Language development in children from different SES backgrounds

Babbling onset and consonant characteristics

Liesbeth Vanormelingen, Jolien Faes, and Steven Gillis
University of Antwerp

The aim of the study is to analyze prelexical speech development in young children with a different socio-economic status (SES): children from low SES backgrounds (lowSES) are compared with mid-to-high SES (mhSES) children. Timing of the onset of babbling and the consonantal development in consonant-vowel (cv) syllables are investigated. Result show that lowSES children reach the babbling onset milestone significantly later than mhSES children. In addition, they use different consonant types in their cv-syllables: they use more glides, but fewer stops, nasals, fricatives, and liquids. These early differences between children of different backgrounds seem to be in line with the literature on SES differences later on in life.

Keywords: babbling onset, consonant development, socio-economic status

1. Introduction

Well before children start to produce their first words, prelexical utterances already appear in their vocal repertoire. Prelexical utterances are all nonconventional vocalizations in children's vocal output (Stoel-Gammon & Cooper, 1984), excluding vegetative sounds such as burping and sneezing, comfort sounds such as laughing, and distress sounds such as crying. During the first year of life, prelexical utterances become more complex and more mature, with canonical babbles as culminating point of prelexical development (Koopmans-Van Beinum & Van der Stelt, 1986; Nakazima, 1975; Nathani, Ertmer, & Stark, 2006; Oller, 1980, 2000; Stark, 1980). Canonical babbling is defined as the production of a sequence of well-formed consonant-vowel syllables (cv-syllables), that sound adult-like (Oller, 2000). The onset of canonical babbling is a crucial milestone in children's vocal development: it is considered to be a precursor of conventional words.

https://doi.org/10.1075/dujal.19032.van | Published online: 16 October 2020
Dutch Journal of Applied Linguistics 9:1/2 (2020), pp. 132–161. issn 2211-7245 | e-issn 2211-7253

Babbling is a robust phenomenon in children's vocal development and a later onset is considered to be a marker of possible language delay (Lohmander, Holm, Eriksson, & Lieberman, 2017; Oller, Eilers, Neal, & Schwartz, 1999; Oller, Eilers, Neal, & Cobo-Lewis, 1998). There is a consensus that babbling takes off between 6 and 11 months of age in typically developing children (Molemans, Van den Berg, Van Severen, & Gillis, 2012; Oller, 2000; Roug, Landberg, & Lundberg, 1989). In other groups of children, however, a delayed onset of babbling has been observed. For instance, the onset of babbling in children with a hearing impairment is considerably later in comparison with their normally hearing peers (Koopmans-Van Beinum, Clement, & Van den Dikkenberg-Pot, 2001; Oller & Eilers, 1988; Oller, Eilers, Bull, & Carney, 1985), even if they received a cochlear implant early in life (Molemans, 2011). Children with Down syndrome also show a later onset of babbling than typically developing children (Lynch et al., 1995). Also, in other developmental disorders, autism spectrum disorder, Rett syndrome, and fragile X syndrome, there is a delayed onset of canonical babbling (Lang et al., 2019). Thus, there is a fairly limited time window in which most children start babbling, though particular groups exhibit (extensive) delays in the onset of babbling.

Canonical babbles contain high frequencies of stops, nasals and glides (e.g. Locke, 1980, 1983; Stoel-Gammon & Cooper, 1984; Vihman, Macken, Miller, Simmons, & Miller, 1985). Even though these manners of articulation are found in high frequencies across languages, evidence suggests that the ambient language influences children's babbled sounds (MacNeilage & Davis, 2000; MacNeilage, Davis, Kinney, & Matyear, 2000; Thevenin, Eilers, Oller, & Lavaoie, 1985). For instance, Brown (1958) showed that children's babbling approaches the ambient adult language over time. Similarly, De Boysson-Bardies and Vihman (1991) showed that the sound patterns of the ambient language are reflected in children's babbles. Velleman and Vihman (2002) showed that these ambient language effects appear also in first word productions, pointing to continuity between the sounds in babbling and in first words. Babbling predicts first words in children (McGillion et al., 2017). Various aspects have been shown to be influenced babbling. For instance in terms of phonemic context, both children's babbles and first word productions contain high frequencies of stops, nasals and glides (e.g.; Locke, 1989; Stoel-Gammon, 1998, Van Severen, 2012). But also the timing of babbling is predictive. For instance Keren-Portnoy, Majorano, and Vihman (2009) showed that children who produced fewer typical canonical babbling consonant-vowel occurrences also had a later onset of meaningful words.

In other words, children learn the statistically frequent patterns in the input language from a very young age onwards (e.g. Johnson & Siedl, 2009; Swingley, 2005; Werker & Tees, 1984). Detailed analyses of these continuity patterns have revealed that individual differences in babbling are reflected into individual differences in word use (e.g. Elbers & Ton, 1985; Keren-Portnoy et al., 2009; Vihman, 2019). So, there is a close relationship between babbles, first words and the input language, that is shown even at the individual level of the child. Moreover, there is increasing evidence that babbling complexity can even be a diagnostic marker for speech and language development later on (e.g. Fasolo, Majorano, & D'Odorico, 2008; Stoel-Gammon, 1992).

2. The role of SES in language development

Despite the interindividual variation, there are some factors that appear to affect language development, and the timing of the onset of babbling, in a more general way. Child-related factors include for instance hearing impairment or the presence of particular symptoms, such as Down, as noted in the previous section. These factors are related to a later onset of babbling, but also to other delays in language development (e.g. Faes, Gillis, & Gillis (2016) for children with cochlear implants' speech accuracy). Another factor that is often linked to slower or even delayed language development is socio-economic status (SES).

It has been shown that there are striking differences in the language environment of children with different SES backgrounds (e.g. Hart & Risley, 1995; Vanormelingen & Gillis, 2016). The language environment of children from lower SES backgrounds (lowSES) is much poorer than that of children from mid-to-high SES backgrounds (mhSES), as became evident as what is now generally known as the "30 million word gap" (Hart & Risley, 2003, i.e. lowSES children hear 30 million fewer words by age four, counted cumulatively over four-year-old's lifetime). Vanormelingen and Gillis (2016) showed that not only the quantity but also the quality of child-directed speech (e.g., the incidence of parental contingent speech) was poorer for children in lowSES environments as compared to children in mhSES environments. Since the amount and quality of input is closely related to children's own language development (Goldstein, King, & West, 2003; Goldstein & Schwade, 2008; Hart & Risley, 1995; Hirsh-Pasek et al., 2015; Hoff & Naigles, 2002; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Rowe, 2018; Weisleder & Fernald, 2013), it may not be surprising that significant differences between children of different SES backgrounds have been found in several linguistic domains, including vocabulary and grammar (for a review, see e.g. Hoff, 2003; Rowe, 2018).

The amount of speech and the diversity of the input predict children's own receptive and expressive vocabulary size at later ages (Hoff, 2003; Hoff-Ginsberg, 1998; Huttenlocher et al., 1991; Pan, Rowe, Singer, & Snow, 2005; Rowe, 2008, 2018). In addition, children with more talkative caregivers acquire new words faster (Huttenlocher et al., 1991). In other words, the richer the input, the better later lexical outcomes. Also, children of mhSES backgrounds produce more complex utterances and use a greater variety of syntactic structures in spontaneous interactions than children from lowSES backgrounds (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010). Moreover, two-year old lowSES children have smaller expressive vocabularies than their mhSES peers (Weisleder & Fernald, 2013). In other words, already by the age of two, lowSES children produce considerably fewer distinct words than their mhSES peers. Fernald, Marchman and Weisleder (2013) also showed that there are already significant differences in vocabulary and language processing efficiency of mhSES and lowSES children at the age of one and a half. And, by the age of two, there was a 6-month gap between SES groups in processing skills that are critical in language development (Fernald et al., 2013).

This gap between children of lowSES and mhSES backgrounds has been traced to a much earlier point in life. In an investigation of foundational preverbal skills and behaviors necessary for emerging communication, including gestures, vocalizations, sound perception and recognition, Betancourt, Brodsky and Hurt (2015) found differences between lowSES and mhSES girls at 7 months of age. In a similar vein, Wild, Betancourt, Brodsky and Hurt (2013) suggest that the effect of SES on expressive and receptive language of preterm infants (i.e. their ability to communicate with words and gestures and their ability to comprehend and respond appropriately to words and requests) appears already earlier in life than previously reported (i.e. from word use onwards, e.g. Hoff, 2003).

3. SES and babbling

Given these early SES related differences, we expect to find differences attributable to SES as well for a specific vocal milestone, viz. the onset of canonical babbling. However, children of somewhat lower SES backgrounds apparently do not babble substantially and significantly later than their peers with an mhSES background (Eilers et al., 1993; Oller, Eilers, Basinger, Steffens, & Urbano, 1995; Oller, Eilers, Steffens, Lynch, & Urbano, 1994). But, the results of these studies were based on parental reporting (checked by a researcher or clinician), without any quantification of the babbled productions (Eilers et al., 1993; Oller et al., 1995). Oller et al. (1994) proposed a more stringent approach by computing the canonical babbling ratio (CBR – for a definition, see section *the present study).* Even though still no differences between lowSES and mhSES children were reported, Oller et al. (1994, p. 33) observed that there was a "reliably lower tendency to vocalize" in lowSES children. However, such differences in sample size are problematic in establishing quantitative thresholds such as in CBR (Molemans, Van den Berg, Van Severen, & Gillis, 2012; Tomasello & Stahl, 2004). Thus, the literature seems to suggest that are no differences in canonical babbling onset between lowSES and mhSES children.

But, there seem to be some methodological issues in the literature that make this conclusion at least premature. In addition, the fact that at two years of age significant differences in spoken language development (lexicon and grammar) and a substantial delay in language processing are found (Hoff, 2013; Weisleder & Fernald, 2013), suggests that this delay may already be building up much earlier in life. And indeed, the results of Betancourt et al. (2015) and Wild et al. (2013) are indicative in this respect. Findings about the relationship between input and output regarding quantity and phonological development during the prelexical stage seem to support this hypothesis. Both Oller et al. (1994) and Vanormelingen (2016) observed that lowSES children are less voluble (i.e. talkative) during the prelexical stage as compared to mhSES children. Vanormelingen (2016) clearly showed that these children also have parents who are less voluble and thus receive less input. So, regarding quantity, there seems to be a relation between the impoverished input and children's own output very early on in life (Albert, Schwade, & Goldstein, 2018; Vanormelingen, 2016).

