

**The Development of Gender-differentiated /ɛ/ Production in Mandarin
Speaking Children**

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ABSTRACT

The goal of the present study is to examine the developmental trajectory of the gender-differentiated /ɕ/ production in Mandarin Chinese in terms of the relative contribution from anatomical development, prenatal hormonal effect, and gender typed behavior. The development of gendered /ɕ/ production has been an uncharted area of research. Mandarin-speaking participants were recruited from Grade 1 (age 7), Grade 6 (age 12), and Grade 10 (age 16) from schools in Luoyang, a city in central China. The participants spoke standard Mandarin and had no known speech, language, or hearing deficiency. They were asked to read a list of 36 Mandarin words with 18 target words beginning with fricatives /ɕ/ or /s/ followed by vowels /a/, /i/, or /u/. All the fricatives were extracted from the recorded speech and their spectral mean frequencies were obtained. The spectral mean frequency was used as an acoustic indicator for gender variation of the fricative production. Anatomical development was measured through height, weight, and head circumference. Prenatal hormonal variation was assessed by the 2D: 4D ratio of the right hand. Gender typed behavior was assessed via a parent-report Child Play Behavior and Activity Questionnaire (CPBAQ). The result showed that only the sound /ɕ/ exhibited gender-differentiated production. Gender difference of /ɕ/ was found to emerge between age 7 and age 12. Significant correlation existed only between gender typed behavior and gendered /ɕ/ production for 16-year old boys ($r=0.40$, $p=0.01$). No anatomical or prenatal hormonal effect was found for gender variation of /ɕ/ production. The emergence of gendered /ɕ/ production was interpreted to be associated with the beginning of sexual maturation at the onset of puberty and gender identity development that excels at adolescence. The development of gendered /ɕ/ production was considered to parallel gender identity development at first and later become part of the gender norms for boys in mid-or late-adolescence.

ACKNOWLEDGEMENTS

This study is part of an ongoing research project that examines the developmental process of both gendered speech production and perception. The research project is composed of two studies in parallel, targeting gendered fricative development among Mandarin-speaking children and among English-speaking children, respectfully, in order to form a cross-cultural comparison between the developmental trajectories of gendered speech. The research presented in this thesis partially fulfilled the gendered speech study targeting Mandarin children. The cross-cultural gendered speech research project is led by Dr. Fangfang Li, Dr. Drew Fendal, and Dr. Paul Vassy, from the Department of Psychology, University of Lethbridge, and is funded by the Community Research Excellence Development Opportunities grant from the University of Lethbridge as well as the Chinook Summer Research Award granted to me for conducting the Mandarin study in June, 2013.

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CHAPTER 1

INTRODUCTION

It is easily noticeable that men and women talk differently. From the commonly experienced communicative frustration when talking with the opposite sex, to the popular notion that “men are from Mars, and women are from Venus”, gender-differentiated speech is prevalent in society and influential in our daily communication. Although we can easily name a number of stereotypes of the “genderlect”, we are usually unaware of the kind of gender-related speech difference that is within individual vowels and consonants. Certain speech sounds are typically differential between male and female speakers and in turn, marks gender. In Mandarin Chinese, a voiceless sibilant fricative /ɕ/ has found to be a gender-marking sound (Cao, 1986; Hu, 1987; Li, 2008). Female speakers tend to produce /ɕ/ in a more anterior position than male speakers. There have only been a handful of studies conducted on gender variation of /ɕ/ and how the gender differentiation comes about has not been looked into. However, the gender-marking Mandarin fricative /ɕ/ finds great resemblance with an English gender-marker /s/ to which a relatively large body of research has been dedicated. Drawing references from both the documentation on gendered /ɕ/ and /s/, the following are proposed to be potential contributing factors to the origin of gendered /ɕ/ production: the anatomical difference in vocal tract length between female and male speakers, prenatal hormonal variation that may affect an individual’s gender-typed propensity, as well as the social influence that underlies an individual’s gender-typical behavior. The present study was undertaken in hope of shedding light on the developmental process of gendered /ɕ/ production in terms of the contribution from the social and biological factors above. Specifically, I am asking the following questions: at what age does gender divergence of /ɕ/

production begin? What is the relative contribution of the anatomical, prenatal biological, and social factor to gendered /ɜ/ production?

1.1 Gender-differentiated speech

Speech communicates not only linguistic information carried by the words and sentences, but also social and personal information about the speaker, including dialectical background, socioeconomic status, gender, age, and emotional state (Purnell, Idsardi, & Baugh, 1999; Clopper & Pisoni, 2004; Van Bezooijen & Gooskens, 1999; Docherty & Foulkes, 2001). Among the speech variations that convey multiple dimensions of the speaker's identity, the type of variation that marks gender is particularly salient. Noticeably, male and female speech differs in a systematic way. Recent studies have provided empirical evidence for some of the stereotypes of "genderlect" in terms of topic, content, word choice, pitch and intonation, as well as communicative styles (e.g., Haas, 1979). For instance, men talk more frequently about sports, money and business while women more about home and family; within a given topic, men refer to objects more often whilst women use more words implying evaluation, interpretation, and emotion; men tend to use more coarse words and less euphemistic expressions than women; men typically have lower pitch and smaller pitch range than women (e.g. Simpson, 2009); men are more direct and less polite in a conversation than women.

Gender-related speech variation is embedded at even the smallest unit of speech, speech sounds (i.e., vowels and consonants). It has been demonstrated that listeners are able to identify the sex of the speaker at a significantly greater-than-chance level from voiced, filtered, whispered, isolated vowels (Las, Waters, & Tyson, 1974) and from isolated voiceless fricatives, such as /f/, /θ/, /s/, and /ʃ/ (Schwartz, 1968; Ingemann, 1968). Gender-related difference in

speech sound production has been extensively documented. For example, female speakers tend to have longer vowel duration (Simpson, 2001, 2002), and longer voice onset time (VOT; the time duration between the release of a stop consonant, such as /b/, /p/, /t/, /d/, /k/, and /g/, and the onset of the voicing of the vowel) than male speakers (Swartz, 1992; Koenig 2000; Robb, Gilbert, & Lerman, 2005).

1.2 Gender marking /ʃ/ in mandarin Chinese

In Mandarin Chinese, there exists a voiceless sibilant fricative /ʃ/ that carries consistent and salient difference between female and male speakers and thus marks gender. It has been found that, on average, /ʃ/ is produced more frontally by female Mandarin speakers than male. The studies on gender variation of /ʃ/ production are scarce. However, the gender-marking Mandarin /ʃ/ is closely related to a relatively well studied English gender marker /s/. The two sounds are related not only because they both are voiceless sibilant fricatives and thus similar in phonetic properties and in manners of articulation, but more importantly, because they share the same way in which they are produced differentially between female and male speakers and similar acoustic consequence of the gendered production. Research on gendered /s/ provides a major source of reference for the present study on gendered /ʃ/ in Mandarin Chinese. Chapter One begins with a brief overview on the gender-marking English /s/, to illustrate its gender-marking property, the gender-differentiated way of production, and the acoustic consequence, that are shared between the English /s/ and the Mandarin /ʃ/.

1.2.1 Gender-marking /s/ in English

Among the gender-differentiated vowels and consonants, the English voiceless sibilant fricative /s/ is recognized as a robust marker for gender and a moderate indicator for male sexual

orientation. Gender-marking function of /s/ has been demonstrated in perception studies (e.g., Schwartz, 1968; Ingemann, 1968). In one of the earliest studies testing listeners' ability in identifying the speaker's sex based on fricatives alone (1968), Scharz found that listeners were able to identify the speaker's sex upon hearing isolated /s/ with a striking 93% accuracy. Meanwhile, perception studies also revealed an above-chance level identification rate of naïve listeners for male speakers' sexual orientation.

Typically, female speakers tend to produce /s/ more frontally than male speakers (Fuchs, & Toda, 2010; Stuart-Smith, 2007; Flipsen, P. Jr., Shriberg, Weismer, Karlsson, & McSweeney, 1999; Strand, 1999), and cases of frontal production among homosexual male speakers have also been reported (Munson & Zimmerman, 2006), known as “lispings” (Van Borsel et al. 2009). What exactly is “frontal production” of /s/? Generally, /s/ is produced by forming a narrow constriction between the front part of the tongue (the blade of the tongue) and the upper roof of the mouth, which creates turbulence when rapid air passes through and strikes the teeth downstream. Figure 1.1 illustrates the oral configuration of /s/ production. The place of constriction on the front-back dimension plays a key role in the gender-related variation of /s/ production. Female speakers tend to have a constriction that is closer to the teeth than male speakers, resulting in a frontally produced /s/. The sound /s/ is typically described as an alveolar fricative, as its place of constriction is at the vicinity of the upper alveolar ridge, between the upper teeth and the hard palate (i.e., the roof of the mouth). However, the exact place of constriction may vary among speakers. A slight alteration of the distance between the constriction and the upper teeth induces phonetic variation that is within the phonemic category of /s/, i.e., native listeners perceive the sound variant as /s/ rather than another speech sound. Such subphonemic variation is associated with the speaker's sex and/or sexual orientation.

