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**Developmental changes in articulation rate and phonic groups during narration
in French children aged 4 to 10 years**

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ABSTRACT

This paper reports on an original study that was designed to investigate age-related change in the way French children produce speech during oral monolog discourse, considering both prosody and linguistic content. Eighty-five French children aged 4 to 10 years were asked to tell a story after they were shown an excerpt from an animated movie. All their remarks were transcribed and coded using *ELAN* as an annotation tool. Each narrative was analyzed for duration, articulation rate and information content (i.e., number of phonic groups, syllables, words, clauses). All measures were found to increase with age, with the duration of the phonic group and its linguistic content showing the stronger significant differences. Results contribute to provide reference data on speech production during childhood. They suggest the existence of two distinct developmental patterns in narrative production.

KEYWORDS:

Children, development, narrative, production, articulation rate, phonic group

Studying speech production in children

For decades, the acquisition of phonological, lexical-semantic, morphologic and syntactic knowledge necessary for speech has been at the heart of the debate in psycholinguistics alongside with that of early pragmatic and later discourse abilities. A related yet less investigated issue is that of the very utterance of the word and its course throughout childhood. The study whose results we report on in this paper investigates the speech production of typically developing French speaking children between the ages of 4 and 10 years with respect to narrative production. The objective of the study is two-fold. First, it documents the overall developmental pattern of narrative production in French in terms of the speaking rate and the packaging of words and clauses into speech prosodic units. Second, it examines duration and linguistic composition both at the macro level of the narrative and at the micro level of the phonic group. Before presenting and discussing the method and results, the paper starts with an overview of past studies on age-related changes in the speaking rate and the prosodic unit of speech, and on cognitive skills that underlie narrative production in speech.

On the speaking rate

As regards speech production, one of the most studied variables is the speaking rate. The reason is the rate at which one speaks provides all kinds of information, and therefore depends on age as well as on other factors such as the presence of a language or cognitive delay or impairment (Flipsen, 2002, 2003; Konopczynski & Vinter, 1994; Logan, Byrd, Mazzocchi, Gillam, 2011; Ryan, 2000), the type of task (Logan et al., 2011; Sturm & Seery, 2007), and the language (Yuan, Liberman & Cieri, 2006), among others.

Articulation rate and phonic groups

A common approach to speaking rate assessment is to determine the number of linguistic units that a speaker expresses per unit of time (Logan et al., 2011). In previous studies words per minute or second, syllables per minute or second, phones per second, were used to measure the speaking rate in a range of tasks including repetition of words and sentences, reading aloud, elicited sentence production, elicited narration and spontaneous talk in conversation. Taken altogether, results indicate an age-related increase of the speaking rate. For instance, studies on Dutch speakers suggest an increase of the average speaking rate from 3 syllables per second at age three years, up to 5-7 syllables per second in adults (den Os, 1990; Koopmans-van Beinum 1993). Studies on English speaking populations also index an increase in the speaking rate. However they provide more detailed and contrasted results (see Table 1 below).

Language put apart, both the task and the method of measurement was proved to impact the speaking rate at a certain age and help explain the variation (Logan et al., 2011; Miller, Grosjean & Lomanto, 1984; Nip & Green, 2013; Sturm & Seery, 2007; Walker & Archibald, 2006). One issue is that of the task demand, which is higher in elicited narration and spontaneous conversation compared to syllable or word repetition, sentence repetition or sentence production in an experimental setting. Another issue is that of whether or not to include pause time as part of the speaking time when measuring the speaking rate. Therefore there are two main approaches to the estimation of speaking rates. The first one corresponds to the overall time used for spoken delivery of a message, and it is referred to as 'speech rate'. Its measure includes the time spent pausing between words (Sturm & Seery, 2007). The second one reflects how quickly sound segments are produced in stretches or runs of speech that have no pauses nor hesitations, and it is referred to as 'articulatory rate' or 'articulation rate'. Its measure thus excludes the time pausing between words (Sturm & Seery, 2007). Consequently, speech rate is expected to be lower than articulation rate for

Articulation rate and phonic groups

one speaker no matter the task, and is more subject to variation, as the length and the number of pauses may vary a lot across speakers and tasks (see Table 1 for examples across results in studies by Sturm & Seery, 2007; Logan et al., 2011; Nip & Green, 2013). Both methods form an essential baseline for the identification and diagnosis of impaired or delayed speech (Flipsen, 2002; Hall et al., 1999; Logan et al., 2011; Miller et al., 1984; Pavao-Martins, Vieira, Loureiro & Santos, 2007; Ryan, 2000; Sturm & Seerie, 2007).

Table 1 presents normative data extracted from studies on English speaking populations from E.U. and Canada engaged in narration and/or conversation. Overall results suggest a steady acceleration of the average speech rate with age (Kowal et al., 1975; Nip & Green, 2013), from around 2 syllables per second in children at preschool age to about 4 syllables per second in teenagers and adults. The average articulation rate also seems to increase with age, however results are not always consistent across studies: Sturm and Seerie (2007), and Nip and Green (2013) report on an acceleration of the articulation rate whereas Pindzola, Jenkins and Lokken (1989), and Walker and Archibald (2006) do not. The studied age span, large versus short, could explain such contrasted results and conclusions.

