

# Speech Timing in Typically Developing Mandarin-Speaking Children From Ages 3 To 4

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## Abstract

This study aims to develop a better understanding of the speech timing development in Mandarin-speaking children from 3 to 4 years of age. Data were selected from two typically developing children. Four 50-min recordings were collected during 3 and 4 years old based on natural conversation among the observers, participants, and the parents, and the picture-naming task. Speech timing were measured by Praat, including speaking rate, articulation rate, mean length of utterance (MLUs), mean utterance duration, mean word duration, pause ratio, and volubility. Major findings of the current study are: 1) Five measurements (speaking rate, mean length of utterance (MLUs), mean utterance length, mean word duration and volubility) decreased with age in both children; 2) Articulation rate of both children increased with age; 3) Comparing with the findings from previous studies, pause ratio of both slightly increased with age. These findings not only contribute to a more comprehensive data for assessment, it also can be a reference in speech intervention.

Keywords: speaking rate, mean length of utterance (MLUs), mean utterance length, mean word duration, volubility

## 1 Introduction

Speech timing, also known as speaking rates, is a product of several factors, including biological factors (e.g., anatomic growth, neurologic and neuromuscular maturation), sensorimotor and language processes (e.g., motor learning, and semantic, lexical, and phonologic access, and motor programming and planning) (Kent, 2004; Nip and Green, 2013; Redford, 2015). Speaking rates could be a crucial indicator of typical speech development and speech disorders, for example, stuttering, cluttering, specific language impairment, apraxias, and dysarthrias. (Hall et al.,

1999; Smith et al., 2011; Flipsen, 2002). Speaking rate not only serves as a metric, it can also be a common target in speech intervention to improve speech production in individuals with speech motor involvement.

## 2 Purpose of Study and Research Questions

Due to limited longitudinal studies and lack of data on Mandarin-speaking children, our knowledge of speech rate development in Mandarin-speakers remains inadequate. Hence, this study was to develop a better understanding of the speech rate development in Mandarin-speaking children from 3 to 4 years of age.

Research questions include: 1) Are there any differences in speaking rate, articulation rate and pause ratio between 3 and 4 years old? 2) Are there any gender differences in speaking rate, articulation rate and pause ratio in Taiwanese Mandarin-speaking children?

## 3 Literature Review

### 3.1 Speech Rate

Speech rate reflects a speaker's global aspects of speech production (e.g. language formation, speed of articulator movement, cognitive, linguistic, and motor workloads). Speech rate is measured from the onset to the offset of the spoken words or sentences including articulation rate, pauses, disfluencies and repetitions. To be more specific, it is calculated by dividing the number of syllables produced by sentence duration, in the unit of words per minute (WPM) or word per second (WPS) and/or syllables per minute (syl/m) or syllables per second (syl/s). In Mandarin Chinese, each word contains only one syllable, which means the number of words is equivalent to the number of syllables, thus, words per minute (WPM) or word per second (WPS) can be used as calculation unit.

### 3.2 Articulation Rate and Pauses

Articulation rate indicates our speech and /or exactness of articulatory movement, and reflects the time used for speech motor control during speech. It calculates only the total number of perceptual fluently syllables or words in a particular amount of time. Perceptual fluently utterance excludes any disfluencies, hesitations, or pauses greater than 250ms (Yaruss, 1997). Walker et al. (1992) indicated that articulation rates in both syllables per second and phones per second were significantly faster in the 5-year-olds than in the 3-year olds.

Pauses is dividing pause duration by total speech duration and may serve as different functions: physiological functions (breathing, swallowing), linguistic functions (syntactic or semantic), super-ordinated, higher-level functions (language formation), pragmatic function (indicating a change of topic or speaker) (Schelten-Cornish, 2007). Pausing will decrease over the remainder of childhood (Tendera et al., 2019).