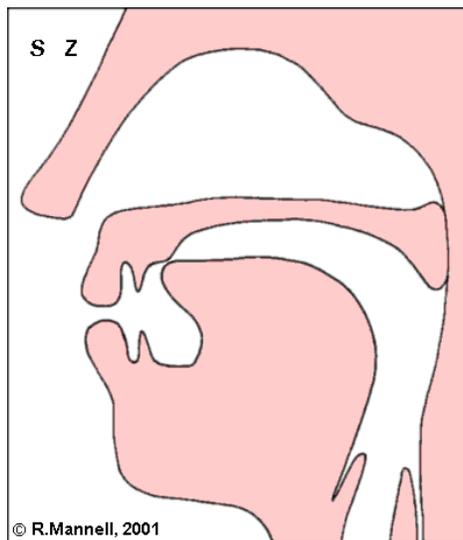


Figure 1.1: Sagittal view of the vocal tract for /s/ articulation

Minuscule variation of the place of constriction on the front-back axis may not result in acute auditory changes of /s/ but can be easily seen from a sound spectrum. A sound spectrum describes the sound in terms of its frequency and energy. Figure 1.2 shows an example of spectrum of a central slice of /s/ from the word “sit”. The acoustic parameter that is commonly associated with the place of constriction in /s/ production is the spectral mean frequency (alternatively named as the weighted mean frequency or the spectral center of gravity). The spectral mean frequency reflects the frequency range where the energy of the sound concentrates. It corresponds to the length of the front resonating cavity formed between the oral constriction and the teeth in /s/ production. A higher spectral mean indicates a shorter front cavity or a place of constriction closer to the teeth, and vice versa. Typically, a female speaker has shorter front resonating cavity than a male speaker and produces /s/ with a higher spectral mean. Figure 1.3 provides the spectra of /s/ produced by a female and a male, with the red-dotted line indicating the location of the spectral mean.

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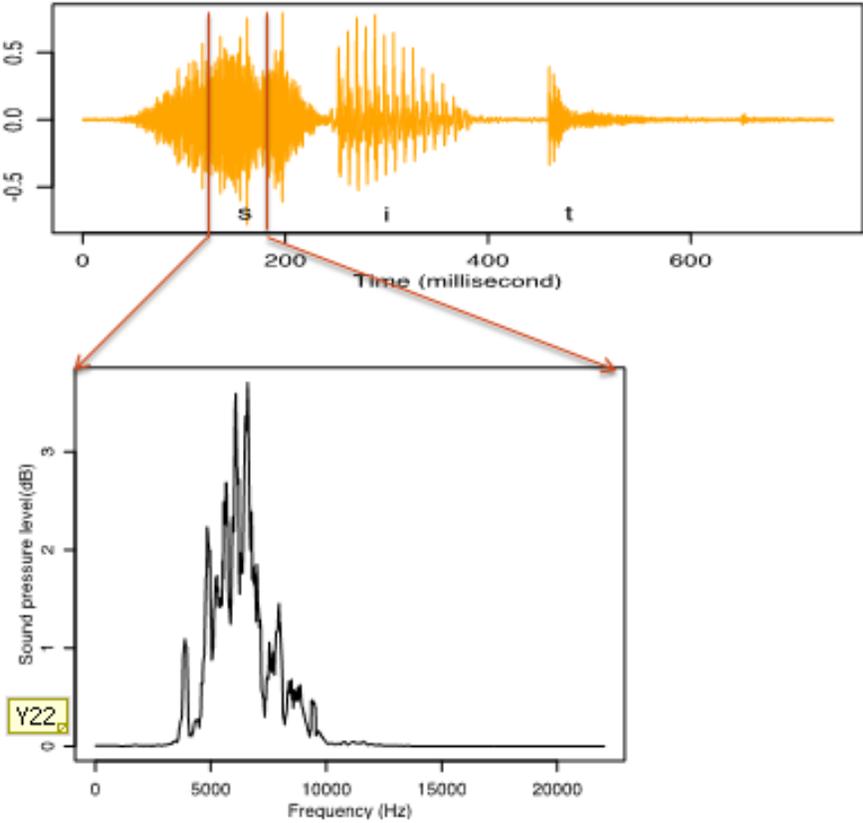
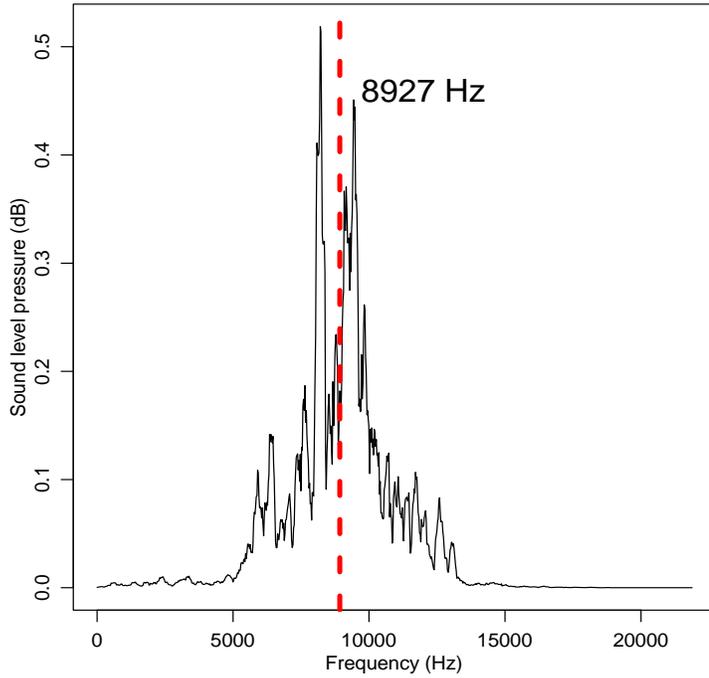
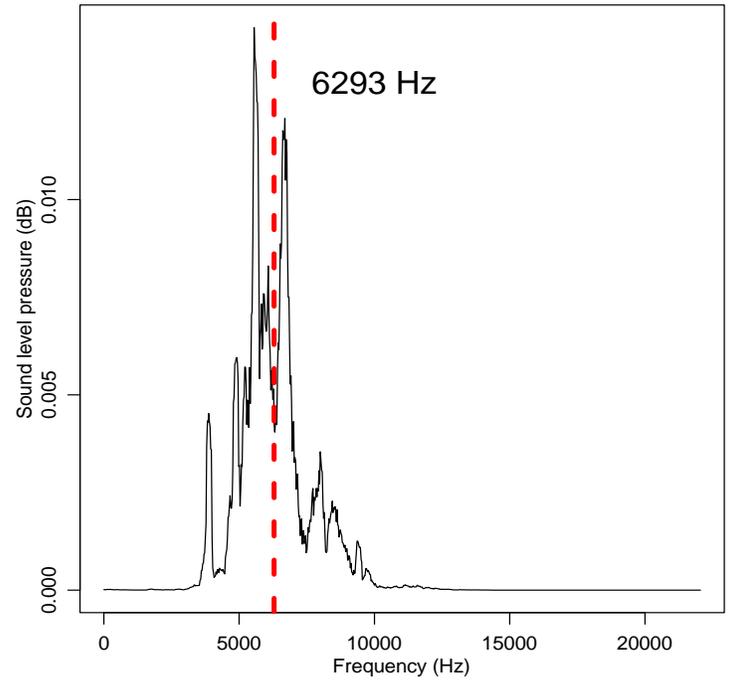


Figure 1.2: The spectrum of the 40ms central slice of /s/ at the beginning of the word “sit”

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a. Female



b. Male

Figure 1.3: Spectrum of /s/ produced by a female speaker (a) and by a male speaker (b), with the red-dotted line marking where the spectral mean frequency is located on the x-axis of the spectrum.

1.2.2 Gender Marking /ɕ/ in Mandarin Chinese

Mandarin Chinese have three voiceless sibilant fricatives dental/alveolar /s/, retroflex /ʂ/, and alveolopalatal /ɕ/ (“s”, “sh”, and “x” in Chinese Phonetic Alphabet). While the mandarin /s/ and /ʂ/ sound nearly identical with the English /s/ and /ʃ/, the sound /ɕ/ is alien to the ears of monolingual English-speakers. It is /ɕ/ rather than /s/ that carries salient gender differentiation, with a frontally articulated female variant. In general, sibilant fricatives are produced by forcing air through a narrow constriction formed by the tongue and the roof of the mouth which strikes the teeth downstream. The articulation of /ɕ/ differs from the English /s/ principally in the tongue posture when forming the oral constriction and in the place of constriction, which is between the alveolar ridge and the palatal region, as “alveolopalatal” designated. By raising the tongue blade close towards the alveolar ridge and simultaneously bunching the body of the tongue, a channel is formed from the alveolar ridge towards the palatal region. /ɕ/ is produced when air passes the constriction/channel (Ladefoged & Wu, 1984). Figure 1.4 shows the oral configuration for the articulation of /ɕ/.



Figure 1.4: Sagittal view of the front part of vocal tract for /ɕ/ articulation

The documentation on gender-specific /ɕ/ dated back to the 1920s when it caught scholars attention that a number of secondary-school girls in Beijing produced a frontal variant of the alveopalatal fricative /ɕ/ (“x” in the Chinese Phonetic Alphabet) in their vernacular speech, resulting a sound similar to the Mandarin alveolar fricative /s/ (“s” in the Chinese Phonetic Alphabet) (Hu, 1987). The frontal production of /ɕ/ found in female vernacular speech was often referred to as the “feminine accent”. Two investigations in the 1980s provided empirical evidence for the existence of the “feminine accent” among young adult female speakers in urban Beijing (Cao, 1986; Hu, 1987). The studies further reported within-gender age variation and the influence of context on gendered /ɕ/. It was relatively rare among females speakers at age 12 and 13, the youngest age group investigated, and the most common among those in late adolescence and early adulthood (Hu, 1987). The gender effect became less common as the age of speakers increases and nearly extinct among the elderly (Cao, 1986). Its presence was found only in vernacular speech and hardly in formal contexts (Hu, 1987).