Regarding quality of input, mhSES children who receive more contingent responses to their own vocalizations during the prelexical stage show advantages in phonological learning during this stage (Goldstein et al., 2003; Goldstein & Schwade, 2008). Moreover, Vanormelingen, De Maeyer, and Gillis (2016) showed conversational differences between lowSES and mhSES children: lowSES children receive less contingent feedback to their speech: parents respond less to their speech, and if they do, they respond less informatively since they often reproduce the child's production without adding extra information (e.g. the child utters 'car': lowSES parents more often react with 'car' whereas mhSES parents would add information, such as 'the red car').

Taken together, it seems odd that an effect of poorer input in lowSES children (both quantitatively and qualitatively) would not be apparent for an important milestone in children's early vocal development, viz. the onset of babbling. In the present study, we will analyze the babbling onset of lowSES children whose input was studied by Vanormelingen (2016) and Vanormelingen and Gillis (2016).

4. The present study

The aim of the current paper is to (1) establish the age at which children who differ in SES reach their babbling onsets, and to (2) examine the consonantal repertoire in these children's canonical syllables.

Babbling onset will be determined using the quantitative measures canonical babbling ratio (CBR^{syl}) and true canonical babbling ratio ($tCBR^{syl}$) (Oller et al., 1994), in a bootstrapping procedure (Molemans et al., 2012). The difference between CBR^{syl} and $tCBR^{syl}$ is that CBR^{syl} calculates the proportion of all non-glottal consonant-vowel sequences (Oller & Eilers, 1988). For the true canonical babbling ratio ($tCBR^{syl}$) not only glottal consonants (such as [h] and glottal stops) are disregarded, but also glides ([w], [j]) (Chapman, Hardin-Jones, Schulte, & Halter, 2001; Stoel-Gammon, 1989). Glides are considered to have a rather "special" status as consonants. For instance, Stoel-Gammon (1989) states that glides are qualitatively different when compared to other consonants and considers them as non-true consonants. Moreover, glides are the most sonorous consonant type, approaching characteristics of vowels, and are hence on the border between consonants and vowels (Booij, 1995). Therefore glides are excluded in the calculation of $tCBR^{syl}$. This means that an utterance like [wawawa] contains three syllables for the CBR^{syl} measure, but none using the $tCBR^{syl}$ measure.

The distinction between CBR^{syl} and $tCBR^{syl}$ clearly highlights the importance of the types of consonants encountered in children's babbling. Moreover, feedback on children's vocalizations (input) shapes phonological learning in children (Goldstein et al., 2003; Goldstein & Schwade, 2008). Since many studies have shown a poorer quantitative and qualitative input in children of lower SES backgrounds – also the children in the present study (Vanormelingen & Gillis, 2016), it may very well be that also the incidence of consonantal types differs in lowSES and mhSES children's babbling. This is the second research aim of the present study.

5. Method

5.1 Participants

The participants in this study consisted of two groups of children: (1) 30 children from a mid-to-high socio-economic background (mhSES), and (2) 9 children from a low socio-economic background (lowSES). The selection criteria for all participating families were identical, except for their SES backgrounds. Children had to come from native Flemish, monolingual, native Dutch-speaking backgrounds, living in Flanders (the northern part of Belgium). None of the children had a hearing impairment or developmental problems, as attested by the Flemish infant welfare center *Kind&Gezin*.

The socio-economic status (SES) of the participating families was determined by the Hollingshead Index (HI) (Hollingshead, 1975), with possible scores ranging from 8 for individuals with the lowest SES to 66 for individuals with the highest SES. HI is a widely used measure of SES, also used in studies on language development, e.g. Fernald et al. (2013); Fish & Pinkerman (2003); Jednoróg et al. (2012); Sarsour et al. (2011); Richels, Johnson, Walden, and Gonture (2013). SES is defined in terms of education and occupation levels. A score for both parents (if applicable) was determined and the mean score was calculated thereof. For the lowSES families, the mean family status score was 18 ($SD=5$), suggesting that our sample of lowSES families represents the lower strata of the lowSES class. By way of comparison, Fernald et al. (2013) categorized all families with a score below 45 as low SES. Hollingshead (1975) defined five different 'strata' of SES and social standing. Our lowSES sample fits in the lowest of these strata, with a score up to 19 on the HI. The mean family score of the mhSES families was 52 ($SD=11$) and 80% of the mhSES families had scores that fitted them into the two upper strata of the HI (Hollingshead, 1975).

The parents in the lowSES families involved in the present study had no higher educational background and finished secondary school at best. The family had an income around the minimum wage or lived from a social security allowance. Concerning the job positions, less than half of the parents (44%) had a job (mostly halftime), 34% was unemployed and the others did not mention their current job position, suggesting that the were not working at the time of data collection. In mhSES families, all parents had a stable income from a full-time job. They all finished at least secondary school and in 84% of the families at least one parent had a bachelor, master or PhD degree.

5.2 Data collection

Data collection consisted of monthly video-recordings of spontaneous interactions between the child and the primary caregiver(s), and possibly other siblings, at the child's home. These interactions were unstructured, since the parents were simply asked to "play with their children as they normally do". All parents signed an informed written consent for participation in the study and the study was approved by the Ethical Committee for the Social Sciences and the Humanities of the University of Antwerp.

Children from mhSES backgrounds

The data of the mhSES families came from the CLiPS Child Language Corpus which was collected as part of a larger research project on language development in this group (Molemans, 2011; Van Severen, 2012; Van den Berg, 2012). 30 children from mhSES families were followed monthly between 6 and 24 months of age. The recordings lasted between 80 and 120 minute. In order to keep transcription time within reasonable limits (about 14 hours for each video-recording) a 20-minute selection was made for each video recording. These selections only consisted of finished interactions and for instance long pauses and very noisy passages were excluded from the data. For more detailed information on this procedure, see Molemans (2011), Van Severen (2012) and Van den Berg (2012). All families participated at every monthly recording (18 recordings for each family). The mean age at which the first word appeared in the 20-minute selection was 13 months (range 10 – 17 months). The mean age at which children reached the onset of word production in the 20-minute selection, defined as the age at which they had produced 10 different words, was 15.77 months (range 13–19 months).

Children from lowSES backgrounds

9 children from lowSES families were followed between 6 and 23 months of age, as part of a larger research project on child-directed speech and language development in this group. The collection of the lowSES corpus proved to be very difficult. Finding indigenous lowSES families who were willing to participate on a monthly basis and to have their daily routines filmed was much more difficult than the collection of the mhSES corpus. Therefore, families were given a small incentive (gift vouchers of 7.5 euros per session) for their participation in the study. In addition, a collaboration was initiated with the department of Social Work and Social Care of the Karel de Grote College (Antwerp). An instructor who was highly familiar with the population and with social welfare initiatives directed at lowSES families was engaged on a part-time basis by the university for establishing and maintaining contact with the lowSES families and for making the video recording for the present study. She recruited the participants through her network, which includes organizations like *Moeders voor Moeders ("Mothers for Mothers")* directed specifically at practically helping mothers from lowSES raising their children.

Given the difficult data collection, fewer data were available for the children from lowSES families. The number of recordings also differed between the families. The mean number of recordings per family was 6.89 ($SD=2.98$, median = 8). One family participated only once, another family four times. The other 7 families participated at least 6 times. In Table 1, the number of recordings and the age ranges are given per participant. The video-recordings lasted on average 45 minutes and 18 second (range = 33 minutes and 57 seconds – one hour, 13 minutes and 26 seconds). Since we had fewer data for the lowSES group as compared to the mhSES group, no data selection was performed for this group.

Table 1. Characteristics of the lowSES children

ID	Number of recordings	Age range (months)	Birth order	Total number of utterances (Mean per recording; SD)	Mean number of utterances per minute (range)	Mean number of canonical babbles per minute (range)	Age at first word production (months)
P1	8	9–17	3	881 (110.13; 77.93)	2.44 (0.64–5.79)	0.69 (0.02–2.34)	16
P2	1	11	1	61 (61.00; 0.00)	1.33 (N.A.)	0.31 (N.A.)	Not observed
P3	9	3–13	2	405 (45.00; 31.26)	1.20 (0.48–2.21)	0.33 (0.09–0.75)	Not observed
P4	6	6–12	1	430 (71.67; 56.95)	1.66 (0.78–4.69)	0.54 (0.14–1.58)	Not observed
P5	6	9–16	5	698 (116.33; 67.30)	2.44 (1.13–4.24)	0.80 (0.42–1.49)	12
P6	4	7–12	1	874 (218.50; 35.35)	4.70 (3.49–5.56)	1.77 (1.10–2.25)	12
P7	8	13–23	6	917 (114.63; 69.21)	2.58 (1.03–7.14)	0.84 (0.25–1.83)	20
P8	10	5–15	1	1949 (194.90; 74.40)	4.66 (2.05–6.84)	1.78 (0.39–3.57)	13
P9	10	8–18	3	1632 (163.2; 64.80)	4.72 (1.74–11.42)	1.84 (0.35–8.75)	13

Even though data collection was difficult for the lowSES families, the lowSES families in this study represent a unique sample in SES research. In the literature, SES differences are mostly studied in an Anglo-Saxon context (e.g. the US) and the lowSES families are mostly a very heterogeneous group with different ethnic backgrounds (e.g. Hart & Risley, 1992, 1995, 1999; Rowe, 2008; Song, Spier, & Tamis-LeMonda, 2014). This brings in cultural differences, which may influence results linked to SES (Song et al., 2014). Moreover, it is possible that many of the parents of such lowSES families are second language learners of the language investigated in the children. The lowSES sample analyzed here consists of native Flemish lowSES families, with all parents being native Dutch. Next to the fact that we have a quite homogenous group, our sample of lowSES families has two other assets that complement the existing literature thus far. First, our corpus is longitudinal, comprising monthly video-recordings over a longer period for all but one child. Secondly, the lowSES data consist of spontaneous speech interactions between child and caregiver(s), whereas the literature often relies on parental reports (Eilers et al., 1993; Oller et al., 1995; Oller et al., 1994).