Insert Table 1 about here

Length and content of the prosodic speech unit

An interesting though less well documented aspect of prosody is that of the length of the speech unit. A speech unit is an uninterrupted segment of speech between two pauses, sometimes named a “run” of speech (Walker, Archibald, Cherniak & Fish, 1992), a “phonetic utterance” (Haselager, Slis & Rietveld, 1991), a “phonetic phrase” (Flipsen, 2002), or a “breath group” (Rochet-Capellan & Fuchs, 2013). Flipsen (2002) reports on two studies that measured the average duration and

Articulation rate and phonic groups

linguistic content (i.e. number of syllables) of the speech unit in children with typical development. The two studies showed a significant increase both in duration and in linguistic content. Walker et al. (1992) found a mean length of 3.87 syll. in children aged three years, and of 4.77 syll. in children aged five. Haselager et al. (1991) provided mean values of 5.4 syll. at age five, 6.6 at age seven, 7.3 at age nine, and 7.4 at age eleven. Studying long term changes in the speech of two groups of children with speech delay, Flipsen (2002) found mean values ranging from 4.85 syll. at age four to 6.97 at age nine, and to 7.32 at age fourteen.

A complementary approach to the speech unit is to consider its linguistic content in words and clauses. For example, in a study on spontaneous speech by female speakers of German, Rochet-Capellan & Fuchs (2013) included the number and type of clauses in their measures of the speech unit – named "breath group" – together with the number of syllables and the timing of phonic exhalations and pauses. Authors report an average of 2.11 clauses per group (mean duration: 3.52 sec.). The kinematics of breathing was found to vary as a function of the group linguistic content, showing some interplay between speech-planning and breathing control. Although its focus is on speech production in adult speakers, Rochet-Capellan & Fuchs's study opens an interesting line of investigation as regards the study of speech production in children which – kinematic measures left apart – we followed in our study.

Processing speech for narration

Increase of speaking rates over age was long interpreted as indexing cognitive and motor skills. Within the Baddeley's cognitive framework on memory span as a main central processor, several studies interpreted and discussed the increase in speaking rates during childhood as an effect of growing skills in memory span (Adams & Gathercole, 1995; Ferguson, Bowey & Tilley, 2002; Hulme, Thomson, Muir, Lawrence, 1984, among others). Taking on a broader perspective, Nip &

Articulation rate and phonic groups

Jordan (2013) report on a study that measured speech rate, articulation rate, and kinematic variables in four speaking tasks varying in task demands. The participants were children, teenagers and adults. Both speaking rates were found to increase with age but did not seem to be constrained by articulator movement speed. The authors concluded that such increase was due to cognitive-linguistic processing and speech motor control. However, relying on the sole speaking rates does not prove sufficient to further investigate the cognitive underpinnings of speech abilities and their course during childhood.

In contrast, considering both the duration and the linguistic content of the speech unit is interesting for the reason that it indexes both speech as motoric vocal behavior and language as organized strings of meaningful sounds bearing semantic and syntactic properties. Given the metric and prosodic relations between phonic groups and syntactic units, syntactic processing necessary comes into play (Lacheret-Dujour & Beaugendre, 1999; Rochet-Capellan & Fuchs, 2013). As a consequence, age-related changes in the informational content of the phonic group are to be related to syntactic development (Diessel, 2004; McDaniel, McKee & Garret, 2009), and to the planning of speech at the level of word and clause packaging (Rochet-Capellan & Fuchs, 2013; Verhoeven, Aparici, Cahana-Amitay, van Hell & Viguié-Simon, 2002).

However, one should also consider the type of language task the speaker is engaged in. In dialog interactive tasks, the production of spontaneous speech is mainly constrained by pragmatic properties attached to the chaining of speech turns. In the narration type of monolog task, it is mainly constrained by textual – coherence and cohesion – properties attached to the goal of narrating an event from start to end, in a relevant if not complete account (Halliday & Hasan, 1976). Studies on children's narratives across cultures pointed out several cognitive abilities underpinning narrative production including: knowledge of the appropriate text format – the '*schéma narratif*'

Articulation rate and phonic groups

highlighted within the structural approach to text and the French school of narratology –; ability to assemble information, organize them and plan text production at the macro level; ability to use the appropriate linguistic resources so as to build reference, contextualize information and distribute it into clauses whose chaining show cohesion via the means of reference tracking and the use of connectors; and information processing skills such as memory and attention focus (Berman & Slobin, 1994; Fayol, 1985, 2000; Hickmann, 2003; Karmiloff-Smith, 1979; Tolchinsky, 2004). The slow implementation of such set of cognitive abilities over age helps explain why narrative development spreads over the years, from the first simple scripts verbalized by the young child before he enters primary school to the detailed and well-commented accounts of the older child about to enter medium school. As a consequence, the narrative is the ‘*place par excellence*’ where it is possible to identify age-related changes both in terms of speech production and planning at the micro level of words and clauses and at the macro level of text.

