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The emergence of rhythmic strategies for clarifying speech: variation of syllable rate and pausing in adults, children and teenagers

Valerie Hazan[1], Michèle Pettinato[2]

[1 2]*Speech Hearing and Phonetic Sciences, UCL, London UK*

v.hazan@ucl.ac.uk, Michele.Pettinato@uantwerpen.be

Abstract

This study focuses on the development of two temporal aspects of speech production, articulation rate and pausing, in children aged 9 to 14 years. Both measures were examined in spontaneous speech produced in interaction with a friend of the same age range and gender while completing a collaborative picture task. To investigate the use of articulation rate and pausing as clear speech strategies, two conditions were used that differed in the ease of communication between the two talkers. Articulation rate was higher in adults than in child groups, in male than female speakers, and was used as a clear speech strategy by all age groups. Pause frequency was variable within groups, but there was greater evidence of an increase in pause frequency as a clear strategy in adults than child groups, with no gender effect found for this measure. Overall, this study provides evidence for ongoing developments in certain aspects of speech production until adulthood.

Keywords: speech production, speech development, connected discourse, articulation rate.

1. Introduction

There has been much attention on early stages of development in speech production, but while children are efficient communicators by the time they enter school there is also evidence that their production of speech sounds is more variable than adults until early adolescence at least (e.g., Lee et al., 1999). Given this lesser degree of control over speech production, one area of interest is the development of intrinsic articulation rate in spontaneous speech, as this is likely to reflect development in articulatory control (Lee et al., 1999). A review of studies of articulation rate, mostly involving American children, suggest a developmental trend in children with increases in articulation rate over the first ten years or so of life (Logan et al., 2011); Sturm and Seery (2007) found no difference in articulation rate for conversational speech between 9 and 11 year olds; the task involved children answering open questions by an adult researcher. Neither of these studies provides comparative articulation rate data for adults. Jacewicz et al. (2010) did include both children aged 8 to 13 and adults aged between 20 and 91 years, and one of the tasks collected conversational speech in response to open questions (e.g. speaking about family, friends, daily activities).The model fitted to the data suggested an increase in articulation with age approximately until the age of 45 years, suggesting that adolescents use slower articulation rates than young adults.

Evidence for gender effects on articulation is mixed. Some adult studies have found evidence of faster articulation rates in men than women (e.g. Jacewicz et al., 2010; Quené, 2008) but, to our knowledge, the effect of gender has not been investigated in depth in studies of articulation rate in children.

The frequency and duration of pausing is another aspect of the development of timing control in speech. Pausing is influenced by cognitive processing and planning, and developmental trends have been found in pause frequency and duration, with changes obtained for these measures between children in kindergarden (aged 5-6) and 7-8 year olds (Sabin et al., 1979). In a recent study comparing 5-6 year olds to adults, using a story narration task to elicit spontaneous speech, Redford (2013) found that young children were less adept than adults at pausing in linguistically-appropriate locations.

Changes in articulation rate and pausing are two prominent strategies that are used when adults attempt to clarify their speech in adverse listening conditions (for a review of clear speech strategie, see Smiljanic and Bradlow, 2009). There has been much interest in the study of clear speaking styles in adult speakers, as these reflect adaptations that speakers make in order to maximize communication efficiency, either in adverse listening conditions, or when conversing with an interlocutor with reduced language abilities (e.g. L2 speaker or young child). Clear speaking styles involve enhancements of a wide range of acoustic-phonetic characteristics; in addition to changes in articulation rate and pausing, as mentioned above, changes can involve pitch characteristics, vowel space area and intensity. It is also known that there are significant individual differences in clear speech strategies (e.g. Ferguson, 2004; Maniwa et al., 2009) and that such strategies are, to an extent, adapted to the specific communication barriers they are seeking to overcome (Hazan and Baker, 2011). Being able to increase the clarity of one's speech for the benefit of an 'impaired' interlocutor is therefore likely to be a skilled aspect of speech production but little is known about the range and extent of clear speech adaptations in children. A study involving 3 to 5 year olds showed that the older children in the study were making some adaptations to their speech but that these adaptations were not adult-like (Redford and Gildersleeve-Neumann, 2009). A more recent study involving 11 children of a similar age engaged in an object naming task involving interaction with a puppet did find evidence of clear speech characteristics: the clear speech condition was characterised by a larger vowel area together with changes to the duration of vowels and to their fundamental frequency (Syrett and Kawahara, in press). In that study, perception tests with adult listeners showed that the two speaking styles produced by the children were discriminable by adults. There is therefore evidence of early stages of clear speech adaptations in preschool children but with the potential for further developments.