As can be derived from Table 1, not all children produced their first word during the period of data collection. Within the lowSES sample, word use was actually rare. P1 had the most developed lexicon and used 40 words tokens in total (but only 4 different ones, i.e. word types) in the video recording at 16 months of age. The production of a first word was not observed during the data collection of P2 (at 11 months of age), P3 (by 13 months of age) and P4 (by 12 months of age). Two children produced their first word at 12 months of age: P5 (one word, also one word at 13 months of age) and P6 (3 times the same word). P7 produced one word at 20 months of age (two times) and two different words 11 times at 21 months of age. Finally, P8 and P9 produced one word at 13 months of age. P8 showed a slight increase in word use and produced nine words (but only four different ones) by 15 months of age. P9, however, did not produce any word at the older ages anymore (15–18 months). In contrast to the mhSES children, none of the lowSES children has produced 10 different words during the entire data collection. This is striking since the results on word onset were based on the full recordings for the lowSES children, that were twice as long as the 20-minute selections for the mhSES children.

5.3 Data transcription

All video-recordings were transcribed in CLAN following the CHAT conventions (MacWhinney, 2000). Each utterance was delineated and the speaker was labeled. All linguistic utterances of the child were further transcribed. A complete phonemic transcription of lexical utterances (words), as produced by the child, was made. Prelexical utterances were transcribed following the coding scheme of Koopmans-Van Beinum and Van der Stelt (1986). Following this coding system, each prelexical utterance (i.e. breath unit) received a two-digit code that represents the structure for phonation and articulation. Phonation could be absent (code 0), uninterrupted (code U) of interrupted (code I), and articulation could consist of no articulatory movements (code 0), one movement (code 1) or two or more articulatory movements (code 2). Canonical babbling was defined as codes U2 and I2, representing prelexical utterances, either interrupted or uninterrupted, with at least 2 articulatory movements, i.e. at least a sequence of two consonant-vowel (cv) syllables. For each prelexical utterance, each consonant-like production was further coded for manner of articulation (stop, fricative, nasal, liquid or glide).

The reliability of the transcriptions was checked for both the mhSES corpus as well as the lowSES corpus. The first author retranscribed about 80% of the lowSES corpus after at least 3 months. The mean percentage of overlap for manner of articulation was 79% (range 74%–86%). For the mhSES corpus, 10% was retranscribed by the transcriber after a couple of months (Molemans, 2011; Van Severen, 2012; Van den Berg, 2012). The mean percentage of agreement for manner of articulation was 79.41% (range 73.53–86.28). The agreement on the coding scheme of Koopmans-Van Beinum and Van der Stelt (1986) equaled 80.17% (range 78.10%–82.10%).

5.4 Data analyses and statistical analyses

The aim of the present paper is twofold: first, examine and compare the onset of babbling in mhSES and lowSES children, and second, examine and compare the incidence of consonantal types in both groups of children's cv-syllables.

Onset of babbling

For children's babbling onset, two measures were used: CBR^{syl} (including glides as consonants) and $tCBR^{syl}$ (excluding glides as consonants). The onset of babbling was reached if the child surpassed a threshold of 0.15 for $(t)CBR^{syl}$ (Oller et al., 1994). Different sample sizes are problematic in establishing quantitative thresholds such as CBR^{syl} (Tomasello & Stahl, 2004). Moreover, Molemans et al. (2012) showed that CBR^{syl} is critically dependent on children's volubility, and thus sample size. Since the amount of data differed between the two corpora (mhSES and lowSES), a bootstrapping procedure was implemented. By bootstrapping, the results are normalized in such a way that for each child, an equal amount of data was taken. In addition, other (within-)group differences, such as the presence or absence of siblings during video-recordings, are leveled out. We followed the bootstrapping procedure implemented by Molemans et al. (2012) (also referred to as Monte Carlo simulation, Tomasello & Stahl, 2004) with random resampling in order to reliably (95% confidence) determine the onset of babbling. This procedure consists of randomly selecting 1,000 samples of 25 syllables, then computing (t)CBR^{syl} for each sample, and finally determining if (t)CBR^{syl} exceeds the threshold in 950 or more of the samples. This procedure establishes babbling onset with 95% confidence.

One lowSES child (P2) had not reached onset of babbling at the last recording and was excluded from the analyses. The parents of this child ceased their participation after only one recording. At this data point, at 11 months of age, the child did not produce enough canonical babbles (mean of 0.03 across the 1,000 samples) to reach the threshold for babbling onset. Therefore, she was excluded from the analyses. Furthermore, three data points of lowSES children, i.e. monthly recordings, were excluded because the child did not produce the minimally required 25 syllables. These were 2 data points of the same child and one data point of another.

Statistical analyses were performed in order to compare the onset of babbling in both groups of children. This was done in JMP® Pro 14.3, using a Wilcoxon signed rank test.

Incidence of consonantal types

For the analyses of the incidence of consonantal types in children's canonical babbles, all consonants in those canonical babbled utterances were coded in terms of manner of articulation, identifying the main phonemic distinctions of standard Dutch consonants (Booij, 1995). The frequency counts of the different manners of articulation were bootstrapped. For each child at each age, 1,000 random samples were taken per consonant manner using JMP® Pro 14.3. The estimated frequencies of the different consonant types were further normalized by calculating the standard scores for each child at each age. So, z-scores were calculated on the bootstrapped frequencies in order to normalize the data.

Statistical analyses for the incidence of consonant types were also performed in JMP® Pro 14.3, using a multilevel model (Baayen, 2008; Bates, Maechler, Bolker, & Walker, 2015). Multilevel modeling was suited here, since the dataset for this part shows a hierarchical structure: observations (first level) are nested in ages (second level), which in turn are nested in children (third level). Multilevel modeling can handle such nested datasets (Hox, 2008; Quené & Van den Bergh, 2004). Multilevel models consist of two parts: a random part and a fixed part. In the random part, the variance between ages and children is taken into account. The fixed part comprises the predicting variables. The predicting variables were SES (mhSES versus lowSES), Age (in months) and Age^2 (in months) and the interaction between Age and SES and Age^2 and SES.

6. Results

6.1 Babbling onset

On average, lowSES children reach the CBR^{syl} milestone at around 0;10 (median = 0;10, range = 0;6–1;1) and the tCBR^{syl} milestone at around 0;11 (median = 0;10, range = 0;9–1;3). The mhSES children reach the CBR^{syl} milestone on average 3.37 months earlier (mean = 0;6.19; median = 0;6.15, range = 0;6–0;9), and the tCBR^{syl} on average 3.73 months earlier (mean = 0;7.7, median = 0;7, range = 0;6–0;10). Statistical analyses reveal a significant difference between the two groups of children as to the age at which the CBR^{syl} milestone (Wilcoxon rank sum test: $z = 3.33$, $p = 0.0009$) and the tCBR^{syl} milestone are reached (Wilcoxon rank sum test: $z = 4.09$, $p = < 0.0001$). In other words, mhSES children reach the CBR^{syl} and tCBR^{syl} significantly earlier than lowSES children. In Figure 1 boxplots for CBR^{syl} and tCBR^{syl} are shown for both groups of children respectively.

Since the later onset of the recordings in some of the lowSES participants could have biased the results, an extra analysis was performed with only the children of the lowSES sample that could have established the babbling onset within the range of the children of the mhSES sample (CBR^{syl} and tCBR^{syl} with P3, P4, P6, P8 and P9 for the lowSES sample). However, this additional analysis pointed to the robustness of the results: also in these analyses children of lowSES families reach the babbling onset (CBR^{syl} and tCBR^{syl}) significantly later than children of mhSES families.

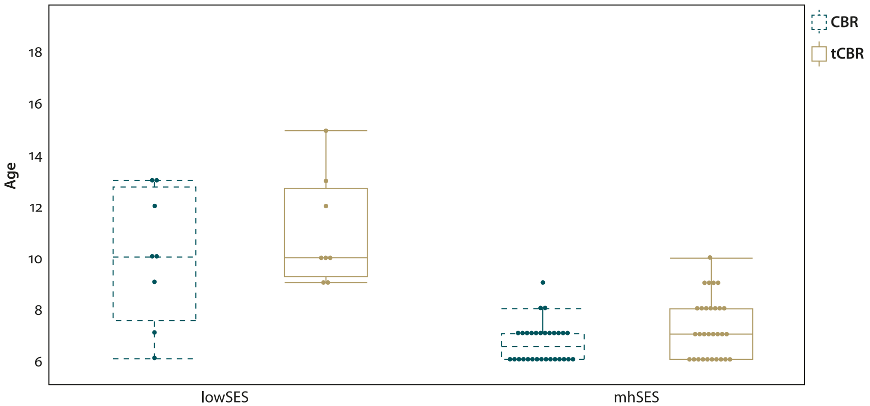

Figure 1. Boxplot of the age of onset of babbling as measured by CBR^{syl} and tCBR^{syl} in lowSES and mhSES children

6.2 Incidence of consonant types

Descriptive results

Table 2 represents the distribution of the different manners of articulation in lowSES children and mhSES children. Results present the mean per consonant type and a range over the children in the two SES groups. Means and ranges are shown per month.

Results show clear differences between both groups of children, especially with respect to the distribution of stops, glides and /h/. When considering stops, the percentages in Table 2 indicate that lowSES children use fewer stops than mhSES children in their canonical babbles. Over the entire age range, the percentage of stops in the lowSES group is often even only less than half the percentage of stops used by mhSES children. This difference in stops is largely explained by the high use of glides by lowSES children. The use of glides diminishes from mean percentages of approximately 30% initially to mean percentages of approximately 10% at the end of data collection. At all age points, the percentage of glide use is higher in lowSES children than in mhSES children. When considering the ranges, it is obvious that some lowSES children use glides very frequently. For instance at 8 months of age, one child uses exclusively glides (100%), and at 17 months of age, one lowSES child uses 86% glides (in comparison to a maximum of 42% in mhSES children).