Purpose of the Study

On an empirical ground, the present investigation aims at documenting the course of both the articulation rate and the duration and linguistic content of the prosodic unit of speech in French typically developing children aged 4 to 10 years, using an elicited narrative task. Even though gathering reference data is important for assessment and clinical purpose, data on the speaking rates in French is not so well documented despite an impressive body of work on prosody (see Embarki & Dodane, 2012; Lacheret-Dujour & Beaugendre, 1999 for an overview). When available, left apart a study by Konopczynski and Vinter (1994), measures of fluency are extracted from adult spoken data (Duez & Nishinuma, 1987; Grosjean & Deschamps, 1975; Schwab & Avanzi, 2015; Zellner, 1998), and from atypical populations (Legendre, Vaissiere, Prang, De Lamaze, Gaillard, Garabedian & Loundon, 2012). As for the duration and content of the prosodic speech

Articulation rate and phonic groups

unit and its course over childhood, our study aims at gathering reference data for French speaking children, as none is available to date.

On a theoretical ground, speech production involves a whole range of abilities, from breathing and speech motor control to linguistic processing at various levels (Berman & Slobin, 1994; Meyer & Wheeldon, 2006). Studies on speech production either focus on short messages, and study the micro level of the packaging of syllables into words or of words into clauses, or stress discourse units such as the narrative, and focus on the macro level of text format, inter-clause relationships and text-cohesion (anaphora, connectors). Relying on a set of measures that includes both prosody and linguistic content, our investigation aims at studying the way the child aged 4 to 10 years processes speech both at the micro level of the speech unit and at the macro level of the narrative, and at characterizing the relationship between abilities involved at both levels as well as its course over age.

Method

Participants

Eighty-five French children aged 3½ to 11½ years participated in the study. All children attended the same school in the Grenoble area (France), where they were selected in the grades corresponding to their age with 24 students in preschool classes (*'PS-Petite Section'* for children aged 3 to 4 years, *'MS-Moyenne Section'* for children aged 4 to 5 years, *'GS-Grande Section'* for children aged 5 to 6 years), and 61 students in primary school classes (*'CP'*, *'CE1'*, *'CE2'*, *'CM1'*, *'CM2'*, corresponding respectively to grade 1 to grade 5).

To allow for a comparison on age rather than on school grades, the sample was divided into six age groups (4 years-olds to 10 years-olds) including 14 participants on average (see details in Table 2).

Articulation rate and phonic groups

The constitution of each group was done with great care considering age limits for inclusion as well as number, grade and gender of participants. As a consequence, each age group did not necessarily correspond to a single school grade (for example, the 4YRS group included both PS and MS students, who were not numerous in the sample, while the 6YRS group included GS as well as the younger 1st grade students, and the 10YRS group included 5th grade students only). Table 2 shows details for each group. Although gender was almost equal within the entire population (N= 40 girls + 45 boys), strict equality could not be established within each age group on the basis of the sample.

To ensure homogeneity on language abilities, we selected children who were L1 speakers of French language. In addition, all children were administered the *ELO (Evaluation du Langage Oral)* language assessment tool. *ELO* is a standardized language test that assesses vocabulary, morphology and syntax in French speaking children aged 3 to 11 years (Khomsî, 2001). As children who showed an atypical profile in terms of their linguistic skills were excluded from the final sample, all participants had their mean scores on *ELO* within the standard norms of their age group.

Insert Table 2 about here

Procedure

The protocol was originally designed for a developmental and cross-linguistic investigation of multimodal narrative abilities in children aged 3 to 11 years. The study was granted by the French *Agence Nationale de la Recherche* (project “Multimodality” ANR-05-BLANC-0178-01 and -02). We proposed a narrative task in which each child had to recount to the experimenter an excerpt from an animated film (e.g., the first three minutes of "A Close Shave" by Nick Park, from the Wallace and Gromit series) that was showed to him/her on a computer in a quiet and separate room in his/her

Articulation rate and phonic groups

school. The stimulus was selected both for its entertaining qualities and its simple narrative characteristics, likely to draw attention from every participant whatever the age. The excerpt shows Gromit the dog awakened at night by a loud noise outside. A sheep escapes from a truck driving Wallace and Gromit's street, and clandestinely enters their home. At breakfast the following morning, strange things start to happen in the house. Gromit starts to investigate. The narrative performance of each child was filmed using a digital video-recorder together with an external sound recording system (a directional microphone placed on the table near the child).

Coding

The 85 narratives were transcribed and coded using *ELAN* as an annotation tool¹. *ELAN* is a multi-tiers annotator that allows fine-grained alignment of the transcript with the audio source.

The first coding step was to transcribe the words of the speaker into speech units that were named “phonic groups” after Leon’s definition of “[...] a group of syllables composing a sound unit with or without meaning” (Leon, 2011, 141, our translation). The label “phonic group” (hereafter referred as “PG”) emphasizes a focus on vocal or phonic behavior and avoids confusion with “utterance” or “phrase”, which label meaningful linguistic units. In our study, a PG refers to a segment of uninterrupted speech between two silences or pauses. Following den Os (1990), we considered any interruption of speech greater than 200ms as a pause. Although pauses and longer silence segments were not annotated in this study, the duration of each pause and silence remains easy to extract under *ELAN*. The words from the speaker were transcribed in aligned PG annotations. A picture of an *ELAN* window is provided as an illustration of our coding in the Appendix.

¹ <http://www.lat-mpi.eu/tools/elan/>

Articulation rate and phonic groups

The transcription of the speakers' words appears in two tiers: one tier for the interviewer, one tier for the child participant. The transcription is orthographical. The convention transcriptions were adapted from the Belgian VALIBEL system². The transcription presents the entirety of the remarks of the speakers.