The research objectives were as follows. First, we wished to establish whether children's articulation rate and pause frequency had reached adult-like values within the 9 to 14 year old age range as suggested by the previous literature. Note that

our measurements are based on spontaneous speech produced with communicative intent during a problem-solving task with another speaker rather than from picture descriptions, answers to open question or story narrations. Second, we wished to examine the use of decrease in articulation rate and increase in pausing frequencies as 'clear speech' strategies when carrying out the task with the same interlocutor hearing in adverse conditions. Third, we wished to investigate whether there was evidence of a gender effect emerging within this age range.

Our initial results (Pettinato and Hazan, 2013) based on a group of 40 children (twenty 9-10 year olds and twenty 13-14 year olds) suggested that a reduction in mean word duration was a primary means of clarifying speech addressed to an 'impaired' interlocutor, but while adults increased the frequency of their pauses in the 'communication barrier' condition, younger children did not. Here, we have extended this work by significantly increasing the number of child participants in our study (96 children aged between 9 and 14 years) and by using a measure of articulation rate rather than mean word duration, to enable an easier comparison with previous studies.

2. Method

2.1. Speech recordings

Recordings were made of spontaneous speech produced in interaction with another talker of the same age and gender while completing a collaborative 'spot the difference' picture task using the diapixUK materials (Baker and Hazan, 2011). The two talkers, who knew each other, were seated in separate sound-treated rooms and could not see each other; they communicated via headsets. Articulation rate and pausing were examined in two conditions that differed in the ease of communication between the two talkers. In the 'no barrier' (NOB) condition, both talkers could hear each other normally and therefore the measures obtained reflect intrinsic articulation rates and pausing frequency in connected discourse. In the vocoder (VOC) condition, communication was degraded by passing the speech of one of the talkers through a three-channel noise-excited vocoder before it reached the other talker. This caused the unimpaired talker to clarify his or her speech in order to maintain efficient communication. This condition is used to investigate whether a talker changes articulation rate and pausing frequency as clarification strategies when communicating with an 'impaired' interlocutor. The speech was analysed for both the NOB and VOC conditions for the unimpaired talker, named 'talker A'. The average duration of each recording was around 10 minutes yielding around 4 minutes of speech to be analysed per talker per condition. Analyses of task transaction time (time taken to find the first 8 differences in the pictures) did not show evidence of an age effect suggesting that the task itself was equally suitable for children and adults. Further details of recording procedure can be found in Hazan and Baker (2011) which reported the analysis of adult speech recording elicited using the same procedures.

2.2. Participants

Recordings were made for 96 child participants as 'talker A': thirty 9-10 year olds (14F, 16 M), twenty-four 11-12 year olds (16F, 8M), forty-two 13-14 year olds (20F, 22 M). The child recordings were compared to those of 20 adults (9F, 11 M) from the published LUCID corpus (Baker and Hazan, 2011), recorded under the same conditions.

3. Results

The following measures were calculated for each talker A in each condition. Articulation rate was calculated as the number of syllables produced by talker A divided by the total duration of speech segments (excluding fillers, silences, etc) for that talker. Syllable counts were calculated from the orthographic transcriptions of the spontaneous speech using the qdap package in R (Rinker, 2013).

Pauses (SIL) had also been manually annotated in the Praat textgrids, using the criterion that a SIL was defined as a within-talker pause of at least 500 ms in duration. A normalised measure of pause rate was calculated as the number of pauses divided by the number of words (excluding fillers and interrupted words). Mean pause duration was also calculated.

Linear mixed effect models were used, with participant treated as a random effect and condition, age group and gender as fixed factors. Statistics were carried out in R using the lme4 package (Bates et al., 2014).