The instant switch between frontal variant and the canonical form of /ɕ/ depending on the speech contexts and the decreasing trend of the “feminine accent” as age increases in adulthood does not have an obvious link to physical changes, clearly indicates that females’ frontal production of /ɕ/ is an active articulatory behavior. Hu and Cao both suggested that female speakers’ frontal articulation is motivated by cultural ideology of femininity. Frontal articulation goes hand in hand with small mouth opening, which is seen as a delicate manner of articulating. The resulting high frequency sound thus carries a connotation of “smallness” and “delicacy”.

In the two early investigations frontally articulated /ɛ/ variants were only auditorily identified through the method of transcription which may not be sufficiently accurate and consistent. Nevertheless, they have provided hard evidence for the gender marking variation of /ɛ/ production in Mandarin and the within-gender age variation among adult females.

Gendered /ɛ/ was previously documented as part of the vernacular speech in urban Beijing. Whether gendered /ɛ/ is specific to the Beijing Mandarin (which is slightly different though by large identical with the standard Mandarin) or widely present among Mandarin speakers is unclear. Further, early research had no clear account on the age of emergence of gender differentiation. A breakthrough has been made on the age of emergence and the geographic prevalence of gendered /ɛ/ by Li's recent study (Li, F., 2011) that took place in Songyuan, a city farther north from Beijing (see Fig. 2.1 to find the approximate locations of the two cities in China). Li found that gendered /ɛ/ exists of the speech of Mandarin speaking children in Songyuan and the gender differentiation begins at the age 3. Li's research provided some answers but raised more questions. How does gendered differentiation of /ɛ/ production emerge? What gender-related physical and/or social attributes may affect the developmental process of this speech difference between genders?

The present study was carried out in exploring the above questions. Regarding how the gender differentiation of /ɛ/ comes to realize, a few possible contributing factors were proposed and tested. At the current state, the scope of research on gendered /ɛ/ is narrow; thus the major portion of the reference for the present study is from literature on gendered /s/. Given the similarities of the gendered /s/ in English and the gendered /ɛ/ in Mandarin, it is plausible to make inferences from the findings on gendered /s/ to specify potential determinants in the

realization of gendered /ɕ/. The following two sections will present the proposed factors and the reference drawn from bodies of research on gendered /s/ and /ɕ/.

1.3 Anatomical, social, and biological determinants of gendered /ɕ/ production

1.3.1 Anatomical variation of vocal tract

First, the anatomical difference of vocal tract length between genders was considered relevant for gendered /ɕ/ production. Gender-related speech variation is systematic and has been found in different cultures throughout the world. It in part results from the physical attributes that typically differs between female and male speakers. At the anatomical level, vocal tract size and shape, as well as vocal fold length, have been found to be contributing factors to the acoustic variations of speech between genders (e.g. Fant, 1960; Whiteside, 1996). Vocal tract length has been recognized as an anatomical parameter partially responsible for gender variation of the English /s/. A recent electropalatographic (EPG) examination (Fuchs & Toda, 2010) found a strong correlation between the length of the palate (roof of the mouth) and the length of the front resonating cavity in /s/ production, which is negatively correlated with the spectral mean of /s/. As previously discussed, a shorter front cavity in (i.e., a constriction closer to the teeth) results in a /s/ variant with higher spectral mean. As the distance between the constriction and the teeth is also the factor associated with gender variation of the Mandarin /ɕ/ production, the vocal tract length, specifically the palate length, may play a similar role in its realization.

The anatomical difference between female and male speakers was included in the study with the goal to investigate the relationship between vocal tract length variation and gender variation of /ɕ/ production. However, direct measurement of the morphological size of vocal tract was not employed due to the high expense of non-invasive imaging techniques (such as magnetic resonance imaging). Instead, variation of vocal tract length was regarded to vary as a function of

the overall anatomical size measured through height, weight, and head circumference. This technique that uses the variation of gross body size to represent vocal tract size variation has been used by previous studies and proved feasible (Bennet, 1981; Perry, Ohde, & Ashmead, 2001; Rendall, Vasey, & McKenzie, 2008).

1.3.2 Social influence

Literature on gendered /ɜ/ suggests a strong social influence. The early-childhood emergence of gendered /ɜ/ indicates a social input. Gender divergence of /ɜ/ production was found among boys and girls as young as age 3 (Li, 2011), who do not exhibit significant anatomical difference in vocal tract length between genders (Fitch & Giedd, 1999). It implies that if the anatomical factor plays a role in the realization of gendered /ɜ/, it is only a co-factor that perhaps may reinforce the gender differentiation after gender /ɜ/ has emerged through social learning process. The age variation of gendered /ɜ/ is also a particularly strong evidence for social influence. Female frontal production of /ɜ/ becomes increasingly uncommon as age increases among adult speakers (Hu, 1987). The age-related decreasing trend of frontal /ɜ/ production after early adulthood is likely to be related to the female speaker's social role and identity changes as they enter marriage and the job market (Cao, 1986; Hu, 1987). Hu (1987) alluded the association between the within-gender variation of gendered /ɜ/ production and marital status. He explained that average age of marriage tends to be the age around which decrease of gendered /ɜ/ for female speakers begins to occur. Therefore, gender-related variation in /ɜ/ production may be influenced by multiple factors on top of gender norms and ideology.

The findings on gendered English /s/ are in line with the current understanding of gendered /ɜ/ which favors social influence over anatomical variation as a primary contributor to gender differentiation of English /s/ production.

First, the EPG study that confirmed anatomy-acoustic relationship between palate length and gendered /s/ (Fuchs & Toda, 2010) also clearly demonstrated that it is the manner of articulation that plays a vital role in gendered /s/ production as opposed to vocal tract morphology: after ruling out parameters of palate size, the articulatory production and the acoustics realization of /s/ remained significantly different between genders. It revealed that male and female speakers actively articulate in a gender-typical way, which confirms the view that the female frontal variant of /ɕ/ results from their active articulatory variation.

Second, empirical evidence substantiated that the gender differentiated articulatory behavior in /s/ production is socially driven. An investigation conducted by Stuart-Smith (2007) demonstrated that the social indexical variation of /s/ is affected by multiple aspects of the speaker's social identity simultaneously. In addition to gender, there are age and class. Strikingly, it was found that the working class girls patterned together with males in /s/ production. Smith's findings echo with the age-related variation of gendered /ɕ/ production. They both reveal that the variation of sound production often found between female and male speakers is socially constructed by various factors that affect an individual's social identity. Gender identity, behind which are social norms and cultural ideology regarding gender role that largely dictates an individual's behavior, may have a profound impact on gender variation of /ɕ/ production.

Third, investigations on gendered /s/ in prepubescent children also have found early emergence of gender differentiation which is in agreement with the findings on gendered /ɕ/ (Fox & Nissen, 2005; Li & Kinsman, 2013). A most recent study on this regard found gender-differentiated /s/ production started as early as age 4 (Kinsman & Li, 2013). Prepubescent boys and girls do not show anatomical distinction in vocal tract length. It implies that the gender-differentiated production of both Mandarin and English is socially acquired rather than

anatomically determined. Children are likely to have started to learn gendered speech production at a very young age as they are learning how to speak. A twist is added to this social-acquisition view by a recent MRI study (Vorperian et al., 2009), suggesting that the growth the oral portion of vocal tract may start to exhibit significant sexual divergence at age 4. Nonetheless, the speculation of social acquisition is plausible, as the EPG study mentioned above established the significant contribution from the way of articulation to gendered /s/.

Literature on gendered /ɜ/ and /s/ both present a social account for the realization of the gendered speech production. Gendered way of speech production may have been acquired through social processes. Culturally-prescribed gender ideology and social norms for gender role motivate individuals to behave in a “gender-appropriate” way, including speaking in a gendered manner. In this study, the social influence on gendered /ɜ/ production was investigated through the examination the relationship between gendered /ɜ/ production and gender-typical behavior.

1.3.3 Prenatal biological factor

Regarding the biological factor, prenatal sex-hormone exposure was speculated to play a part in gendered /ɜ/ production via its influence on an individual’s gender-type propensity. The understanding on biological factors in relation to gendered /s/ is dauntingly opaque. The biological nature of gendered speech production has rarely been addressed in literature except for the vocal tract anatomy. Some suggested that prenatal sex-hormone exposure is part of the biological root of speech variation that cues sexual orientation (Renn, 2002). Sexual orientation, gender-typed behaviors and traits, as well as gender identity are found to be affected by prenatal hormonal exposure (Hines, 2010; Savic, Garcia-Falgueras, & Swaab, 2010; Hines, Ahmed, & Hughes, 2003; Berenbaum & Beltz, 2011). Male sexual orientation can also be indexed by the

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variation of /s/ that often marks genders. It is likely that prenatal hormonal exposure affect the gendered fricative production.

