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Speech Sound Articulation Abilities of Preschool-age Children Who Stutter

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1. Introduction

Bloodstein and Bernstein Ratner (2008) suggested that "there is a rather pronounced tendency of stutterers to have functional difficulties of articulation…'immature' speech and the like" (p. 226). As shown in Table 1, this suggestion supports findings from early (1920 – late 1960's), *informal* or *nonstandardized* assessments indicating that children who stutter (CWS) exhibit poorer articulation abilities than children who do not stutter (CWNS). However, Table 1 also shows that more recent (1980's - present), *formal* or *standardized* assessments have not always reported such between-group differences. Taken together, results from extant empirical studies appear equivocal regarding the association between childhood stuttering and articulation (Nippold, 2002).

In attempts to better understand and interpret extant literature, we examine four salient issues related to this body of knowledge. The first issue relates to two terms sometimes interchangeably used to describe CWS' speech sound abilities— *articulation* and *phonology*. The second issue relates to the apparent motivation for past investigations of the association between childhood stuttering and articulation. Third, as suggested above, is the issue of methodological differences among empirical studies that compared the articulation abilities of CWS and CWNS. Fourth, is the issue of the relative paucity of information regarding the association between CWS' articulation abilities and their frequency, severity and type of stuttering.

1.1 Definition of speech sound abilities: *Articulation* versus *phonology*

Speech sound abilities can be categorized as *articulatory* (i.e., phonetic) or *phonological* (i.e., phonemic) in nature. Specifically, *articulation* refers to "motor processes involved in

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the planning and execution of sequences of overlapping gestures that result in speech" (Bauman-Waengler, 2004, p. 2). In contrast, *phonology* refers to cognitive/linguistic processes involved in how speech sound information is represented/organized, stored, planned and retrieved (Bauman-Waengler, 2004). It is possible for children to exhibit both articulatory and phonological speech sound errors (Bauman-Waengler, 2004).

Some have broadly used the term "phonology," referring to both articulatory (i.e. motoric) and phonological (i.e., cognitive/linguistic) elements of speech production (Gierut, 1998; Shriberg & Kwiatkowski, 1982). Similarly, articulation and phonology have not always been differentiated when discussed in association with childhood stuttering (e.g., Arndt & Healey, 2001; Bloodstein & Bernstein Ratner, 2008; Coulter, Anderson, & Conture, 2009). However, differentiation between these two processes would seem important because studies of each involve varying methodologies, with results having differing implications (i.e., for a comprehensive discussion of this topic, see Bauman-Waengler [2004] and Kamhi [1992]). Similarly, it seems important to distinguish, where possible, between empirical studies of the association between stuttering and *articulation* and those of the association between stuttering and *phonology*. Thus, the present paper focused on the association between childhood stuttering and speech sound *articulation*[1]—recognizing that others have made significant contributions to our understanding of the association between childhood stuttering and *phonology* (e.g., Blood, Ridenour, Qualls & Hammer, 2003; Paden, Ambrose & Yairi, 2002; Paden, Yairi, & Ambrose, 1999).

1.2 Past studies of the association between articulation and stuttering

1.2.1 Motivation—Review of previous empirical investigations of the association between articulation and childhood stuttering suggests that such studies were motivated by: (1) *general* interest in *speech-language* variables possibly associated with childhood stuttering (e.g., St. Louis & Hinzman, 1988); (2) *specific* interest in whether *articulation* errors or disorders may be associated with childhood stuttering (Pellowski, Conture, Anderson, & Ohde, 2001); or (3) the possibility that *articulation* errors or disorders may represent a competing account for the association between stuttering and other variables (e.g., language abilities; Anderson & Conture, 2000). Regardless of the precise motivation, previous researchers have generally attempted to determine whether CWS, compared to CWNS, exhibit *statistically* or *clinically* significant differences in their speech sound development. Findings of *statistically* significant differences in articulation suggest that there are subtle to not-so-subtle articulation *differences* between CWS and CWNS (Pellowski et al., 2001), regardless of whether these differences represent frank or clinically significant articulation disorders. Findings of *clinically* significant differences in articulation suggest that articulation *disorders* are more prevalent among CWS than CWNS (e.g., Blood et al., 2003). Such between-group articulation differences—statistical or clinical—have been suggested to contribute to CWS' challenges establishing normally fluent speech.