3.1. Articulation rate

Box plots of articulation rate as a function of age group and condition are shown in Figure 1, and a table also shows mean articulation rate as a function of gender and age group per condition (Table 1). There was a significant effect of condition [$F(1,108)=333.56$; $p<0.0001$]: articulation rate was slower in the VOC condition (M = 3.2) than NOB condition (M = 4.1). The effect of age group was also significant [$F(3,108) =18.09$; $p<0.0001$]. The age effect was examined in more detail in post-hoc analyses. Adults had a higher articulation rate than all child age groups, and the 13-14 year old group had a higher articulation rate than the 9-10 year old group. The age group by condition interaction was not significant, suggesting that all age groups used a reduction in speech rate as a clear speech strategy. The effect of gender was significant [$F(1,108) =17.84$; $p<0.0001$] due to a slower articulation rate in female (M=3.5) than male (M=3.9) talkers. A gender by condition interaction ($p<0.04$) seemed due to a greater gender effect in the VOC condition. The condition by age by gender interaction ($p<0.006$) was not clearly interpretable.

Table 1: *Means and standard deviations for articulation rates (syllables/second) as a function of age group and sex.*

Age group	sex	NOB	S.D.	VOC	S.D.
9-10 yr olds	F	3.8	*0.4*	2.6	*0.6*
	M	3.7	*0.4*	3.1	*0.5*
11-12 year olds	F	3.9	*0.4*	2.9	*0.6*
	M	4.3	*0.3*	3.4	*0.5*
13-14 yr olds	F	4.0	*0.4*	3.1	*0.5*
	M	4.2	*0.6*	3.4	*0.5*
Adults	F	4.3	*0.5*	3.4	*0.5*
	M	5.0	*0.4*	3.9	*0.7*

The scatterplot in Figure 2 shows individual talkers' articulation rate in the NOB condition plotted against the VOC condition. This highlights the variation in intrinsic articulation rate (NOB) in all age groups. The fact that the great majority of data points are in the lower area of the scatterplot suggests that a majority of talkers did use a reduction in articulation rate as a strategy to clarify their speech for the benefit of their

interlocutor in the VOC condition. It is the case though that a number of talkers in all age groups showed little change in articulation rate across conditions (points near the diagonal).

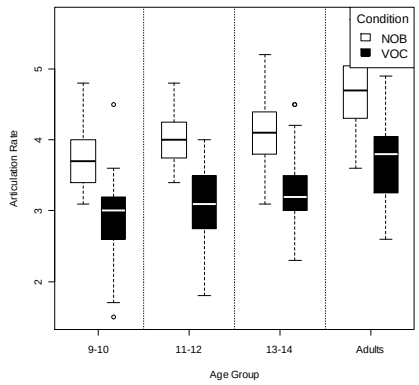

Figure 1: *Box-plot showing articulation rate (syllables per second) as a function of age group and condition. Adults had a significantly higher articulation rate than all child groups. All groups reduced their articulation rate in the VOC condition.*

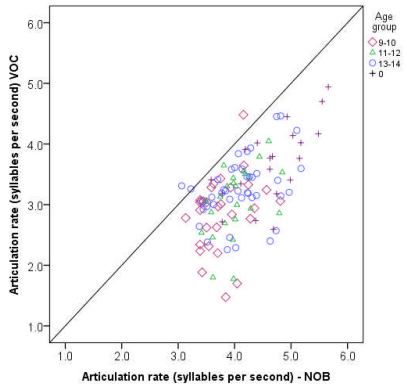

Figure 2: *Scatterplot showing articulation rate (syllables per second) as a function of age group and condition. Adults are labelled as '0'.*

3.2. Normalised pause frequency

Box plots of normalised pause frequency as a function of age group and condition are shown in Figure 3. For certain age groups at least, within-group variability was large suggesting that certain children used pausing as a strategy while others did not, both when communication was easy (NOB) and difficult (VOC). Given this individual variability, a more meaningful measure, in terms of investigating the effect of condition on pausing strategy, is one representing the relative change in normalised pause frequency across the NOB and VOC conditions (Figure 4). The effect of age group was significant [$F(3,110) = 5.87$; $p<0.0001$]. Post-hoc analyses showed that this effect was due to adults showing a greater relative change in pause frequency than all of the child age groups. The effect of gender was not significant.

3.3. Mean pause duration

For mean pause duration (Table 2), the effect of age group was significant [$F(1,108)=3.19$; $p<0.02$]. Post-hoc analyses showed that this was due to adults using shorter pause durations overall while child groups did not differ from each other. The effect of condition was not significant but there was a trend for adults lengthening their pause duration in the VOC condition. Neither the effect of gender nor any of the interactions were statistically significant.