Gendered /ɜ/ production may simply be a natural consequence of the speaker's gender-type inclination that is affected by prenatal hormonal exposure. The hormonal theory of sexuality holds that the presence or absence of certain hormones plays a role in sex differentiation (of reproductive anatomy and of brain organization) during prenatal development, and affects sex-typed behavior after birth. Prenatal hormonal exposure is likely to be one of the biological variations that predispose an individual to a certain point on the gender continuum in terms of both physiological and psychological attributes. One example to illustrate that some gender-typed psychological traits may have a certain degree of innate setup is the different viewing preference between female-and male-infants on the first day after their birth. Female infants prefer human faces while male infants prefer mechanical mobiles (Cerianne, Wilcox, & Woods, 2009). Gendered speech may be a natural consequence of such an inborn physiological and psychological propensity associated with prenatal androgen exposure. In the study, the relation between gendered /ɜ/ production and prenatal hormonal variation will be examined.

The prenatal hormonal exposure can be crudely measured through a simple measure via 2D: 4D digit ratio. The ratio of the length of the index finger to that of the ring finger of the right hand has been suggested to correlate with prenatal hormone exposure(Lutchmaya, Baron, Raggatt, Knickmeyer, & Manning, 2004; Zheng & Cohn, 2011). Prenatal androgen exposure at a proper level will lead to a greater growth rate of the 4th digit during digit formation of the fetus and result in a 2D: 4D ratio value less than one. The 2D:4D ratio will not be affected by hormonal changes after birth and stay invariant throughout the course of development. Thus, the 2D: 4D ratio of the right hand is considered a biomarker of prenatal hormone exposure. A value

roughly equal or slightly greater than one indicates female-typical prenatal hormone effect (which is a lack of androgen exposure), and a smaller value implies male-typical hormone exposure. With this means of assessing prenatal hormonal exposure chosen, the current study will examine the relationship between the gendered /ɛ/ production and the prenatal hormonal variation.

1.4 Investigating the development of gendered /ɛ/ production

Gathering evidence from the literature on both gendered/ɛ/ and /s/, a complex account for the gender-differentiated /ɛ/ production has emerged encompassing both social and biological factors. However, such account only focuses on the dynamics of this gendered /ɛ/ in adult speech but provides little insight on how the different factors work in the emergence and development of gendered /ɛ/ production.

The current study was carried out in hope of shedding light on the social and biological influence on the development of gendered /ɛ/ production. The study aimed to examine the developmental trajectory of gender-differentiated /ɛ/ among Mandarin-speaking children in terms of the contribution from social influence, anatomical development, and prenatal hormonal effect. The result of the present study may advance our understanding on the development of gendered speech-sound production as to whether it is primarily socially constructed or a consequence of biological difference between genders, or a result of the interaction between social and biological factors.

The research questions of the study are:

1. Is gender-differentiated /ɛ/ present in the speech of the targeted Mandarin-speaking children?

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2. At what age does this gender differentiation in /ɔ/ production begin?
3. Do the following factors contribute to the emergence and developmental process of gendered /ɔ/ production—anatomical development, gender typical behavior, and prenatal sex-hormone variation?
4. If they do, what is the relative contribution of each factor to gender variation of /ɔ/ production?

CHAPTER 2

METHODS

2.1 Participants and procedures

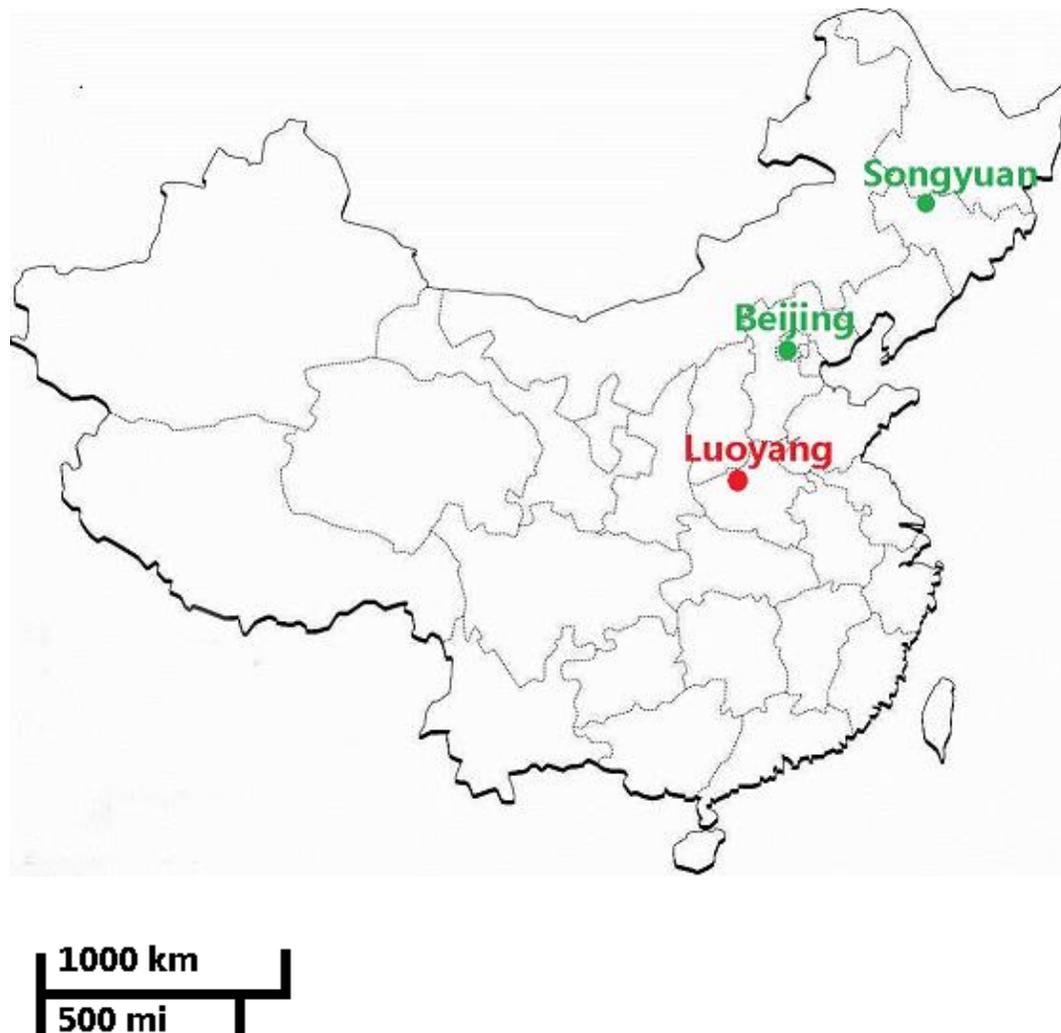


Figure 2.1: Locations of the cities where gendered / ϵ / has been studied, Beijing, Songyuan, and Luoyang city (in red).

The study took place in the city of Luoyang, located in the central part of China (Fig. 4 shows the locations of three cities, Beijing, Songyuan, and Luoyang, where gendered /*ɕ*/ production have been studied among the local Mandarin-speaking populations on a China map). Participants were recruited from Grade 1, Grade 6 and Grade 10 of three local schools in the urban area, roughly at the age of 7, 12, and 15 years old. Each group was composed of approximately equal number of females and males. (See composition of the participants in Table 1.)

	females	males
Grade 1	n= 38 M=7.36 SD=0.55	n=35 M=7.59 SD=0.63
Grade 6	n=39 M=12.57 SD=0.41	n=38 M=12.60 SD=0.44
Grade10	n=38 M=16.60 SD=0.43	n=33 M= 16.71 SD=0.61

Table 2.1: Number and age in years (M=mean, SD=standard deviation) of participants of each gender and age group

The following characteristics of a child are required for participation: The age of the child is within the age range of Grade 1, Grade 6, or Grade 10, i.e., between 6 to 8 years old, 11 to 13

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years old, or 14 to 16 years old; the child spoke standard Mandarin without an accent (from speaking a dialect or another language); he or she had no known speech, language, or hearing pathologies (such as stuttering, incorrect pronunciations of certain sounds, speech delay, and ear infection or the recent history of it); the child chose to participate on a voluntary basis with a parental consent form filled by a legal guardian.

Participants were recruited from a few randomly selected classes in each of the grades. Students who expressed interest in participation received an envelope which they brought to their parents. The envelope contained a letter to the parents that explained the purposes and the procedure of the experiment as well as the rights of participants, a parental consent form, a demographic questionnaire, and a Child Play Behaviour and Activity Questionnaire (CPBAQ). The class teachers helped distribute envelopes and collect the returned ones. The parents signed the consent and completed the accompanied questionnaires if they agreed for their children to participate. All the filled forms were returned to the class teachers in the sealed envelope. They were then reviewed by the researcher prior to the experiment. The students with signed consent forms and completed questionnaires that revealed no speech, language, or hearing deficiency were included in the experiment. Each participant was assigned an ID code. Their information and data retrieved from the experiment were saved under the ID code instead of their names to ensure anonymity. After the experiment, an additional number of participants were excluded before data analysis due to the accent from their dialects, consistent pronunciation errors, or other minor speech-related issues observed in the experiment.

In the production experiment, participants were seated in front of a laptop computer, and were instructed to read a series of words on Power Point slides. Anatomical development of each participant was assessed through physical measurement including height and head circumference.

The 2D:4D ratio of the right hand of each participant was also taken to assess the prenatal hormonal factor.