So, lowSES children seem to use less stops and more glides as compared to mhSES children. When summing the percentages of stops and glides, the percentages of use often approximate each other in both groups of children. If not, this is explained by the high frequency of use of /h/ in lowSES children: whereas /h/ is nearly absent in mhSES children (maximum mean percentage of 2.80%), /h/ represents at least 10%, but often more, of the lowSES children's use of consonants.

Overall, fricatives and liquids appear less often. Nevertheless, there are slight differences between both groups of children as well. LowSES children use fewer fricatives (means do no pass 2% in the entire age range) as compared to children with mhSES (means surpass 5%). From 17 months of age onwards, fricatives are even absent or nearly absent in the canonical babbles of lowSES children. In contrast, mhSES children seem to slightly increase their fricative use in canonical babbles: from 17 months onwards mean percentages increase to 10% and more. For liquids, a similar pattern is observed: they are infrequent in both groups of children, but even more rare in lowSES children (highest mean percentage of 1.2%) than in mhSES children (highest mean percentage of 8.%). In addition, whereas liquids are absent from 16 months of age onwards in lowSES children, there is a sight increase of liquid use by mhSES children.

For nasals, lowSES children increase their use over time, with mean percentages of approximately 5% initially to mean percentages above 20% and even of 30% at the end of the data collection. For mhSES children, the use of nasals seems to decrease only slightly during the studied period, from mean percentages of approximately 15% initially to mean percentages of approximately 10% over time.

Statistical analyses

The results of the multilevel model analysis are presented in Table 3. The fixed effect results for the incidence of consonant types (manners) are presented (estimated z-scores). In Figures 2–7, the estimated z-scores are plotted for each consonant type.

Clear SES differences with respect to the use of the different manners of articulation are apparent. LowSES children use significantly fewer stops, fricatives and liquids ($p < 0.001$, $p < 0.001$ and $p < 0.001$) and use significantly more glides and the glottal /h/ ($p < 0.01$ and $p < 0.001$). For nasals, no significant difference was found ($p = 0.088$). These findings indicate that lowSES children produce fewer true consonants (stops, nasals, fricatives and liquids) than the mhSES children, but more glides and /h/.

Table 3 shows that there are no significant age effects for fricatives, nasals, liquids and glides for mhSES children ($p > 0.05$ for Age and Age^2) nor for lowSES children ($p > 0.05$ for the interaction effects between SES and Age and SES and Age^2). In other words, the differences that were found between the two groups of children remain stable over the entire studied period. Between 6 and 24 months of age, lowSES children use significantly fewer fricatives and liquids than mhSES children and significantly more glides than mhSES children. These effect are plotted in Figures 4, 5, 6 and 7.

For stops, there is a significant (quadratic) effect of age ($p < 0.001$ for Age and for Age^2) as illustrated in Figure 2. As can be seen in Figure 2 and Table 3, there is no significant interaction effect between SES and Age (nor SES and Age^2), indicating that the difference between both groups of children remains similar at all ages.

Finally, for /h/, there was a significant effect of Age ($p < 0.05$), indicating a decrease of /h/ use in mhSES children. The significant interaction effects of SES and Age and Age^2 show a larger decreasing effect in use of /h/ in lowSES children, as illustrated in Figure 3.

Table 2. The mean percentage (and range) of consonant manners per age per SES group

Age in months	Corpus	Stops	Fricatives	Nasals	Liquids	Glides	H
		Mean (range)	Mean (range)	Mean (range)	Mean (range)	Mean (range)	Mean (range)
6	lowSES	13.1 (0–35)	1.4 (0–4)	4.3 (0–13)	1.2 (0–3)	30.0 (0–47)	50.1 (2–100)
6	mhSES	28.5 (0–75)	10.2 (0–50)	17.7 (0–50)	8.4 (0–29)	34.4 (4–78)	0.8 (0–7)
7	lowSES	6.4 (0–11)	0.0 (0–0)	5.6 (0–22)	0 (0–0)	50.8 (34–85)	37.2 (11–60)
7	mhSES	37.5 (5–81)	7.0 (0–38)	12.1 (0–44)	7.4 (0–44)	35.1 (4–92)	0.9 (0–8)
8	lowSES	2.5 (0–10)	0.4 (0–2)	4.4 (0–14)	0 (0–0)	53.4 (29–100)	39.3 (0–57)
8	mhSES	46.5 (12–81)	4.5 (0–25)	15.3 (0–65)	5.7 (0–33)	25.4 (0–73)	2.6 (0–18)
9	lowSES	28.9 (0–74)	0.5 (0–3)	3 (0–10)	1 (0–4)	35.1 (6–80)	31.5 (4–64)
9	mhSES	51 (7–80)	6.2 (0–27)	16.1 (0–82)	2.4 (0–9)	21.9 (0–64)	2.4 (0–25)
10	lowSES	43.5 (0–92)	0.4 (0–1)	3 (0–18)	0.6 (0–4)	30.0 (3–50)	22.5 (2–60)
10	mhSES	49.4 (11–91)	7.4 (0–33)	16.1 (0–85)	3.3 (0–21)	21.5 (0–66)	2.3 (0–9)
11	lowSES	26.5 (0–53)	0.0 (0–0)	6.3 (0–14)	0 (0–0)	44.9 (33–77)	22.3 (8–57)
11	mhSES	51.9 (14–84)	4.3 (0–11)	10.7 (1–40)	2.8 (0–10)	27.5 (5–73)	2.8 (0–12)
12	lowSES	34.1 (4–62)	0.9 (0–3)	14.7 (0–50)	0.2 (0–1)	38.2 (21–62)	11.9 (1–18)
12	mhSES	53.2 (23–87)	8.6 (0–27)	11.2 (0–42)	3.4 (0–21)	21.2 (3–68)	2.4 (0–12)
13	lowSES	42.1 (18–68)	1.1 (0–2)	20.9 (1–50)	0.5 (0–3)	18.6 (14–23)	16.8 (6–43)
13	mhSES	62.7 (22–99)	8.4 (0–27)	8.7 (0–32)	4.9 (0–59)	12.9 (0–36)	2.4 (0–14)
14	lowSES	18.1 (0–27)	1.8 (0–5)	2.7 (0–8)	0 (0–0)	34.6 (27–43)	42.8 (16–67)
14	mhSES	58.4 (26–84)	10.8 (1–31)	9.9 (0–49)	6.4 (0–46)	12.7 (2–30)	1.8 (0–9)
15	lowSES	45 (11–67)	1.9 (0–6)	5.8 (0–11)	0.5 (0–1)	33.6 (14–78)	13.3 (0–31)
15	mhSES	53.7 (26–82)	9.2 (0–34)	14 (1–68)	5.1 (0–28)	16.1 (5–52)	1.9 (0–9)
16	lowSES	33.8 (0–53)	1.4 (0–6)	22.5 (1–67)	0 (0–0)	22.3 (16–30)	20 (9–47)
16	mhSES	58.2 (29–82)	9.1 (0–29)	9.9 (0–30)	3.6 (0–12)	17.8 (0–49)	1.4 (0–8)
17	lowSES	18 (12–24)	0.0 (0–0)	26.5 (1–52)	0 (0–0)	54.0 (22–86)	1.5 (1–2)
17	mhSES	61.1 (34–92)	10.7 (0–23)	9.3 (1–30)	2.6 (0–20)	15.4 (1–42)	0.8 (0–8)
18	lowSES	45.6 (43–49)	0.0 (0–0)	20.2 (8–32)	0 (0–0)	17.8 (11–25)	16.4 (8–25)
18	mhSES	56.7 (17–93)	11.5 (0–28)	13.8 (0–46)	3.1 (0–16)	14.4 (3–47)	0.5 (0–3)
19	lowSES	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
19	mhSES	51.3 (25–77)	11.2 (1–30)	14.5 (0–41)	3.9 (0–26)	17.9 (6–67)	1.1 (0–6)
20	lowSES	33.3 (33–33)	1.4 (1–1)	13.9 (14–14)	0 (0–0)	33.3 (33–33)	18.1 (18–18)
20	mhSES	56.7 (28–82)	9.2 (0–25)	13.6 (0–44)	4.6 (0–22)	14.8 (1–28)	1 (0–5)
21	lowSES	36.8 (37–37)	0 (0–0)	33.3 (33–33)	0 (0–0)	19.3 (19–19)	10.5 (11–11)
21	mhSES	50.8 (29–71)	11.7 (2–26)	14 (0–31)	6.4 (0–18)	16.3 (5–39)	0.7 (0–4)
22	lowSES	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

Table 2. *(continued)*

Age in months	Corpus	Stops	Fricatives	Nasals	Liquids	Glides	H
		Mean (range)	Mean (range)	Mean (range)	Mean (range)	Mean (range)	Mean (range)
22	mhSES	54.8 (23–88)	12.6 (2–45)	12.4 (0–32)	6.3 (0–23)	13.4 (1–28)	0.6 (0–4)
23	lowSES	44.4 (44–44)	0 (0–0)	33.3 (33–33)	0 (0–0)	11.1 (11–11)	11.1 (11–11)
23	mhSES	54.8 (27–90)	12.9 (0–27)	13.8 (1–31)	7.1 (0–21)	10.9 (3–23)	0.5 (0–3)
24	lowSES	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
24	mhSES	52.5 (33–75)	13.4 (3–24)	15.8 (4–27)	5.8 (0–16)	11.6 (0–31)	1 (0–6)