The following steps consisted in adding tiers to the participant's speech transcription tier. The second tier replicates annotations from the speech tier. It was used to extract the number of phonetic syllables out of each annotated PG per se, considering each speaker's behavior as regards pronunciation of the "schwa" (*'e muet'*) and the liaison between words, which are subject to cross-individual variation in French. The three following tiers present the remarks of the speaker segmented into clauses. In order to extract the number of words and clauses, and to ensure cross-individual comparison, the transcripts of raw speech were copied into new annotations on third tier. At this stage, the content of speech was normalized so as to ignore hesitations, filled pauses, vowel lengthening, restarts and other hints of the speaker's on-going process of enunciation, whose production differ greatly from one child to another. We used annotations on fourth tier to extract the number of clauses, and annotations on fifth tier to extract the type of clauses. The content was then tokenized (i.e., segmented into words) on the sixth tier so as to extract the number of words. An example of a narrative produced by a French nine-year-old is provided in the Appendix.

Measures out of our coding included first the narration time. In our study, the time of pauses and silences being excluded, the duration of a narrative is nothing but the average time (in seconds) it takes for the participant to verbalize it. In other words, the narration time is equal to the sum of the length of all PGs contained therein. The articulation rate was calculated by dividing the number of

² http://www.uclouvain.be/cps/ucl/doc/valibel/documents/conventions_valibel_2004.PDF

Articulation rate and phonic groups

syllables by the narration time in seconds. The amount of linguistic information per narrative was measured for PGs, syllables, words, and clauses (as defined in syntax, i.e. as a set of arguments organized around a verb nucleus). Finally, we measured the amount of linguistic information per PG for syllables, words and clauses so as to track age related changes not only at the level of the entire narrative production, but also at the level of the speaking unit. This way we obtained PG density measures for syllables, words and clauses.

Results

In order to select appropriate statistical tests, we analyzed the normality of the distribution for each group, as assessed by Shapiro-Wilk test ($p > .05$). We conducted one-way ANOVA when the distribution was normal and Levene's test of homogeneity of variances was not significant, using Duncan post-hoc test ($p < .05$). We conducted Welch ANOVA when Levene's test was significant, using Games-Howell post-hoc test ($p < .05$). We used the non-parametric Kruskal-Wallis test when the distribution was not normal, and pairwise comparisons were performed using a Mann-Whitney U test.

Overall results showed no effect of gender, but a significant increase with age in the duration of the narration as well as in all other variables. Table 3 shows the mean values for the narration time and the articulation rate. As expected, older children talked longer (95 sec. on average) and spoke faster (4.29 syll/sec. on average) than younger children (narration time: 42 sec.; articulation rate: 3.84 syll/sec.).

Insert Table 3 about here

Articulation rate and phonic groups

A Kruskal-Wallis H test showed that the median scores of narration time were significantly different between groups, $\chi^2(5) = 23.950$, $p < .001$. The post hoc analysis revealed significant differences between the 4YRS group and the four older age groups (7YRS to 10YRS), and between the 6YRS age group and the four older age groups, but not between the 4YRS and 6YRS age groups, as illustrated on Fig.1 (left graph).

Table 3 shows the average scores for the articulation rate measured in syllables per second. A one-way ANOVA showed an effect of age ($F(5,79)=3.956$, $p=.003$, $\eta^2=0.20$). Articulation rate increased from the 4YRS age group to the 6YRS, 8YRS, 9YRS and 10YRS age groups, in that order, with the 7YRS age group remaining the lowest. Duncan post hoc analysis revealed a significant difference in scores between, respectively, the first two age groups (4YRS and 6YRS) and the 10YRS age group. There was another significant difference in scores between the 7YRS group and the three older age groups (8YRS to 10YRS), as illustrated on Fig.1 (right graph).

Insert Figure 1.1 and 1.2 about here

FIGURE 1 –Increase in narration time (left graph) and articulation rate (right graph) with age.

The narration time being twice as long in the older children's groups compared to the younger children's group, one would expect the narratives produced by older children to contain more linguistic information than the narratives produced by their younger counterparts. Indeed, analysis of the linguistic data showed a tremendous increase on all measures, with the mean number of PGs, syllables, words, and clauses per narrative jumping respectively, between the 4YRS age group and the 10YRS age group, from 33 to 50 PGs, from 156 to 407 syllables, from 112 to 304 words, from 19 to 54 clauses (see Table 4).

Insert Table 4 about here

The one-way Welch ANOVA showed an effect of age on the four linguistic variables, i.e. number of PGs (Welch's $F(5, 35.370)=4.371, p=.003$), Syllables (Welch's $F(5, 34.756) = 11.512, p<.001$), Words (Welch's $F(5, 34.479)=13.779, p<.001$), and Clauses (Welch's $F(5, 33.834)=13.913, p<.001$). The scores in these variables increased from the 4YRS age group to the 10YRS age group, but the pattern of changes differed between that of the speech unit (PG) and that of the other variables. Games-Howell post hoc analysis revealed a significant increase in scores in three linguistic variables (Clauses, Words, Syllables) between the 4YRS age group and the last four age groups (7YRS to 10YRS), and between the 6YRS age group and the two older (9YRS and 10YRS) age groups. Figure 2 (left graph) illustrates this pattern for the mean number of clauses across groups. As for the mean number of PGs, the post hoc test revealed a significant difference between the 4YRS age group who displayed the lowest value, and the 9YRS age group who displayed the second highest value (see Figure 2, right graph). We observed other differences between other groups that did not reach the significance threshold.