The experiment was conducted in quiet conference or office rooms at the schools. Upon completion, each participant received a thank-you gift for their participation. The following section will describe each component of the study in more details.

2.2 Speech production experiment

2.2.1 Stimuli

There were 36 words selected as stimuli for the production task. Each word started with either a voiceless sibilant fricative /*s*/, or /*ɕ*/, or a stop /*t*/ or /*d*/, and was followed by vowel /*a*/, /*i*/ or /*u*/. The words beginning with /*t*/ or /*d*/ were used as fillers in this task. The mandarin /*s*/ was included as a target sibilant fricative, because /*s*/ in Mandarin is virtually identical with its English variant. The places of the oral constriction of these two fricatives are both dental/alveolar. Whether this Mandarin sibilant fricative that is identical with the English gender-marking /*s*/ also differs in its articulation between genders was of interest.

There are equal numbers of words starting with each consonant and each vowel. The stimuli included monosyllables (words with one syllable and represented by one single Chinese character in written form), disyllables (words with two syllables and written in two Chinese characters), or trisyllables(words with three syllables and written in three Chinese characters).

vowels	/i/	/a/	/u/
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fricatives			
/s/	[si'kʏ] (four) sì gè 四个	[san'kʏ] (three) sān gè 三个	[su'ljɑʊ'taɪ] (plastic bag) sù liào dài 塑料袋
/ʃ/	[ʃi'kwä] (watermelon) xī guā 西瓜	[ʃia] (shrimp) xiā 虾	[ɛyn'tʃɑʊ] (to search) xún zhǎo 寻找

Table 2.2: Samples of target words in speech production task, denoted by International Phonetic Alphabets (IPAs), Chinese Phonetic Alphabets (Pinyins), and Chinese characters, with English translations in parentheses

Three randomized lists of words were created with the same tokens in different orders. The words are presented in Microsoft Power Point slides. The three sets of slides were rotated for testing among participants. Simple and common words were selected to ensure that the youngest participants (the first graders) were able to recognize and pronounce them. Each target word was shown in both Chinese characters and Chinese Phonetic Alphabets (the official phonetic system that uses roman letters to indicate pronunciation, commonly referred to as “Pinyin”), accompanied by a picture prompt. In Chinese public education system, Pinyin is mandatory and begins to be included in the curriculum as early as preschool. When Grade One

participants encountered a word that they did not recognize, they could still use its Pinyin symbols to pronounce it.

A number of first graders had difficulty pronouncing certain words, such as [ɛyn'ro(ŋ)] “smoked meat” (“xun’ rou” in Pinyin). The researcher explained the meaning of the word or directed the participants to spell out the Pinyin alphabets to assist their reading, but avoided using the syllable(s) of the target word during this interaction. If a word was mispronounced, the participant will be asked to repeat till the correct pronunciation was achieved. A few participants displayed consistent errors in articulating certain sounds and their data were eliminated from later analysis.

2.2.2 Acoustic analysis

All recorded data were analysed acoustically using computer software, Praat (Boersma & Weenink, 2012). Acoustic analysis has been demonstrated to be robust and accurate in capturing fine-grained phonetic differences such as those related to speakers’ gender (Simpson, 2002; Heffernan, 2004; Stuart-Smith, 2007).

Before the data analysis, recorded sound files were segmented into individual words and the fricatives and vowels of the first syllable were denoted. Then the onset and the end of each target fricative and vowel were manually marked. The beginning of a fricative is where the onset of frication is identified in both the waveform window and the spectrogram window. The end of the fricative, which was defined as the onset of the following vowel, was the first upward zero-crossing point in the waveform of the following vowel. A 40-millesecond slice centering the sound band of each fricative was extracted for spectral moment analysis.

Spectral moment analysis is commonly used to examine the spectral properties of fricatives, in which the spectrum is configured as a probability distribution which allows the calculation of statistical moments (e.g., Jongman, Wayland, and Wong, 2000). The first, second, third, and fourth moments, M1 (mean or “centroid” frequency), M2 (standard deviation), M3 (skewness), and M4 (kurtosis), of the spectral distribution have been used to describe various aspects of the place of articulation. For the purpose of this study, only M1, the spectral mean frequency will be focused on, as the spectral mean frequency reflects the frequency range where concentration of spectral energy locates and negatively correlates with the length of the front resonating cavity (e.g., Flipsen et al. 1999 ; Nissen & Fox, 2005; Jongman et al., 2000)

2.3 Demographic questionnaires

Parents filled out a demographic questionnaire before the experiment took place. The demographic questionnaire was used for two purposes. First is to find out whether the child meets the requirement for participating in the study. The questionnaire contains questions enquiring the basic information regarding age, ethnicity, birth place, the place where the child has resided, the spoken language(s) the child and his or her family members/care takers primarily used (whether it is Mandarin or a dialect), and whether the child had any speech, language, or hearing problem or the history of it. The children who were reported to speak a dialect rather than Mandarin at home and/or who grew up in a suburban or rural area (where the predominant spoken language is the local dialect instead of Mandarin) were not included in the experiment. The children whose parents reported the following problems were not asked to continue with their participation either: speech delay, suspected dyslexic symptoms (e.g. trouble in reading, significantly smaller vocabulary compared with peers, etc.), incorrect pronunciation with certain sounds, or chronic ear infections. The second purpose of the demographic questionnaire was to

learn about the child's family composition in terms of siblings, who may influence gendered speech production of the child. Due to the fraternal birth order effect, for boys a greater number of elder brothers predict a higher probability of homosexuality. Male homosexuality may affect the gender variation of sibilant fricative production, as it has been found that homosexual males have a higher chance than heterosexual males to develop a frontal articulation with /s/. Growing up with an elder sibling of the opposite sex, a child is likely to take on some traits and learn certain behaviors (including speech) that are more typical for the opposite gender. However, due to the one child policy that holds strong in China, most participants were reported to have no siblings. Thus the data on this number of siblings were not included in later analysis.

2.4 Gender-typical behavior assessment

The Child Play Behaviour and Activity Questionnaire employed in this experiment was an adapted version of the parent-report CPBAQ designed by Lu Yu et al. (2010) to measure Chinese children's gender-related behaviours. Similar to the original questionnaire, the present CPBAQ was aimed to screen gender-related play preference, behaviour, and the relation with others. It was designed to be responded on a 5-score Likers Scale of frequency from 1 (Never) to 5 (Always) by the participant's parent(s). There were 46 items in total, among which 44 items were directly borrowed or adapted from the original CPBAQ. The modification was made mainly on the wording for clarification purposes. Two new items were introduced based on the researcher's knowledge on girl-or boy-typical games in Luoyang. Except for one cross-gender item (the frequency of the behavior has no significant correlation with the sex of the subject), all the CPBAQ items were either boy- or girl-typical. The gender-typical items used from the original work of Yu et al. showed partial correlation between item and subject sex ranging

from .10 (cooking) to .76 (“playing with boys at school”) in Yu’s findings. The CPBAQ used for the current research can be found in Appendix A.

For data analysis, CPBAQ scores were converted to gender-typicality scores: each score in the boy typical item was made comparable to the girl typical one by being subtracted from 6. The resulting gender-typicality scores ranging from 1 to 5 are correlated with girl typicality. A higher score indicates a higher degree of girl-typicality, as the child more frequently exhibits effeminate behaviors in terms of game plays, intellectual and recreational activities, and playmate choice. The mean and the standard deviation of the gender-typicality scores for each gender in each age group were further calculated. The mean and standard deviation of gender-typicality scores is presented in Appendix B.

2.5 Anatomical measurement

The height, weight, and head circumference (HC) of each participant was measured to assess their physical development. Heights and weights were recorded in centimetres and kilograms respectively. The result was rounded up to whole numbers. HCs were measured with a soft tailor ruler and were also recorded in centimetres and in either whole numbers or .5.. Each participant’s HC was measured three times and the mean of the three results was taken as the actual result for better reliability.

2.6 2D:4D ratio measurement

In order to obtain the 2D: 4D ratios, a Vernier caliper was utilized to measure the length of each participant’s index finger and ring finger of the right hand. The finger length was measured from the midpoint of the bottom crease where the finger joins the palm to the finger tip. Similar to the HC measurement, each finger length was measured for three times and the mean was used as the actual result. The 2D: 4D ratio was then calculated. The finger length was

measured in millimeters and was accurate to one decimal place. The ratios were rounded to retain an accuracy of having two decimal places. The mean and standard deviation of the 2D: 4D ratios for each gender within each group were later calculated.

CHAPTER 3

RESULTS

3.1 Gender differentiation in /ɕ/production and its emergence

To address the question of whether and when gender differentiation in /ɕ/ production occurs, first, two repeated measure ANOVAs were conducted, each with the dependent variable being spectral mean frequency (M1) of each sibilant fricative (/s/ and /ɕ/) and the independent variable including gender, age group, and the interaction between gender and age group. No significant effect was found with any of the three independent variables on /s/ production, indicating /s/ production does not vary with gender or age. The production of the sound /ɕ/ was found to be gender-differentiated. A significant gender effect was found [$F(1, 215)=21.277$, $p<0.000$] on the M1 of /ɕ/, indicating an overall differentiated M1 pattern of /ɕ/ sound between boys and girls. The other two factors, age group and the interaction between gender and age group were not found to exhibit significant effect on M1 of /ɕ/, suggesting there is no age variation in /ɕ/ production and the gender difference stays invariant across age groups. Table 2 presents the means and standard errors of the M1 of /ɕ/ and /s/ of each gender within each age group.