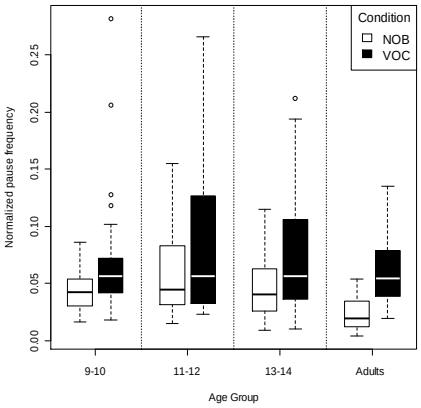

Figure 3: *Box plots of normalised pause frequency (number of pauses/number of words) as a function of age group and condition varying in ease of communication.*

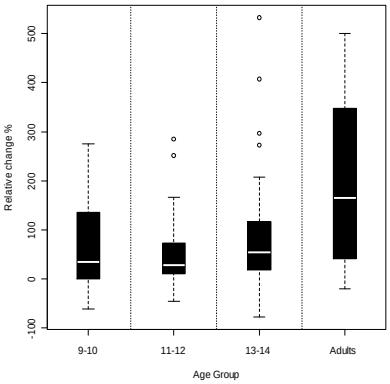

Figure 4: *Box plots showing the percentage relative change in normalised pause frequency across the NOB and VOC conditions. Two data points for the adult group were removed as outliers (>3 SD of the mean)*

Table 2: *Means and standard deviations for pause duration (seconds) as a function of age group*

Age group	NOB	S.D.	VOC	S.D.
9-10 year olds	1.17	*0.4*	1.13	*0.3*
11-12 year olds	1.13	*0.3*	1.22	*0.4*
13-14 year olds	1.12	*0.3*	1.18	*0.4*
Adults	0.89	*0.2*	1.00	*0.2*

4. Discussion and conclusion

In summary, intrinsic articulation rate as measured in a communicative task involving pairs of participants of the same gender and similar age had not reached adult-like levels by the age of 13-14 years. However, all child and adult groups did use a reduction of articulation rate as a strategy to clarify their speech when their interlocutor was experiencing an adverse listening condition. Although there was evidence of individual children and adolescents increasing pause

frequency as a clear speech strategy, group effects showed that the adult group used this strategy to a significantly greater extent than all groups of children and adolescents. Gender effects were found for articulation rate, with girls and women generally using a slower speech rate than boys and men. No gender effects were obtained for pause frequency and duration though.

It should be noted that the intrinsic articulation rates (in the 'no barrier' condition) obtained in our study are rather higher than the 2.7-3.3 syllable per second range cited in the literature for this age range (Logan et al., 2011), although closer to the articulation range seen in Jacewicz et al. (2010); this could be due to the use in our study of a collaborative task carried out between friends rather than more formal picture narrations or open-question interactions with adults used in previous studies. There was some evidence of an ongoing developmental trend within this age range, with 13-14 year olds using a faster articulation rate on average than 9-10 year olds. There was also a further significant difference in articulation rate between young adolescents and adults; this concurs with the findings of Jacewicz et al. (2010) for conversational monologues as they observed a trend for increasing articulation rate until middle age. The finding of a gender effect, with slower articulation rate for female talkers, also concurs with previous findings (e.g. Jacewicz et al., 2010). In that study, sociophonetic factors were argued for this gender effect and so it is of interest to see that these gender effects are already apparent within this age range. Female talkers tend to be more listener-oriented than male talkers, and have been shown to generally be more intelligible than male talkers (e.g., Hazan and Markham, 2004). Less of a developmental trend within the 9 to 14 year old age range was in evidence for pause frequency, and adults tended to use less pauses overall. A further analysis of the location of pauses in relation to discourse structure is needed for a better understanding of these differences (Redford, 2013). The finding that children were using pauses of longer duration than adults could be related to the communicative task involving a greater cognitive load for younger talkers, possibly because of the lack of face-to-face interaction.