1.2.2 Varying sample and methodological characteristics—As noted above, there have been equivocal findings regarding the articulation abilities of CWS versus those of CWNS. In general, such equivocation seems to relate, at least in part, to between-study differences in *sample characteristics* and *methodologies* (Table 1).

[1]Various means may be used to assess speech sound articulation, including but not limited to those which are acoustic, kinematic, physiological, and perceptual in nature. In the current study, we focus on a standardized, perceptual measure of children's (in)correct speech sound production of consonant sounds at the word level (i.e., the Goldman-Fristoe Test of Articulation-2 [GFTA-2], Goldman & Fristoe, 2000). For ease of readability, and given historical and current, conventional uses of the GFTA-2, we will henceforth refer to this measure as an index of "articulation," avoiding the more neutral/specific yet wordy descriptions of the GFTA-2 (i.e., "perceptual (in)correctness of speech sound production").

Regarding *sample characteristics*, varying sample sizes, age-ranges, and inclusion/diagnostic criteria make it challenging to compare findings across various investigations. Specifically, sample sizes range from nine (Arnold, Conture, & Ohde, 2005) to 126 CWS (Schindler, 1955). The relatively small samples assessed by some studies raise the question of statistical power and generalizability to the population of CWS. However, studies assessing larger samples (Schindler, 1955; Williams & Silverman, 1968) have sometimes included wide age-ranges (e.g., 1st through 12th grade children). Given the developmental nature of childhood stuttering, which suggests that the disorder changes over time, it is difficult to extrapolate findings from older children (e.g., St. Louis & Hinzman, 1988), whose articulation abilities are relatively well established, to those of preschool-age children (e.g., Anderson & Conture, 2000), whose articulation abilities are less well established. Additionally, given that articulation difficulties have been shown to co-occur with stuttering more frequently than most other speech, language, or related disorders (e.g., Blood et al., 2003), it seems likely that varying diagnostic criteria across studies (i.e., including children with/without articulation disorders) may also have affected reported findings. Indeed, Table 1 shows that findings of studies employing relatively rigorous diagnostic criteria have not always been consistent with those whose diagnostic criteria were less clear or not reported.

Regarding *methodological* differences, articulation could be studied from various perspectives (e.g., acoustic, perceptual, kinematic and physiological). As shown in Table 1, some empirical studies assessing articulation employed informal/non-standardized perceptual methods (e.g., Williams & Silverman, 1968) whereas others employed formal/standardized perceptual methods (e.g., Coulter et al., 2009). Undoubtedly, both assessment methods provide pertinent information regarding children's articulation abilities. However, it is possible that equivocal findings across studies relate to the fact that *informal* measures of articulation may consist of different tasks or stimuli than *formal* measures of articulation. For example, informal methods may involve relatively unstructured conversation that might not elicit all target sounds, whereas formal methods using single-word picture naming tasks require elicitation of all target sounds. Indeed, Morrison and Shriberg (1992) found significant differences between children's articulatory performance on standardized measures versus during running/conversational speech. Additionally, children's performances on standardized measures are compared against norms of the general population. In contrast, there are generally no norms against which to compare children's performance on informal/non-standardized assessment methods.

Taken together, given the varying sample characteristics and methodologies across studies, it remains unclear how the articulation abilities of CWS, particularly those close to onset of the disorder (i.e., preschool-age), compare to those of CWNS. Thus, further empirical investigation of this topic seems warranted, especially one involving (1) a relatively large sample of participants, (2) a more circumscribed chronological age range, (3) more replicable inclusion criteria, and (4) widely-used standardized means of measuring speech sound articulation.[2]

1.2.3 Association between articulation and stuttering frequency, type, and severity—

Relatively few published studies have reported findings of the association between young CWS' articulation and their stuttering frequency, type, and severity. Ryan (1992, 2001) reported no significant correlation between *preschool-age* CWS' stuttering frequency and their articulation abilities. St. Louis and Hinzman (1988) reported that *school-*

[2]The present authors recognize that employing standardized measures of articulation represents but one line of evidence regarding the *perceived* accuracy with which CWS and CWNS reach broad articulatory targets. This approach does, however, allow one to compare children's performance against normative data, thus providing insight into the relative development of both talker groups' speech sound abilities.