Table 3.1: Mean and standard deviation (in parentheses) of spectral mean frequencies (M1) of /ɕ/, and /s/ for each gender of each age group

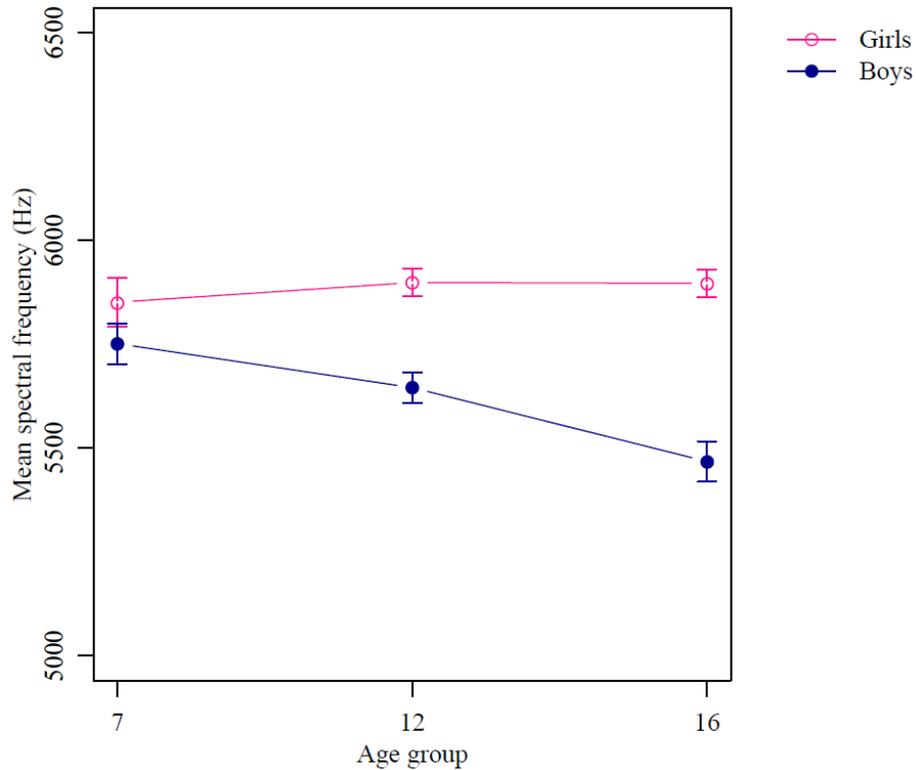
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	7			12			16		
	Female	Male	Overall	Female	Male	Overall	Female	Male	Overall
/ɛ/ (Hz)	5888.5 (1007.4)	5793.6 (730.2)	5842.8 (885.4)	5930.0 (654.7)	5643.8 (712.1)	5787.7 (698.2)	5897.0 (758.2)	5458.4 (664.0)	5693.4 (745.8)
/s/ (Hz)	5808.9 (1211.6)	5820.6 (751.7)	5814.6 (5313.9)	5932.5 (756.0)	5980.2 (642.6)	5956.2 (796.0)	6020.5 (696.9)	5901.7 (719.3)	5964.4 (968.2)

Next, a post-hoc t-test was performed for the each age group separately between gender and the M1 of /ɛ/ to find out what age groups exhibit gender differentiation in /ɛ/ production. The significant gender effect was found in the 12-year old group and 16-year old group [F (1, 70) = 17.790, p<0.001], suggesting gender divergence in /ɛ/ production begins between age 7 and age 12. M1 of /ɛ/ for boys and girls in all three age groups are shown in Figure 5.

Figure 3.1: Spectral mean frequencies (m1s) of /ɛ/ for girls (in pink) and boys (in blue) of three age groups with standard error bars displayed

Development of Gendered /ɛ/ Production



In sum, the gender differentiation was found only with /ɛ/ production and gender-differentiated /ɛ/ production emerged by age 12.

3.2 Correlating M1 of /ɛ/ with physical measurement, 2D: 4D ratio, and gender-typicality score

In order to examine the relative contribution of anatomical growth, prenatal androgen exposure, and gender typicality to the gendered /ɛ/ production, a multiple linear regression analysis was performed each gender. The dependent variable is the M1 of /ɛ/ and the independent variables are the gender-typicality score (converted CPBAQ score), height, head circumference, the 2D: 4D ratio. For girls, no variables included were found significant in accounting for variability in spectral mean frequency. For boys, only gender score is significant ($r^2=0.04$, $p=0.03$) (shown in Figure 3.2). A higher M1 of /ɛ/ indicates more effeminate

production and a higher gender score represents a greater degree of girl-typicality. The positive correlation between M1 of /ɛ/ and gender scores was in accordance with the predicted gender effect on /ɛ/ variation, as a more female typical individual has a more effeminate /ɛ/ production.

To further investigate which age groups contribute to such a correlation, Pearson’s correlation tests were then conducted between the gender scores and the M1 of /ɛ/ for each gender of each age group individually. Significant correlation between M1 of /ɛ/ and the gender scores was only found among boys in the 16-year-old group ($r=0.40$, $p=0.01$). The results of the correlation tests are shown in Table 3.2. Figure 3.3 illustrates the correlation between M1 of /ɛ/ and gender-typicality scores for boys of the 16-year old group.

Table 3.2: Relationship between gender-typicality score (converted from the CPBAQ score) and the gender spectral mean frequencies (M1s) for each gender in each age group

	Age 7	Age 12	Age 16
M1 and Gender Scores for Girls	$p>0.05$ $r=-0.0108$	$p>0.05$ $r=0.29$	$p>0.05$ $r=0.003$
M1 and Gender Scores for Boys	$p>0.05$ $r=0.087$	$p>0.05$ $r=0.14$	$p=0.01^*$ $r=0.40$

Figure 3.2: the relationship between gender-typicality scores and spectral mean frequencies of /ɛ/ for boys of all age groups

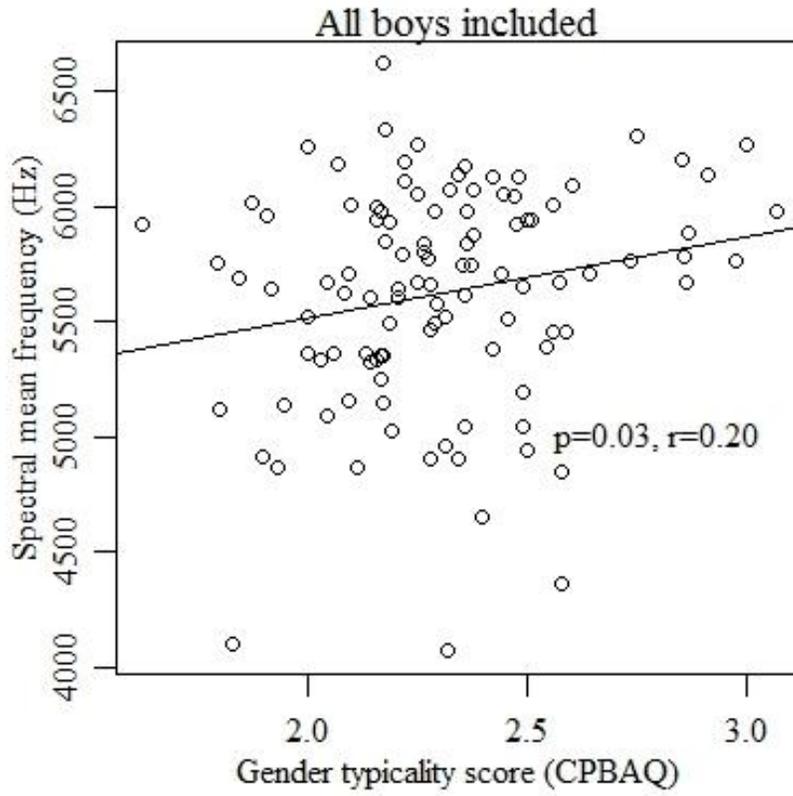
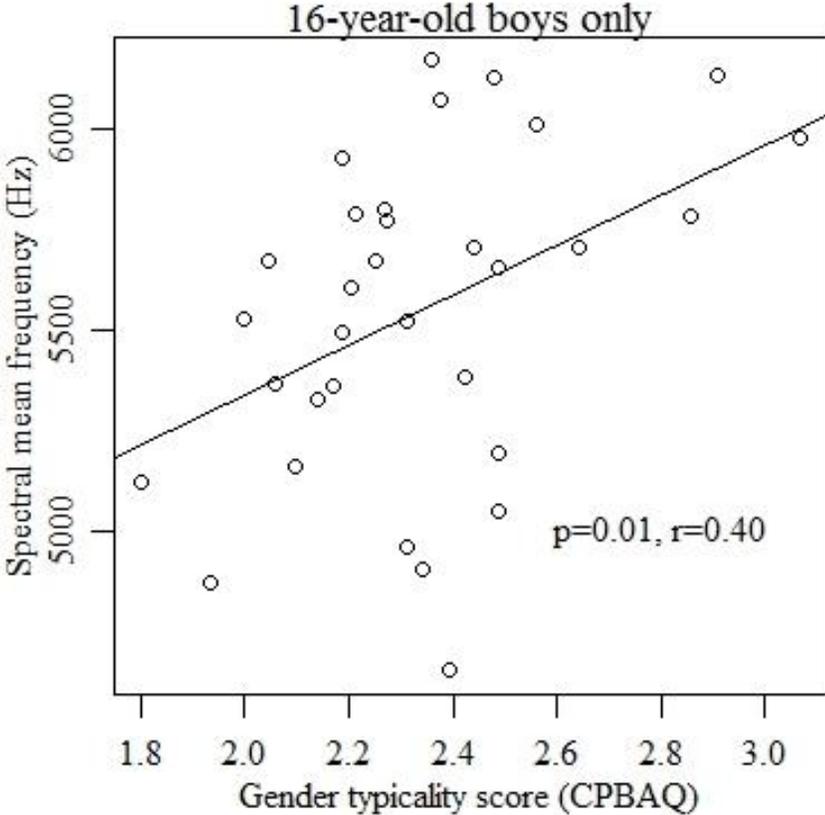