Insert Figure 2.1 and 2.2 about here

FIGURE 2 – Increase in number of clauses (left graph) and of PGs (right graph) with age.

Let us now consider linguistic production at the level of the phonic group. In Table 5, we present results for the PG time (i.e., the mean duration of a PG) within each age group, and PG density measures (mean number of syllables/words/clauses per PG) within each age group. Not only does the number of PGs per narrative increase with age, the mean duration of a PG also increases with age and jumps from 1.25 sec to 1.97 sec. between the 4YRS age group and the 10YRS age group.

Articulation rate and phonic groups

Yet, the course of PG time over age follows a very distinct pattern from that of the number of PG per narrative.

Insert Table 5 about here

The one-way ANOVA showed that mean PG time scores were significantly different between age groups, $F(5,79)=5.868$, $p<.0005$, $\eta^2=0.271$. Duncan post hoc analysis revealed that the increase from the younger 4YRS age group to the five other groups was significant, as well as the increase between the first four age groups (4YRS to 8YRS) to the 10YRS age group, but that there was no significant difference between the 6YRS, 7YRS, 8YRS and 9YRS age groups, as illustrated in Fig.3 (left graph).

Considering the linguistic content of the PG over age, and following our reasoning on the narration time and its effect on the amount of linguistic information, we would expect the PGs produced by older children to contain more linguistic information than the PGs produced by their younger counterparts. Analysis of the linguistic content of PGs in the data confirmed an important increase on all measures, with the syllabic, lexical and clausal content jumping respectively, between the 4YRS age group and the 10YRS age group, from 4.73 to 8.32 syllables per PG, from 3.44 to 6.30 words per PG, from 0.60 to 1.11 clauses per PG (see Table 5).

The Kruskal-Wallis H test showed that the median scores of each of the three PG density measures were significantly different between groups, $\chi^2(5)=37.061$, $p<.001$ for syllables per PG, $\chi^2(5)=30.982$, $p<.001$ for words per PG, and $\chi^2(5)=29.383$, $p<.001$ for clauses per PG. The post hoc analysis revealed significant differences in median scores for each of the three density measures between the 4YRS age group and the five other age groups, and between the 10YRS age

Articulation rate and phonic groups

group and all other age groups. Fig.3 (right graph) illustrates this pattern for the median scores of clauses per PG across age groups.

Insert Figure 3.1 and 3.2 about here

FIGURE 3 – Increase in PG time (left graph) and in number of clauses per PG (right graph) with age.

In line with these results, a correlation analysis (Pearson test) we conducted between age and all measures revealed stronger positive correlations for PG density measures ($R = 0.571$ for the relationship between age and number of syllables per PG; $R = 0.533$ for the relationship between age and number of clauses per PG) than for other variables (e.g., $R = 0.325$ for the relationship between age and articulation rate). In addition, the regression analysis showed that age explains 32% of the variance in the number of syllables per PG, and 28% of the variance in the number of clauses per PG.

Discussion

The purpose of the study we report in this paper was first to help document articulation rate and the packaging of words and clauses into speech units in French typically developing children aged 4 to 10 years in an elicited narrative task. Second, it aimed at characterizing the relationship between speech production at the micro level of the phonic group and speech production at the macro level of the narrative, and at questioning its course during childhood.

To sum up our results, the older the child gets, the longer his narration becomes, the faster he talks, the more he recounts from the visualized animated movie extract, and most importantly, the more he distributes the linguistic information in phonic groups that grow longer and become syntactically more complex so as to include more than one clause on average in the older children's narration.

Articulation rate and phonic groups

Our study extends results on French speaking children previously established from a smaller sample (Colletta, Pellenq & Rousset, 2008) for both the articulation rate and the duration and linguistic content of the phonic group. It is interesting to note that the average articulation rate we find in children aged four and ten years matches well with several studies on English speaking populations as exposed in Table 1, and that they confirm a slow increase over age for this measure. It is also interesting to note that the stronger and significant increase of measures we observe in the duration and linguistic content of the phonic group also matches with results from other studies (Haselager et al., 1991; Walker et al., 1992). In our view, this convergence in results suggests that together with articulation rate, measures of the speech unit are a robust index to estimate speech production during childhood.

Assessment and clinical issues

Our study yields reference data for speech production in French speaking children aged four to ten years. These are critical ages for language assessment, diagnosis, and treatment services by language pathologists and speech therapists, and for special needs education by trained teachers. Examples below focus on two contrasted speech production performance, with that of the child aged four years, and that of the ten-year-old. On average, the four-year-old child produces a short narration of 42 seconds containing 112 words organized in 19 clauses, and he/she makes many pauses, as the mean number of phonic groups is 33. On average, he/she produces 3.84 syllables per second, and he/she packages linguistic information into phonic groups of 1.25 sec. containing 4.73 syllables which is equivalent to 0.60 clauses. On average, the child aged ten years produces a longer and elaborate narration of 1.5 minute made up of 304 words organized in 54 clauses, and he/she makes relatively fewer pauses than his younger counterpart, given that the mean number of phonic groups is 50. On average, the ten-year-old child produces 4.29 syllables per second, and he/she

Articulation rate and phonic groups

packages linguistic information into phonic groups of 1.97 sec. containing 8.32 syllables which equals to 1.11 clauses. As standard deviation extracted from the data shows, articulation rate and phonic group measures vary less between children in all age groups, and they seem far less sensitive to the task than narration itself. Therefore, one should consider the sole results on articulation rate and phonic groups as reference data.