### 3.3 Different Variables of Speech Timing

#### 3.3.1 Ages

Several age-related studies suggest speaking rates are gradually increase from the one-word stage in toddlerhood until it reaches a stable level in adolescence or early adulthood (Nip and Green, 2013; Tingley and Allen, 1975). As cited in Tendera et al., (2019), Amster (1984) suggested children between ages 2;6 and 3;5 show a slight increase from 2.78 to 2.91 syllables per. However, possible absence of change in speech rate between ages 4;0 and 6;0 (Amir and Grinfield, 2011; Hall et al., 1999; Pindzola et al., 1989), and 7;0 and 9;0 (Sturm and Seery, 2007) suggests that speaking rate development is not in a smooth developmental trajectory.

#### 3.3.2 Cognitive-linguistics load and Contextual Differences

Other studies suggest that both articulation rate and pause time vary with cognitive–linguistic load and contextual differences (Logan et al., 2012; Nip and Green, 2013; Walker and Archibald, 2006; Walker et al., 1992). Darling-White and Banks (2021) suggested that sentence length differentially impacts the component parts of speech rate, articulation rate and pause time. By around age 3, pausing will become more frequent due to children

attempting to produce more complex linguistic structures (Rispoli and Hadley, 2001). Hence, increases in sentence length led to increases in speech rate, primarily due to increases in articulation rate.

For the context differences, as cited in Tremblay and Deschamps (2017), according to Duchin and Mysak (1987, p.256), “Speech rate differs significantly, in decreasing order for oral reading, conversation, and picture description”, which means narrative contexts may result in slower rates than rate in conversation speech, because narrative contexts require more language formulation than do conversational speech contexts.

## 4 Methodology

### 4.1 Participants

Two typically developing children (one male and one female) are involved in current research. For inclusion in the study, participants were native speakers of Mandarin Chinese with no significant defects in the structure or function of the speech and hearing mechanisms, no significant cognitive deficits or psychosocial dysfunction. The data is part of a database with about 30 children conducted through grants from National Science and Technology Council. In this ongoing longitudinal study, the data have been recorded once every 3 months and annotated for future research purposes. In current research, data were selected at two ages of two children (3;0 and 4;0). All recordings were taken at home under the natural interaction with caregivers and an experimenter. A total of 4 recordings were selected; each session lasted for around 50 minutes. The SHURE mini microphone connected to TASCAM recorder were used to collect speech sounds. To ensure children speech were recorded properly, the mini microphone was stapled on children’s clothes.

Subject	Sex	1 <sup>st</sup> Recording (year; month, day)	2 <sup>nd</sup> Recording (year; month, day).
Child A	F	3;0,11	4;0,10
Child B	M	3;3,01	4;0,07

Note. F=female; M=male.

Table 1. Ages of the two children in each recording.

### 4.2 Coding and Data Analysis

The child’s speech was divided into utterances. Utterances were defined as follows: “it is a string

of words that communicate an idea, is bounded by a simple intonational contour, and/or grammatically complete” (Golinkoff and Ames 1979). For 3-17 years old individuals, if two clauses were produced on a single breath, they were coded as one utterance. Utterances could not be clearly heard because of interfering toy noise or adult speech were excluded from analysis. Phrases were also excluded if (a) they were frank imitations of the examiner, (b) they were produced during obviously excited states, (c) utterances with any pause of 250ms or greater.

Each utterance was displayed in Praat (Boersma and Weenink, 2022) and an associated textgrid was generated. There were three tier added in Praat: the first tier was the total count of child’s utterances, the second tier was the brief transcription of child’s spontaneous speech, and the last tier was the number of syllables counted. Segmentation on onset and offset of each child’s speech turn was done by using auditory judgment and visual cues. Onsets are at the first evidence of speech-related spectral energy evidenced on both the spectrogram and the waveform enhanced display; while offsets are at the last evidence of speech-related spectral energy within the displayed utterance.

## 5 Findings

Major findings of the current study are: 1) Except for the articulation rate and pause ratio, other five measurements (speaking rate, mean length of utterance (MLU), mean utterance length, mean word duration and volubility) decreased with age in both children; 2) Articulation rate of both children increased with age; 3) Comparing with the findings from previous studies, pause ratio of both slightly increased with age. The measures of each recording from the two participants were presented in Table 2 and 3.

