voicing	e	ø	Roundness
18	Corentin	k	g	Voicing	o	ø	Place
19	Chloé	k	g	Voicing	o	ø	Place
20	Capucine	k	g	Voicing	a	ɛ	Height
21	Jules	ʒ	j	Manner	y	u	Place
22	Lucie	l	d	Manner	y	u	Place
23	Nathan	n	l	Manner	a	ɛ	Height
24	Camille	k	g	Voicing	a	ɛ	Height
25	Zélie	z	s	Voicing	e	ø	Roundness
26	Emma	m	b	Manner	e	i	Height
27	Pauline	p	t	Place	ɔ	œ	Place

Note: Information is given for each infant included in the final sample, including infants' name, correct (CP) and mispronounced (MP) consonants and vowels (in International Phonetic Alphabet), and the feature changed from correct to mispronunciation.

APPENDIX B

The section contains the model output for the mixed-effects model reported in Experiment 1.

TABLE B1 Output of the mixed-effects model examining orientation time results in 5- and 8-month-olds (Experiment 1)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	2.76	0.11	140.38	25.79	<.001	***
Age	−0.68	0.11	54	−6.01	<.001	***
Type	−0.13	0.06	377.97	−2.2	.03	*
Order	−0.15	0.03	378	−5.75	<.001	***

Note: Significance codes: $p < .001$ = ***; <.01 = **; <.05 = *; <.1 =+

TABLE B2 Output of the mixed-effects model examining the relationship between acoustic factors and orientation times in 5- and 8-month-olds (Experiment 1)

	Estimate	*SE*	*df*	*t*-value	*p*-value	Sig
(Intercept)	3.29	0.39	56.03	8.37	<.001	***
Age	−0.72	0.11	53.66	−6.63	<.001	***
Vdiff.Spectral	−0.57	0.23	53.66	−2.52	.01	*

Note: Significance codes: $p < .001$ = ***; <.01 = **; <.05 = *; <.1 =+

TABLE B3 Output of the mixed-effects model examining the relationship between lexical factors and orientation times in 8-month-olds (Experiment 1)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	−1.39	1.88	18.01	−0.74	.47	
Typec	−0.03	0.11	18.74	−0.27	.79	
Comp	0.14	0.14	17.96	1.02	.32	
Cprop	2.06	1.77	17.96	1.16	.26	
Vprop	0.92	1.13	17.96	0.81	.43	

TABLE B4 Output of the mixed-effects model examining the relationship between vocabulary growth over the first 2 years of life and the preference for cMPs or vMPs at the time of test for 8-month-olds (Experiment 1)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	−1.85	0.21	82	−8.68	<.001	***
Age	0.12	0.01	82	9.24	<.001	***
OT.diff	0.06	0.07	82	0.84	.4	
Age:OT.diff	0	0	82	−1.02	.31	

Note: Significance codes: $p < .001$ = ***; <.01 = **; <.05 = *; <.1 =+

APPENDIX C

TABLE C1 Details of the individual stimuli presented to 11-month-olds in Experiment 2

5-month-olds							
		Consonant			Vowel		
	Infant name	CP	MP	Feature	CP	MP	Feature
1	Léonie	l	r	Place	e	ø	Roundness
2	Clara	k	g	Voicing	a	ɛ	Height
3	Oceane	s	t	Manner	o	ø	Place
4	Lielle	l	d	Manner	i	y	Roundness
5	Camille	k	t	Place	a	ɛ	Height
6	Thibault	t	d	Voicing	i	y	Roundness
7	Chloé	k	g	Voicing	o	ø	Place
8	Héloïse	l	d	Manner	e	ø	Roundness
9	Emmy	m	n	Place	e	ø	Roundness
10	Phédre	f	v	Voicing	ɛ	œ	Roundness
11	Maëna	m	b	Manner	a	ɛ	Height
12	Émile	m	n	Place	e	ø	Roundness
13	Maël	m	b	Manner	a	ɛ	Height
14	Louise	l	z	Manner	u	y	Place
15	Sienna	s	z	Voicing	i	y	Roundness
16	Adèle	d	b	Place	a	ɛ	Height
17	Héloïse	l	d	Manner	e	ø	Roundness
18	thomas	t	d	Voicing	o	ø	Place
19	Joachim	ʒ	z	Place	o	ø	Place
20	Louise	l	r	Place	u	y	Place
21	Joachim	ʒ	z	Place	o	ø	Place
22	Lou	l	d	Manner	u	y	Place
23	Liv	l	z	Manner	i	e	Height
24	Guillaume	g	k	Voicing	i	y	Height
25	Dimitri	d	t	Voicing	i	e	Height
26	Paul	p	t	Voicing	ɔ	œ	Place
27	Mathilde	m	n	place	a	ɛ	Height

Note: Information is given for each infant included in the final sample, including infants' name, correct (CP) and mispronounced (MP) consonants and vowels (in International Phonetic Alphabet), and the feature changed from correct to mispronunciation.

APPENDIX D

The section contains the model outputs for the mixed-effects models reported in Experiment 2.

TABLE D1 Output of the mixed-effects model examining orientation time results in 11-month-olds (Experiment 2)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	1.64	0.17	30.05	9.5	<.001	***
Type	0.61	0.2	180.21	3.01	<.01	**
Order	0.04	0.06	21.95	0.74	.47	
Type:Order	−0.24	0.07	161.01	−3.3	<.01	**

Note: Significance codes: $p < .001$ = ***; <.01 = **; <.05 = *; <.1 =+

TABLE D2 Output of the mixed-effects model examining the relationship between acoustic factors and orientation times in 11-month-olds (Experiment 2)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	1.3	0.61	30.64	2.12	.04	*
Type	0.02	0.1	44.28	0.25	.81	
Cdiff.Intensity	1.33	0.66	29.49	2	.05	
Vdiff.Intensity	1.15	1.61	29.48	0.71	.48	
Cdiff.Duration	0.35	0.39	29.49	0.89	.38	
Vdiff.Duration	0.12	0.21	29.48	0.56	.58	
Cdiff.Spectral	0.04	0.25	29.6	0.15	.88	
Vdiff.Spectral	0.22	0.21	29.46	1.03	.31	

Note: Significance codes: $p < .001$ = ***; <.01 = **; <.05 = *; <.1 =+

TABLE D3 Output of the mixed-effects model examining the relationship between lexical factors and orientation times in 11-month-olds (Experiment 2)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	4.11	0.97	24.84	4.23	<.001	***
Cprop	−4.02	1.53	24.79	−2.62	<.01	*
Vprop	1.68	0.75	24.79	2.25	.03	*

Note: Significance codes: $p < .001$ = ***; <.01 = **; <.05 = *; <.1 =+

TABLE D4 Output of the mixed-effects model examining the relationship between vocabulary growth over the first 2 years of life and the preference for cMPs or vMPs at the time of test for 11-month-olds (Experiment 2)

	Estimate	*SE*	*df*	*t*-value	*p*-value	sig
(Intercept)	−2.13	0.24	100	−9.01	<.001	***
Age	0.13	0.01	100	9.4	<.001	***
OT.diff	0.12	0.07	100	1.73	.09	.
Age:OT.diff	−0.01	0	100	−2.17	.03	*

Note: Significance codes: p < .001 = ***; <.01 = **; <.05 = *; <0.1 =+