N.A. = No data available
Numbers are presented in percentages

Table 3. Parameter estimates for consonant distribution

	Stops	Fricatives	Nasals	Liquids	Glides	/h/
	Estimate (SE)	*Estimate (SE)*	*Estimate (SE)*	*Estimate (SE)*	*Estimate (SE)*	*Estimate (SE)*
Intercept	−1.10 *** (0.36)	−0.48 * (0.23)	−0.17 (0.36)	−0.35 (0.20)	1.49 *** (0.38)	0.49 * (0.21)
Age	0.28 *** (0.06)	−0.01 (0.04)	−0.05 (0.06)	−0.04 (0.03)	−0.10 (0.06)	−0.07 * (0.03)
Age²	−0.01 *** (0.01)	< 0.01 (0.03)	< 0.01 (< 0.01)	< 0.01 (< 0.01)	< 0.01 (< 0.01)	< 0.01 (< 0.01)
SES (lowSES)	−0.41 *** (0.06)	−0.22 *** (0.04)	0.13 (0.07)	−0.13 *** (0.04)	0.23 ** (0.08)	0.38 *** (0.05)
Age x SES (lowSES)	0.06 (0.06)	< −0.01 (< 0.01)	0.03 (0.06)	0.01 (< 0.01)	0.04 (0.06)	−0.12 *** (0.03)
Age² x SES (lowSES)	< −0.01 (< 0.01)	< −0.01 (< 0.01)	< 0.01 (< 0.01)	< −0.01 (< 0.01)	< −0.01 (< 0.01)	< 0.01 * (< 0.01)

Estimates and SE are expressed in z-scores, SE = standard error
The intercept is set for mhSES children.
* $p<.05$ ** $p<.01$ *** $p<.001$

7. Discussion

The aim of the current paper was twofold: (1) establish the age at which children who differ in socioeconomic status reach their babbling onsets, and (2) examine the consonantal repertoire in these children's canonical syllables.

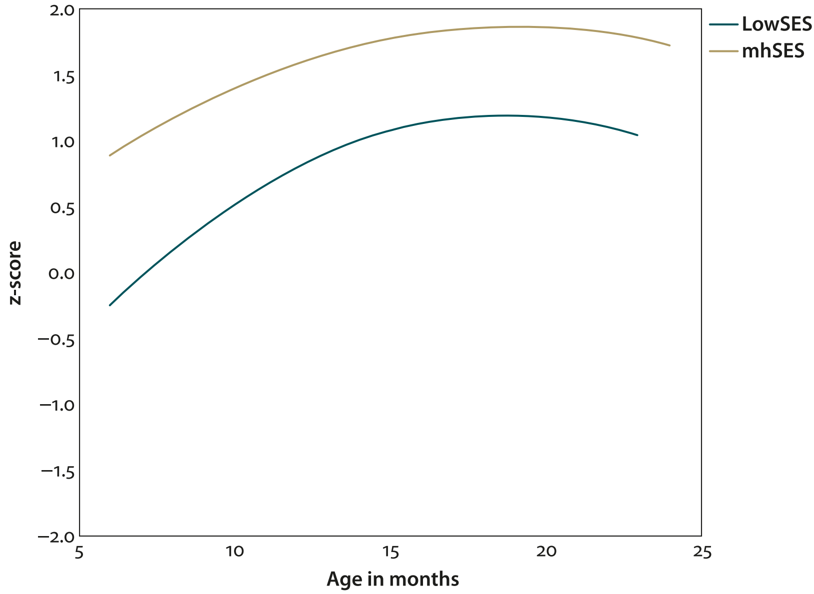

Figure 2. The longitudinal development of stops in lowSES and mhSES children (estimated z-scores)

LowSES children reach the babbling onset milestone at a significantly later age than the mhSES children for both CBR^{syl} and $tCBR^{syl}$, with on average a delay of approximately 3 to 4 months. Looking at children's consonantal development in babbling, clear differences have been found in this study as well: lowSES children produce significantly fewer stops, fricatives and liquids and significantly more glides and /h/. No difference for nasals was found. For fricatives, nasals, liquids and glides the percentage of use fluctuates minimally in the entire studied period. The frequency of stops increases in both groups of children, but the initial difference is still present at the end of the data collection, i.e. also by 24 months of age, lowSES children use significantly fewer stops in their canonical babbling than mhSES children. With respect to /h/, lowSES children seem to approximate mhSES children over time, by diminishing their use of /h/ to a larger extent than mhSES children do. So mhSES children use mainly stops, which is consistent with the literature (i.a. Oller & Eilers, 1982), whereas lowSES children use mainly glides and initially also /h/. The increased use of glides, generally seen as less mature sounds (e.g. Stoel-Gammon, 1989), in the lowSES group is also reflected in their later acquisition of $tCBR^{syl}$, which expresses also a later use of non-glides.

A key factor for the differences between the lowSES children and mhSES children is the input they receive. The lowSES children studied here are shown to

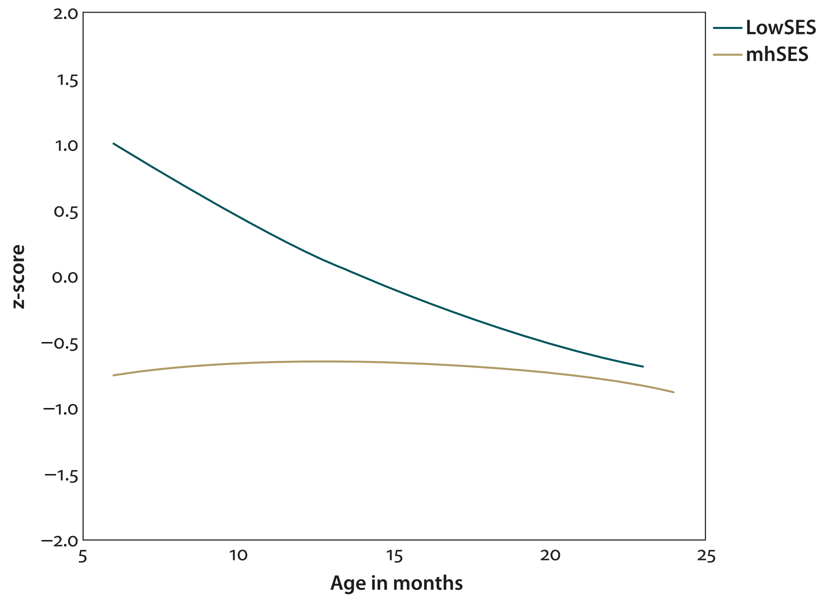

Figure 3. The longitudinal development of /h/ in lowSES and mhSES children (estimated z-scores)

receive quantitatively and qualitatively poorer input as compared to the mhSES children of the present study (Vanormelingen & Gillis, 2016), which is in line with general findings about SES and language input (e.g. Hart & Risley, 2003). However, it has also been shown that the amount and quality of child-directed speech is directly linked to children's own language development at later ages (Cartmill et al., 2013; Hart & Risley, 1995; Hoff & Naigles, 2002). For prelexical development, Albert, Schwade and Goldstein (2018) already showed that adult feedback and social interaction affects phonological learning in mhSES children. The current study shows that SES differences, reflected in a poorer amount of input and social interaction in the lowSES group, have a tremendous negative influence on the onset of canonical babbling: lowSES children reach the first linguistic milestone significantly later than mhSES children. The increased use of non-true consonant types (i.e. /h/ and glides) in the lowSES group also indicates a less mature speech and language development already this early in life (Stoel-Gammon, 1989) and is in line with Albert, Schwade and Goldstein (2018)'s findings about the relation between input and phonological learning.

Thus, our results indicate that lowSES children start to babble significantly later than children of mhSES. This contradicts earlier studies in which no difference in the age at babbling onset was found between lowSES and mhSES children

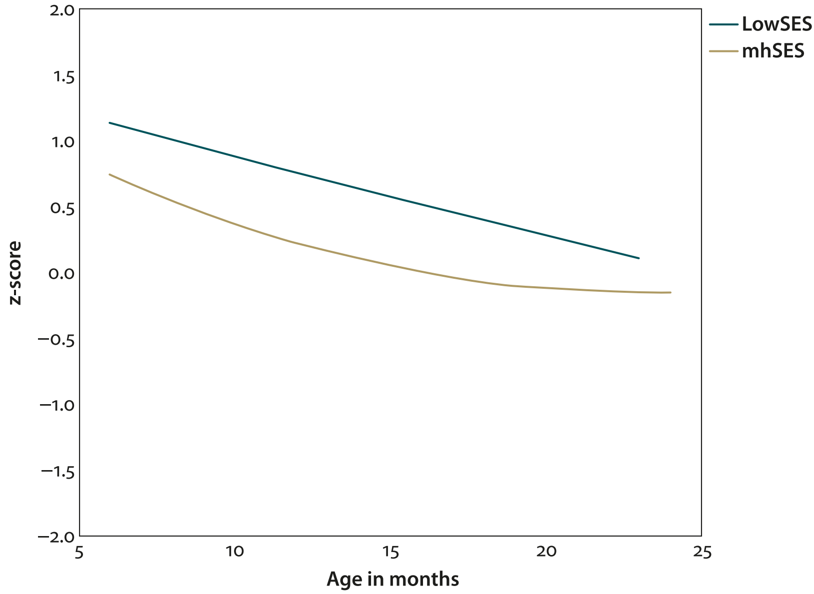

Figure 4. The longitudinal development of glides in lowSES and mhSES children (estimated z-scores)

(Eilers et al., 1993; Oller et al., 1995; Oller et al., 1994). The difference between our results and the literature may very well be explained by some methodological differences. A first factor is the procedure of measuring babbling onset in a corpus. Even though the sample size was small in the present study, a bootstrapping procedure (adopted from Molemans et al., 2012) for computing children's onsets with 95% confidence enabled us to provide a reliable and robust outcome. In previous research, determining the babbling onset was mainly based on parental reports (instead of corpus analyses) (Eilers et al., 1993; Oller et al., 1995) or on only one calculation from unequal sample sizes in a corpus study (Oller et al., 1994), which is shown to be suboptimal (e.g. Molemans et al., 2012).