Child A		
<b>Age of Recordings (year; month, day)</b>	3;0,11	4;0,10
<b>Total words</b>	1441	1076
<b>Speaking rate (w/sec)</b>	0.464	0.354
<b>Articulation rate (w/sec)</b>	3.432	3.463
<b>Mean utterance duration (syll/utt)</b>	1.900	1.726
<b>Mean word duration (syll/w)</b>	0.291	0.289
<b>Pause ratio (%)</b>	86.48%	89.77%
<b>Mean Length of Utterance, MLU (w/utt)</b>	6.520	5.978
<b>Volubility (utt/min)</b>	4.270	3.555

<b>Mean word duration (syll/w)</b>	0.291	0.289
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<b>Mean Length of Utterance, MLU (w/utt)</b>	6.520	5.978
<b>Volubility (utt/min)</b>	4.270	3.555

Note. w=word; sec=second; syll=syllables; utt=utterance; min=minute.

Table 2. Age of recordings, total words and seven speech rate measurements of Child A.

Child B		
<b>Age of Recordings (year; month, day)</b>	3;3,01	4;0,07
<b>Total words</b>	1386	877
<b>Speaking rate (w/sec)</b>	0.463	0.287
<b>Articulation rate (w/sec)</b>	3.273	4.196
<b>Mean utterance duration (syll/utt)</b>	1.546	1.187
<b>Mean word duration (syll/w)</b>	0.306	0.238
<b>Pause ratio (%)</b>	85.86%	93.16%
<b>Mean Length of Utterance, MLU (w/utt)</b>	5.058	4.983
<b>Volubility (utt/min)</b>	5.487	3.457

Note. w=word; sec=second; syll=syllables; utt=utterance; min=minute.

Table 3. Age of recordings, total words and seven speech rate measurements of Child B.

Figure 1 and Figure 2 describe the distribution of speech rate of two participants in 3 and 4 years old. In both participants, the speaking rate, mean length of utterance (MLU), mean utterance length, mean word duration and volubility decreased with age, while the articulation rate and pause ratio increased with age in both children. In 4 years old, the articulation rate and pause ratio of Child A are less than those in Child B (Figures 3 and 4).

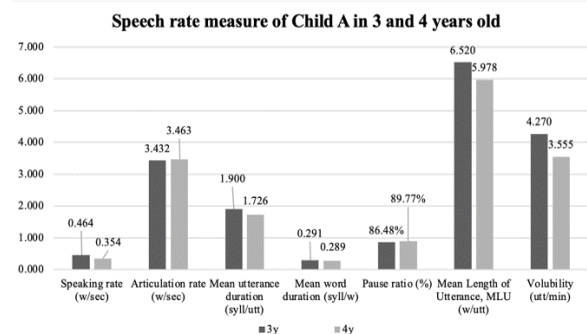


Figure 1. The distribution of speech rate of Child A in 3 and 4 years old.

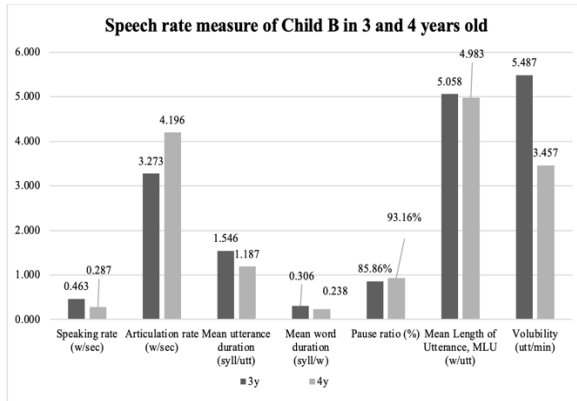


Figure 2. The distribution of speech rate of Child B in 3 and 4 years old.