Figure 3.3: the relationship between gender-typicality scores and spectral mean frequencies of /c/ for boys of 16-year old group



CHAPTER4

DISCUSSION

The study found gender-differentiated speech production for /ɛ/ but not for /s/, which is consistent with previous observations noting gender-marking variation within alveolopalatal sounds only (Cao, 1986; Hu, 1987). Gender differentiation of /ɛ/ production was found in the 12 and 16 year-old groups but not in the 7-year old group, indicating gender-differentiated /ɛ/ production begins at one point between mid-childhood and adolescence. M1 of /ɛ/ production was only found significantly correlated with gender typicality but not with anatomical measurement or prenatal hormonal variation. Therefore, the development of gendered /ɛ/ production is not affected by the anatomical difference between boys and girls that start to appear at puberty or to the inborn psychological inclination towards a certain gender type. Correlation between /ɛ/ production and gender typicality was only significant among boys in the 16-year old group, which indicates that the gender variation of /ɛ/ production develops a correlation with gender typicality after it has emerged. It can be regarded as that the emergence of gendered /ɛ/ production is not contributed by the anatomical, biological, or social factors examined in the study. However, gendered /ɛ/ production becomes correlated with gender typicality for boys in late adolescence, suggesting that for young adult males, gender-specific /ɛ/ production has developed to carry social meanings of their gender identity and thus become socially expected for gender behavior for males.

4.1 Emergence of gendered /ɛ/ production

The emergence of gendered /ɛ/ production takes place after mid-childhood (age 6-8) and by the onset of adolescence, which is not due to anatomical development or the development of gender-typical behavior nor related to prenatal hormonal effect. If the time of emergence of

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gendered /ɜ/ is the onset of adolescence, the beginning of gender divergence is likely to relate to the drastic physiological and psychosocial changes children typically experience around this time. Adolescence is a transitional stage of development from childhood to adulthood, during which physical and psychological maturation takes place. Adolescence is usually considered to start from puberty, the beginning of which is typically at age 10 to 11 for girls and 11-12 for boys. The majority of participants in the 12-year old age group have started puberty based on the demographic results that revealed the age of menarche for girls and on the researcher's observation that most boys have some degree of voice change (salient pitch drop compared with Grade 1 boy participants)..

The emergence of gendered speech production may be related to sexual maturation and gender identity development at early adolescence. At puberty, individuals experience sexual maturation which includes the maturation of both reproductive capabilities and sexual attractions. Gendered speech may become a manifestation of a heterosexual individual's sexual identity to achieve attraction from the opposite sex. Among heterosexual individuals, the desire to be sexually attractive to the opposite sex may subconsciously motivate girls to behave more effeminate and boys more masculine, as heterosexual males tend to be sexually attracted to characteristics of femininity and females to masculinity.

In addition, peer influence and group identity may also play a role in the emergence of gendered /ɜ/ production. Adolescence is characterized by a dramatic increase in time spent with peers. Peer groups may retain comparable significance to family and school in the socialization of adolescents (Dunphy, 1963) The sense of identity on the basis of the membership of a peer group is particularly salient at early adolescence, when single-sex friend groups are dominant in one's social network. These adolescents are likely to be motivated by group identity or pressured

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to modify their speech in order to conform to their peers. In this way, gendered speech behavior spreads around peer groups, becoming common and prominent..

It is necessary to acknowledge the potential link between gendered /ɜ/ production and pubescent hormonal changes, regardless the hormonal impact on sexuality and sexual identity. One relevant finding for hormonal effect on gender variation of speech is that the voice onset time of female speakers, which is usually longer than male speakers, correlates with the hormone level during menstrual cycle (Whiteside, S. P., Hanson, A., & Cowell., P. E., 2004; Wadnerkar et al., 2006). Admittedly, the association between hormone-related variability of the system and gendered speech production is illusive. It is uncertain whether hormonal change would affect gendered speech through its influence on the central nervous system or on the peripheral tissue system. However, the possibility of the “instant effect” of hormonal change on speech behavior is worth a few lines in this discussion.

Other factors such as gender-specific speech learning process and gender segregation in childhood socializing behavior are likely to be involved to gendered speech behavior as well; however, they are disfavored as contributing factors to the emergence of gendered /ɜ/ due to the timing mismatch. Gender-differentiated child-directed speech and children’s selective learning during speech acquisition in early childhood were suggested as major factors that account for the early emergence of gendered /ɜ/ at age 3 found in Li’s study. Child-directed speech is differentiated according to the gender of the child. Adults speak in a gender-appropriate way in accordance to the gender of the child (Foulkes, Docherty, & Watt, 2005). On the other hand, when learning speech, children are able to reflect differential input and tend to direct attention selectively to different types of input. Children may be more biased towards the speech of individuals whose gender they identify with. Thus, children may be learning a gender-specific

speech in their speech acquisition. The results of the present study, indicating gendered /ɛ/ production emerges after mid-childhood, is in conflict with Li's findings. Evidently, this gender-specific learning theory cannot explain the timing of the emergence, which is at late childhood. For the same reason, sex segregation in childhood friendship does apply to the late arrival of gendered /ɛ/. Sex segregation refers to the separation between boys and girls in friendship and casual encounters due to children's preference for associating with individuals of the same sex (Thorne, B., & Luria, Z., 1986). Sex segregation among Chinese children is suggested to be most rigid at age four to five and starts to become flexible by age seven (Du & Su, 2005). If the sex segregation has an impact on the children's gender-related speech production, gendered speech should begin around the age where gender segregation is prominent and but not after age seven when it becomes less rigid.

Finally, the age of emergence for gendered /ɛ/ production found in this study is in great contrast with that found in Li's study. The reason for this conflict is puzzling. Speculation is reserved at this point in attempt to explain the large disparity between the ages of emergence for gendered /ɛ/ found in two Mandarin-speaking populations.

4.2 Gender typicality in relation to the development of gendered /ɛ/ production

The only factor found significantly correlated with /ɛ/ production is gender-typical behavior among 16-year boys. Two implications are of particular interest here. First, association between gender behavior and gendered /ɛ/ production only exists among boys. Second, such correlation occurs after gendered speech has begun, in mid-or late-adolescence.

Regarding the gender difference in the relationship between gendered /ɛ/ production and gender behavior, the speculation is that gendered speech production has different social

meanings to male adolescents than to female due to the more rigid gender-related social protocols for boys than for girls. Girls may simply adopt gendered speech in conforming to the speech style of their same-sex peers while boys may consider gendered speech as a gender rule or a requirement to stay away from the stigmatization for being “like a girl”. In general, the culture in urban areas of mainland China hold a relatively strong egalitarian view towards gender roles, however, gender equality seems to grant more freedom to females in terms of their gender role than males. Male gender role is more rigidly defined with relatively restricted gender rules whilst female gender role is less definitive with relatively flexible gender expectations. A male exhibiting effeminate traits and behaviors tend to be socially unaccepted and is likely to be responded with denouncement from other males. By contrast, a female deviating from female prototypes and possessing certain male-typical traits tend to be responded in a more objective way and with less overt discouragement. It is conceivable that gendered speech of boys is more strongly associated with gender-typicality score or gender role than that of girls. Taking a step further, gender-marking /ɹ/ may only function as a gender marker as it by nature marks degree of masculinity or male’s gender role. The within-gender indexing for male typicality of gendered speech production may explain the variation of the English /s/ which indexes both gender and male homosexuality, gender-marking variation of /s/ may in essence mark male typicality.

Gendered speech does not form strong association with gender typicality among boys till mid- or late-adolescence. At the beginning of adolescence, when sexual maturation begins, development of gender identity enters a critical stage. Adolescence is a critical phase of an individual’s social identity development (according to Erickson’s theory of stages of development), which includes the development of gender identity. Adolescents are motivated to recruit various types of behavior to establish their gender identity while simultaneously acquiring

more knowledge regarding gender-related ideology and norms (gender role behavior). Gendered speech may not take on any social meanings and enter their gender-knowledge repertoire until mid-or late-adolescence. Thus, gendered /ɛ/ production may start at the same time when gender identity development starts to excel, yet due to the process of the gender identity construction, the speech aspect of gender norms may not be acquired till later in adolescence.