Second, and importantly, the classification of children in the lowSES groups differs as well. Based on the Hollingshead Index (Hollingshead, 1975), the lowSES children in the present study belong to the lowest SES (level 5) on a five-level scale of SES and social standing, whereas the lowSES children in the studies of Oller and colleagues (Eilers et al., 1993, Oller et al., 1994) belong to levels 3 and 4 on the same scale. In other words, our sample represents children of the lower lowSES, whereas the children in the other studies are representative of the somewhat higher lowSES. So, it may be that babbling onset is delayed only in children living in families with the lowest lowSES. In a similar way as the difference

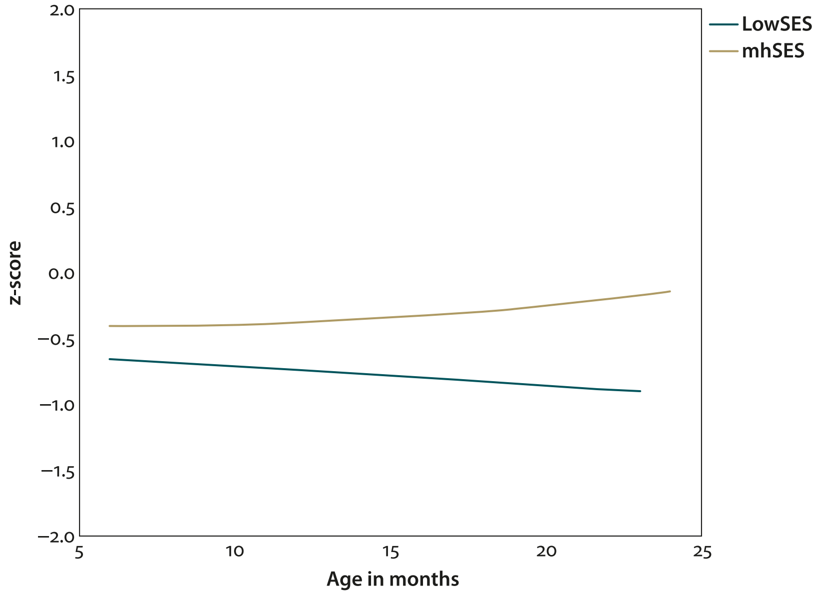

Figure 5. The longitudinal development of fricatives in lowSES and mhSES children (estimated z-scores)

between mhSES and lowSES are explained (lowSES children receiving fewer and qualitatively less diverse input as compared to children from mhSES backgrounds (Hart & Risley, 2003; Hoff & Naigles, 2002; Rowe, 2008, 2012; Vanormelingen & Gillis, 2016)), the amount and quality of the input may explain the difference between higher lowSES in the literature and lower lowSES outcomes in this study. Possibly the amount and quality of the input even differs even between these two strata on the SES index, resulting in poorer language developmental outcomes in the lower lowSES children. However, this hypothesis is entirely open for future research.

Oller and colleagues (1998, 1999) revealed that the age of children's babbling onset is a possible marker of delayed or even deviant language development: later babbling onset is associated with later language delays and even deviances. For instance, children who started to produce canonical babbles at a later age had smaller vocabularies at 18, 24 and 36 months of age (Oller et al., 1998). The fact that the lowSES children in our dataset reach the babbling onset significantly later than their mhSES peers suggests that they are vulnerable to delays in their further language development. In the literature, effects of SES on several aspects of children's later language development have been found, with poorer results for the lowSES children with respect to lexical development and processing skills (Hart

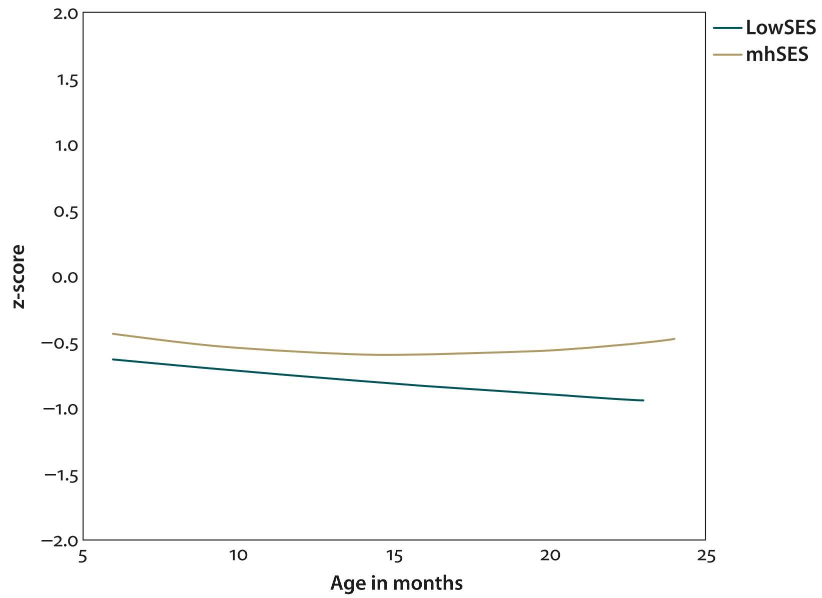

Figure 6. The longitudinal development of liquids in lowSES and mhSES children (estimated z-scores)

& Risley, 1995; Hoff, 2003; Weisleder & Fernald, 2013). The present study adds to this body of knowledge that lowSES children's delay is already apparent early in life, i.e. during the prelexical stage. In this way, our results are in line with those of Betancourt et al. (2015), suggesting a similar difference at 7 months of age for preverbal language and behavioral skills, and Wild et al. (2013), also suggesting that SES effects on language development appear early in life.

Finally, our findings are also in line with recent findings regarding children's brain development (Jednoróg et al., 2012; Noble, Houston, Kan, & Sowell, 2012; Tomalski et al., 2013). For instance, Tomalski et al. (2013) showed that disparities in the brains of children who differ in SES were already visible at 6 and 9 months of age, i.e. the age at which typically developing children reach the babbling onset. It remains to be shown how these observations fit into a coherent explanation. But since our sample of low SES children was fairly restricted in several respects, a replication with a larger sample of very low SES children is required first. Maybe a sample with a gradient of ascending SES levels is a valuable suggestion.

The present study showed that lowSES children reach their onset of canonical babbling significantly later than mhSES children and that they have an increased use of glides (i.e. less mature sounds) as compared to mhSES children. This effect could be at least partly be attributed to the difference in input language, in that

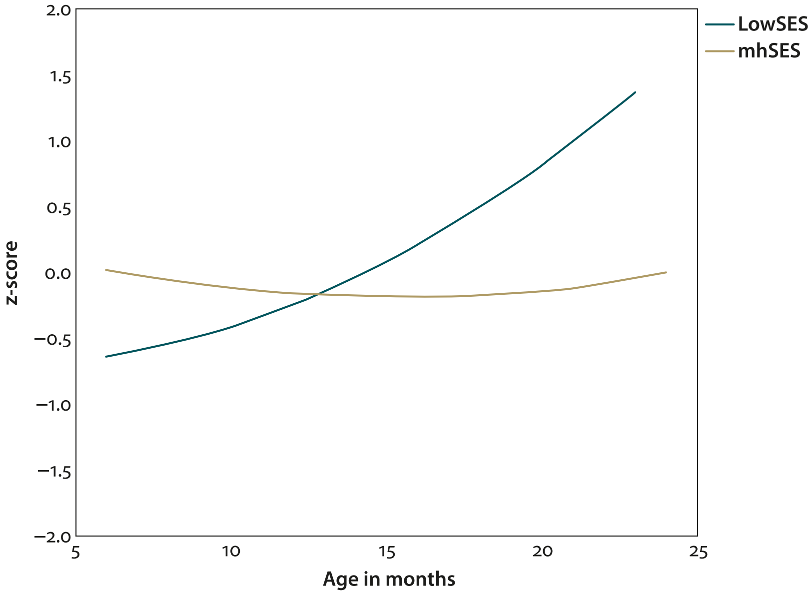

Figure 7. The longitudinal development of nasals in lowSES and mhSES children (estimated z-scores)

sense that parents of lowSES children talk less, respond less to their children's speech and if they do, often imitate their speech without providing additional information (Vanormelingen et al., 2016).

At this point the question crops up if lowSES inevitably leads to children's delayed vocal development, i.c., later onset of babbling and deviant consonant use? Is intervention possible at all? According to Rowe (2008, 2018) the differences in quality and quantity of speech directed to children, at least partly stem from differences in parents' approach toward their children. Parental knowledge about language development and the crucial role of interaction with children, mediates parents' way of interacting with their children. Intervention studies did indeed show that mothers positively changed their behavior when they were taught about the importance of child-directed speech and turn-taking and when they were given the proper tools to enhance their interactions (Leffel & Suskind, 2013; Sparks & Reese, 2012; Suskind et al., 2016; Taumoepeau & Reese, 2013; Yazejian et al., 2017). We believe that attempts at increasing lowSES caregivers' awareness of their parental importance are an excellent first step in intervention.

Funding

This research was supported by grant G009511N of the Fund for Scientific Research Flanders (FWO) to Steven Gillis

Acknowledgements

We would like to thank all families for participating in this study.

References

Albert, R. R., Schwade, J. A., & Goldstein, M. H. (2018). The social functions of babbling: acoustic and contextual characteristics that facilitate maternal responsiveness. *Developmental science*, *21*(5), e12641. https://doi.org/10.1111/desc.12641

Baayen, H. (2008). *Analyzing linguistic data. A practical introduction to statistics using R*. Cambridge (UK): Cambridge University Press. https://doi.org/10.1017/CBO9780511801686

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effect models using lme4. *Journal of Statistical Software*, *67*, 1–48. https://doi.org/10.18637/jss.v067.i01

Betancourt, L. M., Brodsky, N. L., & Hurt, H. (2015). Socioeconomic (SES) differences in language are evident in female infants at 7 months of age. *Early Human Development*, *91*(12), 719–724. https://doi.org/10.1016/j.earlhumdev.2015.08.002

Booij, G. (1995). *The phonology of Dutch*. Oxford: Clarendon Press.

Brown, R. (1958). *Words and things*. Glencoe, Illinois: The Free Press.