On the development of speech production in a narrative task

Now turning to theoretical considerations, the fact that the older child produces longer narratives and makes use of more linguistic information to recount in more details than his younger pair is no surprise. The results on narration time and linguistic content here obtained from children aged 4 to 10 years only replicates findings from past studies on children performing narrative tasks (Berman & Slobin, 1994; Colletta, 2004; Colletta, Pellenq & Guidetti, 2010; Hickmann, 2003). In a similar way, our results on articulation rate confirm for French speaking populations a slow increase during childhood, as suggested from results on English speaking populations in the studies reviewed in section 1 of this paper.

More interesting results come from analysis of the duration and linguistic content of the speech unit, showing a significant increase in the duration of the phonic group with age, and most importantly, a significant increase in its informational content that can be observed both at the syntactic level of the clause and at the levels of its lexical and syllabic components. The fact that at the age of ten years, the child's phonic group is made up of more than one clause on average whereas the four-year-old child has to verbalize two phonic groups to produce one clause is particularly significant. Tentatively, we interpret this increase in phonic group measures as an index of growing cognitive abilities in the planning of verbal output at the micro level of the clause. We discuss this point below, while sketching a broader output from our results.

Articulation rate and phonic groups

Another interesting result comes from the confrontation of both sets of measures, narration measures on one hand (i.e., narration time and overall syllable/word/clause production), phonic group measures (i.e., PG time and number of syllables/words/clauses per PG) on the other, which suggest the existence of two distinct developmental patterns: the first with a significant increase in the duration and linguistic content of the narrative between the ages of 6 and 7 years, the second with two significant increases in the length and informational content of the PG, one between the ages of 4 and 6 years and the other around 10 years of age.

The duration and the amount of linguistic information in the narrative are indicators (among others) of the narrative skills that are gradually emerging in children (Berman & Slobin, 1994; Colletta, 2004; Hickmann, 2003). Corresponding to grade one at school, the stage of 6-7 years seems important both in terms of the building of the concept of text and the linguistic tools which ensure the textual cohesion/coherence in monolog discourse. Previous studies demonstrated that children this age produce fewer scripts (short sequences of prototypical action) in favor of chains of events demonstrating a narrative organization (Fayol, 2000), and that their use of linguistic markers specialized in text cohesion (pronouns, determiners, spatial and temporal locators) begins to generalize (Hickmann, 2000). In other words, considering narrative production, there seems to be a major milestone for narrative abilities when the child enters primary school, which our results reflect.

In contrast, measures of the phonic group such as its duration and its linguistic content shed light on the micro level of speech production as well as on its online structuring in uninterrupted linguistic segments. As exposed in section 1, speech production at the level of the speech unit involves bio-physiological constraints on breathing, cognitive skills such as the working memory span, lexical access and phonetic encoding, and it depends on the nature of the linguistic information to be transmitted (see Meyer & Wheeldon, 2006, for an overall review). The results

Articulation rate and phonic groups

from our study point to two milestones, the first one when the child is in its last year of nursery schooling, the second one towards the end of primary schooling, during which the phonic group becomes significantly longer and allows for the verbalization of speech segments that contain more linguistic information. Without denying the effect of age on the up-cited abilities, one cannot fail to relate this evolution to syntactic development in production. Studying the emergence of complex syntactic structures between age two and age five, Diessel (2004) showed that the child utterance evolves from simple syntactic structures (fixed constructions based on structures such as "to want to do + something", dialogue structures such as "P because Q" with P being verbalized by the speaker) towards expressing the complex relationships involving coordination and/or subordination. In the Diessel study, such developmental change was reflected in longer utterances in the verbal repertoire of older children. A follow up research should examine the relationship between prosody and syntax through the detailed syntactic analysis of the phonic group in the data – over 4200 occurrences in total. One would expect to find some qualitative change in the syntactic structures that compose the phonic groups in the speech of the six-year-olds compared to the phonic groups in the speech of the four-year-olds.

As for the second milestone located at around 10 years of age, we view it as related to new conceptions of text and new textual skills (e.g., the ability to construct a complete representation of a storyline, the ability to extract relevant information from a set of facts, the ability to summarize linguistic information) that emerge at this age (Fayol, 1985, 2000). As a consequence, while children aged 9 to 10 years struggle in delivering an accurate and complete account of events from the story, children at the threshold of secondary schooling – aged 11 years and over – and adults who can be credited with such abilities omit secondary events, focus on main information from the story, and produce shorter oral narrations than the former, which they commonly enrich with commentaries (Colletta, 2004; Colletta, Pellenq & Guidetti, 2010). Our hypothesis is that the

Articulation rate and phonic groups

emergence of new textual abilities – which enable the narrator to plan speech at the macro level of the narrative – show in the planning of speech at the micro level of the speech unit, more specifically in the ability to verbalize several clauses in a phonic group, and thus in the processing of speech at the inter-clause level. Here again, a follow up study should focus on the relationship between prosody and syntax through the detailed syntactic analysis of the phonic group in the speech of the children who belong to the older age groups (six years and over).