age CWS with *severe* stuttering exhibited significantly more articulation errors than those with *moderate* stuttering severity, a finding that did not replicate in a later study (St. Louis, 1991). In a related study of the relation between speech disfluencies and articulation disorders, Ragsdale and Sisterhen (1984) reported a greater frequency of speech disfluencies, particularly *repetitions*, exhibited by 5- to 6-year-old children with versus those without articulation disorders. Suffice it to say, the association between children's articulation abilities and their frequency, severity, and type of speech disfluencies is still uncertain

1.3 Present Study

1.3.1 Motivation—As the preceding review suggests, it is challenging to readily interpret the association between perceptual measures of speech sound articulation and childhood stuttering based on extant findings. This is at least partially due to the fact that such findings were based on different sample characteristics and methodologies. Therefore, motivated to improve our ability to interpret the association between articulation and stuttering, the present authors addressed these sample and methodological concerns by (1) studying a relatively large sample of participants (*N*=277); (2) employing a widely used standardized measure of speech sound production (i.e., the Goldman-Fristoe Test of Articulation-2 [GFTA-2], Goldman & Fristoe, 2000); (3) explicating replicable inclusion criteria; and (4) a circumscribed chronological age range of preschool-age children (i.e., 3- to 5-year-old children). Studying the articulation abilities of CWS and CWNS within a restricted age range, particularly *preschool-age children*, is important because: (1) this is the time period when most children begin to stutter; (2) this is a time period when children continuously develop and refine their speech sound systems; and (3) relatively little empirical attention has been paid to the association between the articulation abilities of *preschool-age* CWS and their stuttering frequency, type, and severity.

1.3.2 Purpose and hypotheses—Thus, it was the purpose of the present study to attempt to provide a more comprehensive understanding of the association between articulation and childhood stuttering. In doing so, we examined two major issues regarding this association, while concurrently addressing the aforementioned sample and methodological concerns. The first issue relates to the association between articulation and the *diagnosis* of stuttering (i.e., CWS vs. CWNS); that is, whether there are statistically significant differences between preschool-age CWS' and CWNS' performance on a standardized, perceptual measure of articulation (i.e., GFTA-2 scores). We hypothesized that CWS' GFTA-2 standard scores would be significantly lower than those of CWNS, and that these differences would be impacted by age and gender. The second issue relates to the association between articulation and stuttering *behaviors*; that is, whether preschool-age CWS' articulation abilities (as indicated by their performance on a standardized, perceptual measure of articulation) are associated with various measures of their stuttering behaviors (i.e., frequency and severity of stuttering, as well as the sound prolongation index ([SPI]; Schwartz & Conture, 1988). We hypothesized that for CWS, GFTA-2 standard scores would be inversely related to stuttering frequency, severity, and SPI (i.e., the number of sound prolongations per stuttered disfluencies).

2. Methods

2.1 Participants

Participants included 277 monolingual, English speaking preschool-age children (3;0–5;11 years of age), 128 of whom stutter (CWS; 101 males, *M* = 48.26 months, *SD* = 9.01) and 149 who do not stutter (CWNS; 76 males, *M* = 51.23 months, *SD* =9.58). As will be discussed in the Data Analysis section below, variables such as chronological age and gender were included as covariates in the statistical models to reflect competing explanations for possible between-group differences in GFTA-2 scores.

These participants' data were previously collected as part of a large-scale empirical investigation of linguistic and emotional associates of childhood stuttering (e.g., Arnold, Conture, Key, & Walden, 2011; Choi, Conture, Walden, Lambert, & Tumanova, 2013; Johnson, Walden, Conture, & Karrass, 2010; Richels, Buhr, Conture, & Ntourou, 2010; Walden et al., 2012). All were paid volunteers whose parents either learned of the study from an advertisement in a free monthly parent magazine circulated throughout Middle Tennessee, were contacted from Tennessee State birth records, or were referred to the Vanderbilt Bill Wilkerson Hearing and Speech Center for an evaluation. All parents signed an informed consent, and all children assented.