Cartmill, E. A., Armstrong, B. F., Gleitman, L. R., Goldin-Meadow, S., Medina, T. N., & Trueswell, J. C. (2013). Quality of early parent input predicts child vocabulary 3 years later. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 11278–11283. https://doi.org/10.1073/pnas.1309518110

Chapman, K. L., Hardin-Jones, M., Schulte, J., & Halter, K. A. (2001). Vocal development of 9-month-old babies with cleft palate. *Journal of Speech, Language and Hearing Research*, *44*, 1268–1283. https://doi.org/10.1044/1092-4388(2001/099)

De Boysson-Bardies, B., & Vihman, M. (1991). Adaptation to language: Evidence from babbling and first words in four languages. *Language*, *67*(2), 297–319. https://doi.org/10.1353/lan.1991.0045

Eilers, R. E., Oller, D. K., Levine, S. L., Basinger, D. L., Lynch, M. P., & Urbano, R. (1993). The role of prematurity and socioeconomic status in the onset of canonical babbling in infants. *Infant Behavior & Development*, *16*, 297–315. https://doi.org/10.1016/0163-6383(93)80037-9

Elbers, L., & Ton, J. (1985). Play pen monologues: The interplay of words and babbles in the first words period. *Journal of Child Language*, *12*, 551–565. https://doi.org/10.1017/S0305000900006644

Faes, J., Gillis, J., & Gillis, S. (2016). Phonemic accuracy development in children with cochlear implants up to five years of age by using Levenshtein distance. *Journal of Communication Disorders*, *59*, 40–58. https://doi.org/10.1016/j.jcomdis.2015.09.004

Fasolo, M., Majorano, M., & D'Odorico, L. (2008). Babbling and first words in children with slow expressive development. *Clinical Linguistics & Phonetics*, *22*(2), 83–94. https://doi.org/10.1080/02699200701600015

Fernald, A., Marchman, V.A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science*, *16*(2), 234–248. https://doi.org/10.1111/desc.12019

Fish, M., & Pinkerman, B. (2003). Language skills in low-SES rural Appalachian children: normative development and individual differences, infancy to preschool. *Journal of Applied Developmental Psychology*, *23*, 539–565. https://doi.org/10.1016/S0193-3973(02)00141-7

Goldstein, M., King, A., & West, M. (2003). Social interaction shapes babbling: Testing parallels between birdsong and speech. *Proceedings of the National Academy of Sciences*, *100*(13), 8030–8035. https://doi.org/10.1073/pnas.1332441100

Goldstein, M., & Schwade, J. (2008). Social feedback to infants' babbling facilitates rapid phonological learning. *Psychological Science*, *19*(5), 515–523. https://doi.org/10.1111/j.1467-9280.2008.02117.x

Hart, B., & Risley, T.R. (1992). American parenting of language-learning children: Persisting differences in family-child interactions observed in natural home environments. *Developmental Psychology*, *28*, 1096–1105. https://doi.org/10.1037/0012-1649.28.6.1096

Hart, B., & Risley, T.R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, Maryland: Paul H. Brooks Publishing Co.

Hart, B., & Risley, T.R. (1999). *The social world of learning to talk*. Baltimore, Maryland: Paul H. Brooks Publishing Co.

Hart, B., & Risley, T.R. (2003). The early catastrophe: The 30 million word gap by age 3. *American Educator, Spring* 2003, 4–9.

Hirsh-Pasek, K., Adamson, L.B., Bakeman, R., Owen, M.T., Golinkoff, R.M., Pace, A., Yust, P.K., Suma, K. (2015). The contribution of early communication quality to low-income children's language success. *Psychological Science*, *26*(7), 1071–1083. https://doi.org/10.1177/0956797615581493

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child development*, *74*(5), 1368–1378. https://doi.org/10.1111/1467-8624.00612

Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: Implications for closing achievement gaps. *Developmental Psychology*, *49*, 4–14. https://doi.org/10.1037/a0027238

Hoff, E., & Naigles, L. (2002). How children use input to acquire a lexicon. *Child Development*, *73*, 418–433. https://doi.org/10.1111/1467-8624.00415

Hoff-Ginsberg, E. (1998). The relation of birth order and socioeconomic status to children's language experience and language development. *Applied Psycholinguistics*, *19*, 603–629. https://doi.org/10.1017/S0142716400010389

Hollingshead, A.A. (1975). *Four-factor index of social status*. Unpublished manuscript. Yale University, New Haven, CT.

Hox, J. (2008). *Multilevel analysis: Techniques and applications*. New York; London: Psychology Press.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology*, *27*(2), 236–248. https://doi.org/10.1037/0012-1649.27.2.236

Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L.V. (2010). Sources of variability in children's language growth. *Cognitive Psychology*, *61*, 343–365. https://doi.org/10.1016/j.cogpsych.2010.08.002

Jednoróg, K., Altarelli, I., Monzalvo, K., Fluss, J., Dubois, J., Billard, C., Dehaene-Lambertz, G., & Ramus, F. (2012). The influence of socioeconomic status on children's brain structure. *PLOS ONE*, *7*(10) 1371/journal.pone.0042486.

Johnson, E.K., & Siedl, A.H. (2009). At 11 months, prosody still outranks statistics. *Developmental science*, *12*(1), 131–141. https://doi.org/10.1111/j.1467-7687.2008.00740.x

Keren-Portnoy, T., Majorano, M., & Vihman, M.M. (2009). From phonetics to phonology: The emergence of first words in Italian. *Journal of Child Language*, *36*, 235–267. https://doi.org/10.1017/S0305000908008933

Koopmans-Van Beinum, F., Clement, C.J., & Van den Dikkenberg-Pot, I. (2001). Babbling and the lack of auditory speech perception: A matter of coordination? *Developmental Science*, *4*, 61–70. https://doi.org/10.1111/1467-7687.00149

Koopmans-Van Beinum, F., & Van der Stelt, J. (1986). Early stages in the development of speech movements. In B. Lindblom, & R. Zetterström (Eds.), *Precursors of early speech* (pp. 37–50). New York: Stockton. https://doi.org/10.1007/978-1-349-08023-6_4

Lang, S., Bartl-Pokorny, K., Pokorny, F., Garrido, D., Mani, N., Fox-Boyer, A., Zhang, D., & Marschik, P. (2019). Canonical babbling: A marker for earlier identification of late detected developmental disorders? *Current Developmental Disorders Reports*, *6*, 111–118. https://doi.org/10.1007/s40474-019-00166-w

Leffel, K., & Suskind, D. (2013). Parent-directed approaches to enrich the early language environments of children living in poverty. *Seminars in Speech and Language*, *34*, 267–278. https://doi.org/10.1055/s-0033-1353443

Locke, J.L. (1980). The prediction of child speech errors: Implications for a theory of acquisition. In G.H. Yeni-Komshian, J.F. Kavanagh, & C.A. Ferguson (Eds.), *Child Phonology* (Vol. *1*, pp.193–209). New York: Academic Press. https://doi.org/10.1016/B978-0-12-770601-6.50015-2

Locke, J.L. (1983). *Phonological acquisition and change*. New York: Academic Press.

Locke, J.L. (1989). Babbling and early speech: Continuity and individual differences. *First Language*, *9*, 191–201. https://doi.org/10.1177/014272378900900606

Lohmander, A., Holm, K., Eriksson, S., & Lieberman, M. (2017). Observation method identifies that a lack of canonical babbling can indicate future speech and language problems. *Acta Paediatrics*, *106*, 935–943. https://doi.org/10.1111/apa.13816

Lynch, M.P., Oller, D.K., Steffens, M.L., Levine, S.L., Basinger, D.L., & Umbel, V. (1995). Onset of speech-like vocalizations in infants with Down syndrome. *American Journal of Mental Retardation*, *100*, 68–86.

MacNeilage, P., & Davis, B. (2000). On the origin of internal structure of word forms. *Science*, *288*, 527–531. https://doi.org/10.1126/science.288.5465.527

MacNeilage, P., Davis, B., Kinney, A., & Matyear, C. (2000). The motor core of speech: A comparison of serial organization patterns in infants and languages. *Child Development*, *71*(1), 153–163. https://doi.org/10.1111/1467-8624.00129

MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk*. Mahwah: NJ: Lawrence Erlbaum Associates.

McGillion, M., Herbert, J., Pine, J., Vihman, M., DePaolis, R., Keren-Portnoy, T., & Matthews, D. (2017). What paves the way to conventional language? The predictive values of babble, pointing, and socioeconomic status. *Child Development*, *88*, 156–166. https://doi.org/10.1111/cdev.12671

Molemans, I. (2011). A longitudinal investigation of aspects of the prelexical speech repertoire in young children acquiring Dutch: Normally hearing children and hearing-impaired children with a cochlear implant. Unpublished doctoral dissertation, University of Antwerp, Antwerp.