Moreover, to gain a better insight on the issue of planning speech both at the micro level of the speech unit and at the macro level of the narration, one cannot but take into account the utterance production parameters mentioned in the literature, which are hesitations and pauses on the one hand (Campione & Veronis, 2004), and on the other hand, the co-speech gesture which we know is an integral part of the process of speech production (Mayberry & Jacques, 2000; McNeill, 2000). For instance, the study of representational gesture production in spontaneous talk as well as in elicited language tasks led psycholinguists to reconsider the theoretical models for speech production (de Ruiter, 2000; McNeill & Duncan, 2000; Kita & Özyürek, 2003). Thanks to its imagistic properties, the import of representational gesture production in the study of online speech production in children would help better understand the processing and planning of speech at different ages. Given results from the present study, the linking of prosody (phonic groups and pauses), syntax, and gesture production in the study of children's narratives sounds an exciting and promising line of research for tomorrow.

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Articulation rate and phonic groups

Articulation rate and phonic groups

Appendix

The screenshot displays the ELAN 4.9.4 software interface. At the top, the title bar reads "ELAN 4.9.4 - Baptiste.CM1.Sy.RWG.eaf". The menu bar includes "File", "Edit", "Annotation", "Tier", "Type", "Search", "View", "Options", "Window", and "Help". Below the menu bar, there are tabs for "Grid", "Text", "Subtitles", "Lexicon", "Comments", "Recognizers", "Metadata", and "Controls".

The main window is divided into several sections:

- Video View:** Shows a child sitting at a desk in a classroom, narrating. The video is currently paused at 00:00:30.500.
- Text View:** Displays the transcript of the child's narration. The selected text is: "et qui va chez wallace et gromit// et y a une pénurie d(e) laine".
- Waveform:** Shows the audio waveform corresponding to the selected text.
- Annotation Tiers:** A hierarchical list of linguistic tiers is shown on the left, including "Tiers", "Adulte", "Enfant", "GroupedeSouf", "TDP", "Synt.TDP.net", "Synt.Complexit", "Synt.Prop.", "Synt.Type Pr", "Synt.Mots", "Synt.Cat.gr", and "Disc.Cat.gr".
- Annotation Grid:** A detailed view of the selected text with various linguistic annotations. The text is "et qui va chez wallace et gromit et y a une pénurie de laine donc voilà". Annotations include "Ct de Nom foc.", "Independante Prés", "PrRelatif", and "Conn".

Screenshot of an ELAN window showing a child narrating from the video extract

Articulation rate and phonic groups

Tables

	Age Task	Rate (type)	3	4	5	6	7	9	10	11	13	16	Ad.
Kowal et al., 1975		SR			2.15		2.86	3.24		3.26	3.83	4	
Pindzola et al., 1989		AR	2.9	3.1	3								
Walker et al., 1992	Narr	AR	3.8		4.3								
Hall & al., 1999	Conv	AR	3.84	3.94	3.92								
Ryan, 2000	Conv	AR		3.8									
Walker & Archibald, 2006	Narr	AR		3.6	3.2	3.4							
Sturm & Seery, 2007	Narr	AR					4.5	5.3		5.3			
	Conv	AR					4.52	5.6		5.5			
	Narr	SR					2.4	2.7		2.9			
	Conv	SR					2.4	2.7		2.7			
Logan et al., 2011	Narr	AR				3.87		3.95					
	Conv	AR				3.54		3.99					
	Narr	SR				2.72		2.89					
	Conv	SR				2.58		2.88					
Nip & Green, 2013	Narr	AR		3			3.7		3.5		4.2	4.3	4.6
		SR		1.9			2.5		2.9		3.5	3.7	4

Table 1 – Selected results from studies examining the effect of age upon articulation rate (AR) and speech rate (SR) measured on syll. per sec. (\bar{x}) in typically developing children in conversation (Conv) and narration (Narr) tasks.

	4YRS	6YRS	7YRS	8YRS	9YRS	10YRS
Average age (year;month)	4;4	6;1	7;1	8;4	9;9	10;9
Age span (months)	43-60	66-78	80-92	94-109	113-121	123-136
Number of participants	15	15	12	13	16	14
Girls/Boys	5/10	8/7	5/7	4/9	8/8	10/4

Table 2 – Study population

	4YRS	6YRS	7YRS	8YRS	9YRS	10YRS
Narration time (sec)	41.66	61.04	100.39	87.33	103.38	95.43
	(19.97)	(34.78)	(52.76)	(38.42)	(48.25)	(33.87)
	33.25	57.20	95.92	71.85	100.92	103.36
Articulation rate (syll/sec)	3.84	3.88	3.54	4.02	4.08	4.29
	(0.42)	(0.40)	(0.50)	(0.41)	(0.47)	(0.50)

Table 3 – Mean (SD) *Median* for narration time and speech rate by age.

Articulation rate and phonic groups

	4YRS	6YRS	7YRS	8YRS	9YRS	10YRS
PG (\bar{x})	33.13 (14.42)	37.47 (21.71)	63.00 (33.72)	55.62 (28.44)	62.19 (28.58)	49.85 (20.07)
Syllables (\bar{x})	156.53	234.20	346.17	354.62	423.81	407.36
Words (\bar{x})	112.27	173.67	257.75	260.23	316.19	304.43
Clauses (\bar{x})	19.13 (7.42)	28.87 (16.44)	45.67 (23.97)	44.62 (22.75)	56.88 (32.67)	53.64 (18.24)

Table 4 – Mean number (SD) of PGs, syllables, words and clauses by age.