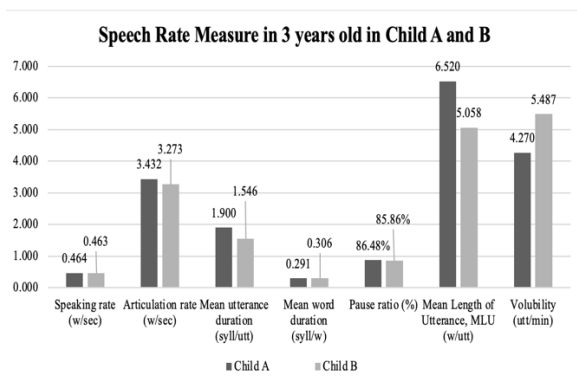


Figure 3. The distribution of speech rate in 3 years old of Child A and Child B.

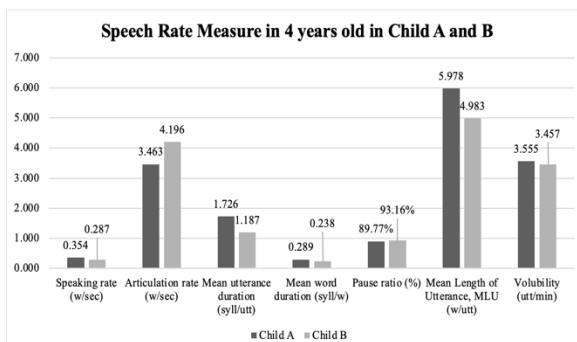


Figure 4. The distribution of speech rate in 4 years old of Child A and Child B.

## 6 Discussions

### 6.1 Comparison of speech rates with previous studies

In general expectation, speaking rate will increase gradually with age (Nip and Green, 2013; Tingley and Allen, 1975), while the pausing ratio will decrease with age. Results of this study show, contrary to expectations, that a developmental increase in speaking rate did not occur. The findings of the present study, together with those of Pindzola et al. (1989), Hall et al. (1999), Amir

and Grinfeld (2011) and Walker and Archibald (2006) suggest that speaking rate may not increase with age in the preschool years. However, it is possible that speech rate development are nonlinear. In Amir and Grinfeld (2011), for example, the articulation rates of Hebrew-speaking participants ( $n=20$ ) at age 3 and 5 were decreased (3;0=137.70 word per minute (WPM); 5;0=132.95 WPM; however increased at age 7 and 9 (7;0=162.13 WPM; 9;0=174.64 WPM). The increasing of pausing ratio suggest that children attempt to use more complex linguistic structures, especially by around age 3 (Rispoli and Hadley, 2001). Moreover, the correlation between speech rate and pause ratio is observed from the data, which is as the pause ratio increases, the speech rate decreases.

Only a few studies have reported sex differences in speech rate (Ryan, 2000; Walker and Archibald, 2006). In this study, the girl (Child A) speaks faster than the boy (Child B), but further statistical analysis is needed to prove if there are any significantly differences. In contrast, the boy produced significantly shorter utterances at age 3;0 (girl's MLU= 6.520; boy's MLU= 5.058) and 4;0 (girl's MLU= 5.978; boy's MLU= 4.983). Comparing with previous studies, these findings are controversial because most studies that reported sex comparisons did not find differences (e.g., Sturm and Seery, 2007; Walker and Archibald, 2006) or showed the opposite pattern in which preschool girls spoke slower than preschool boys (Tendera et al., 2019).

### 6.2 Limitations of the Study and Suggestions for Future Studies

Due to the limitations of time and data sources, the speech samples in this study only included two 3 to 4 years old children (only one male and one female). The findings, however, show that examining two age groups is insufficient to accurately represent the variations in rate that occur throughout time in the course of development in young children. Additional longitudinal studies with wider age groups and a larger number of children are needed to provide more definitive information on the nature of this development.

Overall speaking, for future research, speech samples could be collected through random sampling and include more participants with different age, gender and context (e.g. oral reading, conversation, and picture description) in order to

develop a better understanding of the speech rate development in Mandarin-speaking children.

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