Molemans, I., Van den Berg, R., Van Severen, L., & Gillis, S. (2012). How to measure the onset of babbling reliably? *Journal of Child Language*, *39*(3), 523–552. https://doi.org/10.1017/S0305000911000171

Nakazima, S. (1975). Phonemicization and symbolization in language development. In E.H. Lenneberg, & E. Lenneberg (Eds.), *Foundations of language development, a multidisciplinary approach* (Vol. *1*, pp. 181–187). New York: Academic Press. https://doi.org/10.1016/B978-0-12-443701-2.50021-4

Nathani, S., Ertmer, D.J., & Stark, R.E. (2006). Assessing vocal development in infants and toddlers. *Clinical Linguistics & Phonetics*, *20*(5), 351–369. https://doi.org/10.1080/02699200500211451

Noble, K.G., Houston, S.M., Kan, E., & Sowell, E.R. (2012). Neural correlates of socioeconomic status in the developing human brain. *Developmental Science*, *15*, 516–527. https://doi.org/10.1111/j.1467-7687.2012.01147.x

Oller, D.K. (1980). The emergence of the sounds of speech in infancy. In G.H. Yeni-Komshian, J.F. Kavanagh, & C.A. Ferguson (Eds.), *Child phonology. Volume 1: production* (pp. 93–112). New York: Academic Press. https://doi.org/10.1016/B978-0-12-770601-6.50011-5

Oller, D.K. (2000). *The emergence of the speech capacity*. Mahwah: Lawrence Erlbaum. https://doi.org/10.4324/9781410602565

Oller, D.K., & Eilers, R.E. (1982). Similarities of babbling in Spanish- and English-learning babies. *Journal of Child Language*, *9*, 565–577. https://doi.org/10.1017/S0305000900004918

Oller, D.K., & Eilers, R.E. (1988). The role of audition in infant babbling. *Child Development*, *59*, 441–449. https://doi.org/10.2307/1130323

Oller, D.K., Eilers, R.E., Basinger, D.L., Steffens, M.L., & Urbano, R. (1995). Extreme poverty and the development of precursors to the speech capacity. *First Language*, *15*, 167–187. https://doi.org/10.1177/014272379501504403

Oller, D.K., Eilers, R.E., Bull, D., & Carney, A. (1985). Pre-speech vocalizations of a deaf infant: A comparison with normal metaphonological development. *Journal of Speech and Hearing Research*, *28*, 47–63. https://doi.org/10.1044/jshr.2801.47

Oller, D.K., Eilers, R.E., Neal, A.R., & Schwartz, H. (1999). Precursors to speech in infancy: The prediction of speech and language disorders. *Journal of Communication Disorders*, *32*, 223–245. https://doi.org/10.1016/S0021-9924(99)00013-1

Oller, D.K., Eilers, R.E., Neal, A.R., & Cobo-Lewis, A.B. (1998). Late onset canonical babbling: A possible early marker of abnormal development. *American Journal of Mental Retardation*, *103*, 249–263. https://doi.org/10.1352/0895-8017(1998)103<0249:LOCBAP>2.0.CO;2

Oller, D.K., Eilers, R.E., Steffens, M.L., Lynch, M.L., & Urbano, R. (1994). Speech-like vocalizations in infancy: An evaluation of potential risk factors. *Journal of Child Language*, *21*, 33–58. https://doi.org/10.1017/S0305000900008667

Pan, B.A., Rowe, M.L., Singer, J.D., & Snow, C.E. (2005). Maternal correlates of growth in toddler vocabulary production in low-income families. *Child Development*, *76*, 763–782.

Quené, H., & Van den Bergh, H. (2004). On multi-level modeling of data from repeated measures designs: A tutorial. *Speech Communication*, *43*, 103–121. https://doi.org/10.1016/j.specom.2004.02.004

Richels, C., Johnson, K., Walden, T., & Gonture, E. (2013). Socioeconomic status, parental education, vocabulary and language skills of children who stutter. *Journal of Communication Disorders*, *46*, 361–374. https://doi.org/10.1016/j.jcomdis.2013.07.002

Roug, L., Landberg, I., & Lundberg, L. J. (1989). Phonetic development in early infancy: A study of four Swedish children during the first eighteen months of life. *Journal of Child Language*, *16*, 1–40. https://doi.org/10.1017/S0305000900013416

Rowe, M. L. (2008). Child-directed speech: Relation to socioeconomic status, knowledge of child development and child vocabulary skill. *Journal of Child Language*, *35*, 185–205. https://doi.org/10.1017/S0305000907008343

Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*, 1762–1774. https://doi.org/10.1111/j.1467-8624.2012.01805.x

Rowe, M. L. (2018). Understanding socioeconomic differences in parents' speech to children. *Child Development Perspectives*, *12*, 122–127. https://doi.org/10.1111/cdep.12271

Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, T. (2011). Family socioeconomic status and child executive functions: The roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society*, *17*, 120–132. https://doi.org/10.1017/S1355617710001335

Song, L., Spier, E. T., & Tamis-LeMonda, C. S. (2014). Reciprocal influences between maternal language and children's language and cognitive development in low-income families. *Journal of Child Language*, *41*, 305–326. https://doi.org/10.1017/S0305000912000700

Sparks, A., & Reese, E. (2012). From reminiscing to reading: Home contributions to children's developing language and literacy in low-income families. *First Language*, *33*, 89–109. https://doi.org/10.1177/0142723711433583

Stark, R. E. (1980). Stages of speech development in the first year of life. In G. H. Yeni-Komshian, J. F. Kavanagh, & C. A. Ferguson (Eds.), *Child phonology. Volume 1: production* (pp. 73–92). New York: Academic Press. https://doi.org/10.1016/B978-0-12-770601-6.50010-3

Stoel-Gammon, C. (1989). Prespeech and early speech development of two late talkers. *First Language*, *9*, 207–224. https://doi.org/10.1177/014272378900900607

Stoel-Gammon, C. (1992). Prelinguistic vocal development: Measurement and predictions. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 439–456). Maryland: York Press.

Stoel-Gammon, C. (1998). Role of babbling and phonology in early linguistic development. In A. M. Wetherby, S. F. Warren, & J. Reichle (Eds.), *Transitions in prelinguistic communication* (pp. 87–110). Baltimore, Md: Paul H. Brookes.

Stoel-Gammon, C., & Cooper, J. (1984). Patterns of early lexical and phonological development. *Journal of Child Language*, *11*, 247–271. https://doi.org/10.1017/S0305000900005766

Suskind, D. L., Leffel, K. R., Graf, E., Hernandez, M. W., Gunderson, E. A., Sapolich, S. G., Suskind, E., Leininger, L., Goldin-Meadow, S., & Levine, S. C. (2016). A parent-directed language intervention for children of low socioeconomic status: A randomized controlled pilot study. *Journal of Child Language*, *43*, 366–406. https://doi.org/10.1017/S0305000915000033

Swingley, D. (2005). 11-month-olds' knowledge of how familiar words sound. *Developmental Science*, *8*(5), 432–443. https://doi.org/10.1111/j.1467-7687.2005.00432.x

Taumoepeau, M., & Reese, E. (2013). Maternal reminiscing, elaborative talk, and children's theory of mind: An intervention study. *First Language*, *33*, 388–410. https://doi.org/10.1177/0142723713493347

Thevenin, D.M., Eilers, R.E., Oller, D.K., & Lavoie, L. (1985). Where's the drift in babbling drift? A cross-linguistic study. *Applied Psycholinguistics*, *6*, 3–15. https://doi.org/10.1017/S0142716400005981

Tomalski, P., Moore, D.G., Ribeiro, H., Axelsson, E.L., Murphy, E., Karmiloff-Smith, A., Johnson, M.H., & Kushnerenko, E. (2013). Socioeconomic status and functional brain development-associations in early infancy. *Developmental Science*, *16*, 676–687. https://doi.org/10.1111/desc.12079

Tomasello, M., & Stahl, D. (2004). Sampling children's spontaneous speech: How much is enough? *Journal of Child Language*, *31*, 101–121. https://doi.org/10.1017/S0305000903005944

Van den Berg, R. (2012). Syllables inside out: A longitudinal study of the development of syllable types in toddlers acquiring Dutch: A comparison between hearing impaired children with a cochlear implant and normally hearing children. Unpublished doctoral dissertation, University of Antwerp, Antwerp.

Van Severen, L. (2012). A large-scale longitudinal survey of consonant development in toddlers' spontaneous speech. Unpublished doctoral dissertation, University of Antwerp, Antwerp.

Vanormelingen, L. (2016). Are you talking to me? Child-directed speech and language development: hearing children of different socio-economic statuses and deaf children with a cochlear implant. Unpublished doctoral dissertation, University of Antwerp, Antwerp.

Vanormelingen, L., De Maeyer, S., & Gillis, S. (2016). A comparison of maternal and child language in normally hearing and children with cochlear implants. *Language, Interaction and Acquisition*, *7*(2), 145–179. https://doi.org/10.1075/lia.7.2.01van

Vanormelingen, L., & Gillis, S. (2016). The influence of socio-economic status on mothers' volubility and responsiveness in a monolingual Dutch-speaking sample. *First Language*, *36*(2), 140–156. https://doi.org/10.1177/0142723716639502

Velleman, S.L., & Vihman, M.M. (2002). The optimal initial state. *Rutgers Optimality Archive*, 552–1002.

Vihman, M. (2019). *Phonological templates in development*. Oxford: Oxford University Press. https://doi.org/10.1093/oso/9780198793564.001.0001

Vihman, M., Macken, M.A., Miller, R., Simmons, H., & Miller, J. (1985). From babbling to speech: A re-assessment of the continuity issue. *Language 61*(2), 397–445. https://doi.org/10.2307/414151

Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science*, *24*(11), 2143–2152. https://doi.org/10.1177/0956797613488145

Werker, J.F., & Tees, R.C. (1984). Cross-language speech perception: evidence for perceptual reorganization during the first year of life. *Infant Behavior & Development*, *7*, 49–63. https://doi.org/10.1016/S0163-6383(84)80022-3

Wild, K.T., Betancourt, L.M., Brodsky, N.L., & Hurt, H. (2013). The effect of socioeconomic status on the language outcome of preterm infants at toddler age. *Early Human Development*, *89*(9), 743–746. https://doi.org/10.1016/j.earlhumdev.2013.05.008

Yazejian, N., Bryant, D. M., Hans, S., Horm, D., St. Clair, L., File, N. and Burchinal, M. (2017). Child and parenting outcomes after 1 year of Educare. *Child Development*, *88*, 1671–1688. https://doi.org/10.1111/cdev.12688

Address for correspondence

Jolien Faes
Computational Linguistics & Psycholinguistics (CLiPS) Research Center
University of Antwerp
Lange Winkelstraat 40-42
B-2000 Antwerp
Belgium
jolien.faes@uantwerpen.be

Co-author information

Liesbeth Vanormelingen
Computational Linguistics & Psycholinguistics (CLiPS) Research Center
University of Antwerp
liesbeth.vanormelingen@uantwerpen.be

Steven Gillis
Computational Linguistics & Psycholinguistics (CLiPS) Research Center
University of Antwerp
steven.gillis@uantwerpen.be

Publication history

Date received: 14 August 2019
Date accepted: 11 September 2020
Published online: 16 October 2020