	4YRS	6YRS	7YRS	8YRS	9YRS	10YRS
PG time (sec)	1.25 (0.28)	1.65 (0.26)	1.67 (0.48)	1.62 (0.29)	1.70 (0.44)	1.97 (0.39)
Syllables (\bar{x} per PG)	4.73	6.44	5.81	6.51	6.91	8.32
Words (\bar{x} per PG)	3.44	4.79	4.37	4.86	5.21	6.30
Clauses (\bar{x} per PG)	0.60 (0.13) <i>0.58</i>	0.79 (0.23) <i>0.79</i>	0.76 (0.26) <i>0.69</i>	0.82 (0.19) <i>0.80</i>	0.90 (0.27) <i>0.85</i>	1.11 (0.24) <i>1.05</i>

Table 5 – Mean (SD) *Median* for PG time and PG density measures by age.

Articulation rate and phonic groups

Figures

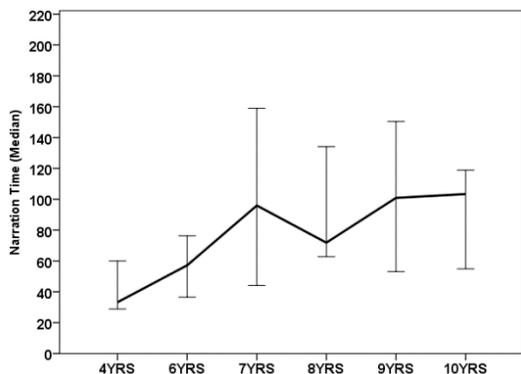


Fig1.1_Narration time (Mdn)

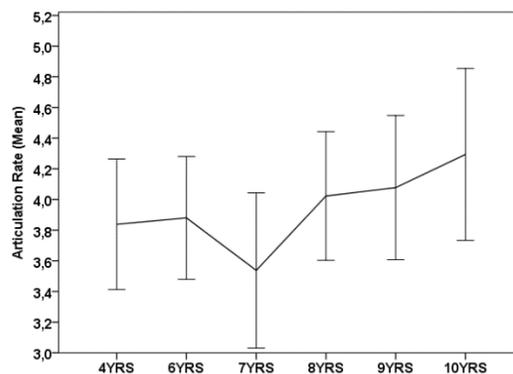


Fig1.2_Articulation rate (M)

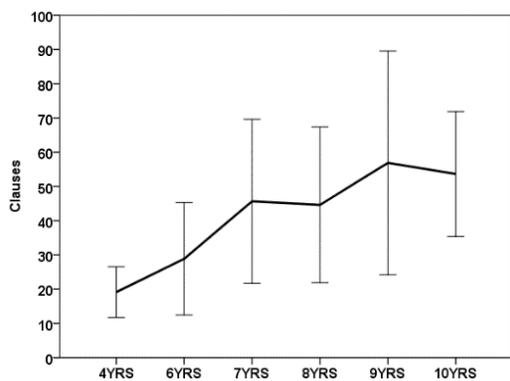


Fig2.1_Clauses (M)

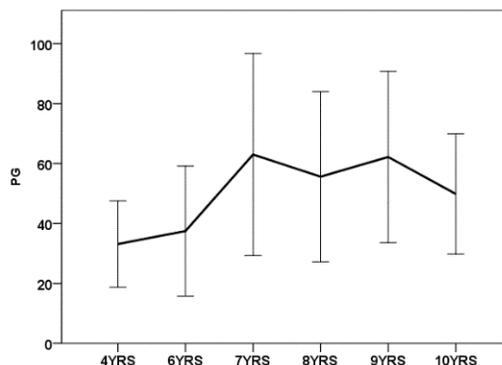


Fig2.2_PG (M)

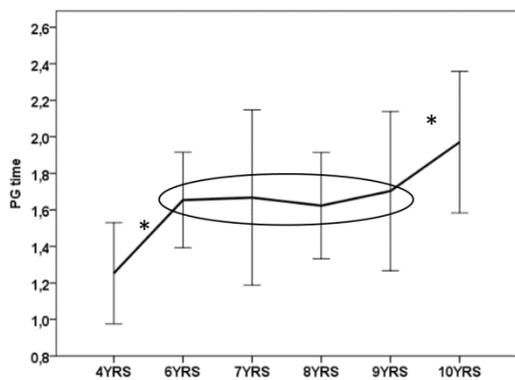


Fig3.1_PG time (M)

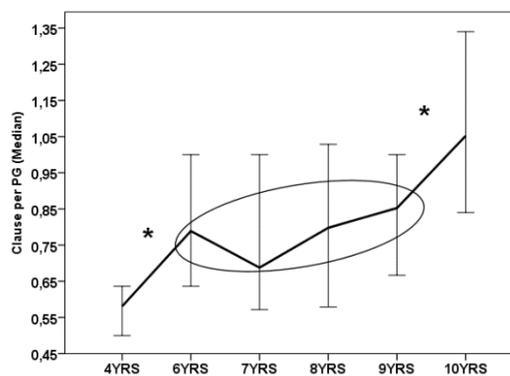


Fig3.2_clause per pg (Mdn)