4.3 Limitations of the research

4.3.1 Indirect measurement to assess vocal tract size variation

Anatomical development was not found correlated with /ɛ/ production. It suggests the vocal tract length which varies as a function of gross body size does not have effect on the gender variation of /ɛ/ production. However, the lack of correlation between the anatomical measurement in the study and /ɛ/ production needs to be interpreted with caution. The anatomical parameter intended to be examined was the length of vocal tract. In the present study, it was only inferred from height, weight, and head circumference, based on the assumed correlation between the vocal tract length and the parameters of the anatomical size. It is unclear whether the lack of correlation between physical measurement taken in the study and /ɛ/ production has implication on the actual association between vocal tract length and gendered /ɛ/ production. Imaging techniques or inventions of alternative methods that allow direct measurement of parameters of vocal tract size are called for in future studies.

4.3.2 Controversial prenatal hormonal theory and problematic 2D: 4D measurement

The result of the study did not show significant correlation between the spectral mean of /ɛ/ production and prenatal hormonal variation. This indicates the inborn physiological and psychological propensity towards a gender type does not have significant contribution to

gendered / ϵ / production which emerges over the course of development. However, it is important to announce a few caveats for such a conclusion. First, there has not been clear evidence substantiating the suggested prenatal hormonal effect on sex-related behaviors and characteristics in normative development. The prenatal hormonal theory for sexuality is formed mainly based on experiments with non-human mammals and studies on individuals who experienced marked prenatal hormone abnormalities and associated ambiguities of genital development (e.g. congenital adrenal hyperplasia) (Hines, et al. 2003). Questions remain regarding whether the neurobehavioral effect on humans will be similar to that of the mammals and whether prenatal androgen variation within the normal range leads to sex-typed variations. Second, Prenatal hormonal effect is only a co-factor that affects an individual's gender identity and gender-related behaviors, how much impact it has in comparison with genes and environment is unknown. Studies have provided support for the effect of prenatal androgen on sex-typed behavior in childhood (e.g., Hines, 2010), but no dramatic influence on gender identity and little or no influence on cognitive abilities of mental rotation (which exhibit marked gender difference). Third, prenatal hormonal variation was measured through the 2D:4D ratio, however, the validity of regarding digit ratios as an indicator of prenatal androgen remains controversial, as many other prenatal factors may play a role in bone growth in the prenatal stage of development (Gooren, 2006). It has been found that 2D: 4D ratios are influenced by factors other than prenatal hormonal exposure, which complicates the correlation between 2D:4D and prenatal hormone level. 2D:4D ratios have been found to vary significantly among different ethnic groups. Further, findings also suggested the influence of genes inherited from the father (which has no apparent association with the hormonal environment in the uterus) on the formation of 2D: 4D (Manning et al., 2000).

Despite the controversy surrounding the prenatal hormonal theory, there are merits in exploring its relationship with gendered /ɕ/ production. Challenges come from the lack of effective measurement of the prenatal hormone level. It is worthy of experimenting with different measures of assessment. Future endeavors in estimating prenatal hormonal variation and in exploring its association with gendered speech are encouraged.

4.3.3 Practicability issues with the CPBAQ in the current study

The CPBAQ that is designed for children and is completed by parents may have not been an ideal tool to assess the gender development for this particular study. First, the age of the participants ranges from mid-childhood to late adolescence. The items of the CPBAQ are concerned with behavior and relation in childhood only, which does not reveal the current state of gender development for adolescents. Second, from the feedback of the parents and the participants themselves, the researcher learned that a number of parents simply do not have adequate knowledge regarding their children's day-to-day behaviors. It is the specific social condition in mainland. In most Chinese families, both parents are employed and do not have much time dedicated to family life. Many if not most Chinese parents do not spend as much time with their children as the parents in the Western world do. It is expected that some parents may not know sufficient knowledge about their children's daily life to be capable of answering all questions of the CPBAQ. The parent-report questionnaire that has been proved effective may not work as well under the social social condition in China. In future studies, interviews or psychological tests directed to participants are suggested for the assessment of their gender development.

4.3.4 Non-absolute relationship between spectral mean frequency and frontness of production

The use of the acoustic parameter as an indicator for the relative frontness of constriction in /ç/ production also carries limitations. The acoustic-articulatory relationship between the spectral mean frequency and the frontness of articulation is more complicated than one-equals-the-other relationship. Munson (2009) has discussed this issue citing the findings from the study by Jongman, Wayland, & Wong (2000): /θ/, a sound anterior to /s/, has a significantly lower spectral mean than /s/; these two sounds are mostly clearly differentiated with the second spectral moment (M2: the i.e., the spread of the distribution of energy in the fricative), rather than the spectral mean. Revision can be made in the future studies by including multiple acoustic parameters in examining the speech production rather than spectral mean alone. The following acoustic variables can be included: the main spectral peak (the frequency of the most prominent peak) that is also found negatively correlated with the length of front resonating cavity (e.g., Hughes & Halle, 1956), and the third spectral moment, skewness (indicating how skewed the spectral shape is), which have been repeatedly relevant to variation of /s/ production associated with gender and sexual orientation (Flipsen et al., 1999; Stuart-Smith, 2007; Munson, B., McDonald, E. C., DeBoe, N. L., & White, A., R., 2006)

CHAPTER 5

CONCLUSION

The present study was designed to fill the gap of research on gendered production of /ɕ/ in Mandarin Chinese regarding its origin, specifically the developmental process prior to adulthood. This pioneer study takes a comprehensive view towards gendered speech production as it examined the gendered /ɕ/ production from multiple dimensions including anatomical development, prenatal biological effect, and social influence. The results depicted a socially-constructed developmental trajectory for gendered speech production among Mandarin speaking children and settled with “nurture” as the key factor contributing to gendered speech in the “nurture vs nature” debate. The study illuminated that gender-marked divergence of /ɕ/ production begins at the dawn of sexual maturation when gender-identity development also excels. Despite the lack of contribution from anatomical development, prenatal biological effect, or gender role behavior to the emergence of this gender disparity, gendered /ɕ/ may develop in parallel with gender identity and becomes correlated with gender role behavior for boys after early adolescence. Particularly, a valuable insight was provided on the relation between the development of male’s gender role and of gendered production: gender-marking of /ɕ/ variation may be in essence “male-typicality indexing”, as the variation of /ɕ/ production only develops to be part of the male gender norms and to in turn convey gender identity for males only. Despite the breakthrough achieved on the understanding of gendered speech production, as a pioneer project, the study bore a number of methodological limitations and the results of which should be interpreted with discretion. For future directions, this comprehensive study has offered empirical regard on anatomical, prenatal biological, and sociocultural aspects of gendered speech production, and opened up a broad research field, suggesting both biological and social approaches for future studies with respect of gendered /ɕ/

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Appendix A

Child Play Behavior and Activity Questionnaire

INSTRUCTIONS: Please rates the frequency of the occurrence of the following behaviors exhibited by your child in the past six months, and answer the questions in a way that best describes your child.

1= Never 2 = Seldom 3 = Frequently 4 = Very often 5= Always 0=not applicable (never have been introduced to this games/been in the situations where this type of tendency could be shown)

1. He/she plays with Barbie or similar types of dolls ()
2. He/she plays football or basketball ()
3. He/she plays house ()
4. He/she plays toy guns ()
5. He/she plays with stuffed animals ()
6. He/she plays with mechanical or machine-like toys, like robots ()
7. He/she likes fairy tales like Snow White ()
8. He/she plays as spaceman or soldier ()
9. He/she plays teacher or nurse games ()
10. He/she likes building fort in games ()
11. He/she likes to play games like “Puts a handkerchief behind you” a ()
12. He/she likes to dress in female clothing, such as skirts ()
13. He/she likes to dress in male clothing, such as shorts ()
14. In dress-up games, he/she likes to dress-up in women’s clothing ()
15. In dress-up games, he/she likes to dress-up in men’s clothing ()
16. He/she likes dressing up and make up ()
17. He/she plays rough-and-tumble games ()
18. At school, he/she plays with boys ()
19. At school, he/she plays with girls ()
20. He/she likes to use tools, such as hammers, screw drives, etc. ()
21. At school, he/she plays with boys ()
22. He/she imitates female characters seen on T.V. or in the movies ()
23. He/she likes real automobile ()
24. He/she wears things like towels around waist as a skirt ()
25. He/she imitates male characters seen on T.V. or in the movies ()
26. He/she likes knitting or sewing ()
27. He/she is popular among boys ()
28. He/she is popular among girls ()

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29. He/she prefers staying with female relatives ()
30. In playing “mother/father”, “house” or “school” games, he/she takes the role of a girl or woman ()
31. He/she is good at imitating females ()
32. He/she is good at imitating males ()
33. He/she is interested in sports competition ()
34. He/she likes singing ()
35. He/she likes dancing ()
36. He/she plays wrestling or Wushu ()
37. He/she plays Cooking games ()
38. He/she plays jump-rope ()
39. He/she plays jump-rubber band ()
40. He/she plays hopscotch ()
41. He/she plays with plasticine ()
42. He/she plays store ()
43. He/she climbs trees ()
44. He/she plays chess ()
45. He/she likes to play Dangong (* A kind of a toy catapult that is considered to be popular among young boys)
46. He/she reads books about dinosaurs and space ()

Appendix B

**Table A: Mean and standard deviation of the scores of Child Play Behaviour and Attitude
Questionnaire for boys and girls of each age group**

	Age 7	Age 12	Age 16
Girl CPBAQ	M=3.72 SD=0.335	M=3.49 SD=0.315	M=3.44 SD=0.364
Boy CPBAQ	M=2.35 0.301	M=2.24 SD=0.246	M=2.33 SD=0.283