This study also examined clear speech strategies used by children within the temporal domain. Articulation rate reduction appeared to be a strategy used by all age groups as shown by the lack of an age by condition interaction. This comes as no surprise as this strategy is evident in the great majority of clear speech studies. It should be noted though that the kind of individual differences in clear speech strategies often seen for adults (e.g., Krause and Braida, 2004; Maniwa et al., 2009) is also present here, as a number of children and adults showed little or no reduction in articulation rate in the condition involving effortful communication between the two speakers. Increasing the frequency of pauses as a clear strategy was however much more variable, as shown by the sizeable within group variance. It was mostly in evidence in adult speakers, as a significant age effect was obtained, with adults differing from all groups of children, but in all groups, as shown in Figure 4, there was evidence of some individuals using this strategy. Overall, this study provides evidence for ongoing developments in certain aspects of speech production until adulthood.

5. Acknowledgements

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6. References

Baker, R., Hazan, V. (2011). "DiapixUK: task materials for the elicitation of multiple spontaneous speech dialogs", *Behavior Research Methods*, 43, pp. 761-770.

Bates, D.M., Maechler, M., & Bolker, B. (2014*). lme4: Linear mixed-effects models using S4 classes*. R package version 1.1-5.

Ferguson, S.H. (2004)."Talker differences in clear and conversational speech: Vowel intelligibility for normal-hearing listeners", *J. Acoust. Soc. Am.*, 116, pp. 2365–2373.

Hazan, V. & Baker, R. (2011). "Acoustic-phonetic characteristics of speech produced with communicative intent to counter adverse listening conditions", *J. Acoust. Soc. Am.*, 130, pp. 2139-2152.

Hazan, V. & Markham, D. (2004). "Acoustic-phonetic correlates of talker intelligibility for adults and children", *J. Acoust. Soc. Am.*, 116, pp.3108-3118.

Jacewicz, E., Fox, R. A., and Wei, L. (2010). "Between-speaker and within-speaker variation in speech tempo of American English", *J. Acoust. Soc. Am.*, 128, 839-850.

Krause, J.C., Braida, L.D. (2004), "Acoustic properties of naturally produced clear speech at normal speaking rates", *J. Acoust. Soc. Am.*, 115, pp. 362-378.

Lee, S., Potamianos, A. and Narayanan, S. (2009) "Acoustics of children's speech: Developmental changes of temporal and spectral parameters", *J. Acoust. Soc. Am.*, 105, pp. 1455-1468.

Logan, K.J., Byrd, C.T., Mazzocchi, E.M., & Gillam, R.B. (2010). "Speaking rate characteristics of elementary-school-aged children who do and do not stutter", *Journal of Communication Disorders*, 44, pp. 130-147.

Maniwa, K, A. Jongman, & T. Wade (2009). "Perception of clear English fricatives by normal-hearing and simulated hearing-impaired listeners", *J. Acoust. Soc. Am.*, 125, pp. 3962-3973.

Pettinato, M. and Hazan V. (2013). "The development of clear speech strategies in 9-14 year olds", *Proceedings of Meetings on Acoustics*, 19, pp. 060121.

Quené, H. (2008). "Multilevel modeling of between-speaker and within-speaker variation in spontaneous speech tempo", *J. Acoust. Soc. Am.*, 123, pp. 1104-1113.

Redford, M.A. (2013). "A comparative analysis of pausing in child and adult storytelling", *App. Psycholinguistics*, 34, pp. 569-589.

Redford, M.A., & Gildersleeve-Neumann, C.E. (2009). "The development of distinct speaking styles in preschool children", *J. Speech Lang. Hear. Res.*, 52, pp. 1434-1448.

Rinker, T. W. (2013). *qdap: Quantitative Discourse Analysis Package. version 1.3.1*. University at Buffalo. Buffalo, New York. http://github.com/trinker/qdap

Sabin E, Clemmer E, O'Connell D, Kowal S. (1979). "A pausological approach to speech development". In: Siegman A, Feldstein S, editors. *Of speech and time: temporal speech patterns in interpersonal contexts. Hillsdale*, NJ: Lawrence Erlbaum, pp. 35–55

Smiljanic, R. and Bradlow, A. R. (2009). "Speaking and hearing clearly: Talker and listener factors in speaking style changes", *Linguistics and Language Compass*, 3, pp. 236–264.

Sturm, J.A., Seery, C.H. (2007). "Speech and articulatory rates of school-age children in conversation and narrative contexts", *Lang., Speech, & Hearing Services in Schools*, 38, pp. 47–59.

Syrett, K., & Kawahara, S. (in press). "Production and perception of listener-oriented clear speech in child language", *J. Child Language.*