2.2 Classification and Inclusion Criteria

Participants were classified as CWS if they (a) exhibited three or more stuttered disfluencies ([SD] i.e., sound/syllable repetitions, sound prolongations or single-syllable whole-word repetitions) per 100 words of conversational speech (Conture, 2001; Yaruss, 1998), ***and*** (b) scored 11 or greater (i.e., severity of at least "mild") on the Stuttering Severity Instrument-3 (SSI-3; Riley, 1994). In contrast, participants were classified as CWNS if they (a) exhibited two or fewer SD per 100 words of conversational speech, ***and*** (b) scored 10 or lower on the SSI-3 (i.e., severity of less than "mild").[3] Children's speech fluency behaviors were considered "ambiguous"—rendering them unclassifiable—based on the following criteria (either [a] or [b]): (a) if the child exhibited two or fewer SDs per 100 words ***and*** scored 11 or greater on the SSI-3; ***OR*** (b) if the child exhibited three or more SD per 100 words ***and*** scored 10 or lower on the SSI-3. Children were required to meet all of the criteria listed above to be considered a CWS, CWNS, or unclassifiable.[4]

Participants were only included in the present study if they were classified as either CWS or CWNS based on *both* their stuttering frequency and total SSI-3 scores (see criteria [a] and [b] above); unclassifiable children (criteria [c] above) were excluded from participation. Additionally, included children were required to have no known or reported hearing, neurological, developmental, or intellectual disorders. Included participants were further required to have complete data for all standardized tests but were allowed to freely vary in their scores on the articulation and language measures.[5]

2.3 Final Data Corpus

The initial cohort consisted of 301 children, seven of whom were removed from the study because it was not possible to determine their talker group classification (i.e., their frequency of SD and SSI-3 scores placed them in the unclassifiable category). Of the remaining 294 children, five were excluded from the study because they did not fall within

[3]It should be noted that the SSI-3 does not include a "no stuttering" category. Given that the lowest stuttering severity category on the SSI-3 is "very mild," which corresponds with a total overall score of 10 or below, there could be some overlap between CWS and CWNS who fall under this category. To minimize such potential overlap, *only* children who scored 11 or above on the SSI-3 *and* exhibited 3 or more stuttered disfluencies (SD) per 100 words were classified as CWS. Similarly, *only* children who scored 10 or below on the SSI-3 *and* exhibited below 3 SDs per 100 words were classified as CWNS. The present authors acknowledge that there will always be an error term or potential overlap between the talker groups, wehtehr using the present or other stuttering classification schemas.

[4]See Howell, Bailey, and Kothari (2010) as well as Jiang, Lu, Peng, Zhu, and Howell (2012) for reviews of other classification schemes that have been used to diagnose stuttering in older individuals (i.e., *school-age* children and *adults*) who stutter.

[5]As previously mentioned, all participants (N=277) were analyzed regardless of whether their GFTA-2 scores were within- (*n*=260; 122 CWS, 138 CWNS) or below-normal limits (*n*=17; 6 male CWS, 11 CWNS). The present authors separately analyzed preschool-age participants (1) with freely varying GFTA-2 scores (N=277) and (2) who scored with-normal limits (*n*=260). Given the substantial overlap between the two samples, which resulted in similar findings, results herein are only reported for the total 277 participants with freely varying GFTA-2 scores.

the target age range (i.e., <3;0 or >5;11 years of age), and 12 were excluded from further consideration because either one or more of their standardized speech or language data were missing. The removal of the abovementioned 24 children resulted in the final 277 participants (128 CWS, 149 CWNS) who were analyzed in the present study.

2.4 Measure of Speech Sound Articulation Abilities

Participants' standard scores on the norm-referenced "Sounds in Words" subtest of the GFTA-2 were assessed to determine their speech sound articulation abilities. More specifically, GFTA-2 standard scores reflect examiners' perceptual judgment of children's (in)correct speech sound production of consonants at the word level. A greater standard score indicates that the child has better articulation abilities. As described by Anderson, Pellowski, & Conture (2005):

> The GFTA-2 examines an individual's articulation of consonant sounds in Standard American English via spontaneous single-word elicitation in response to pictures.[6] The GFTA-2 was standardized on a normative sample of 2350 participants aged 2;0 to 21;11 and has a median coefficient alpha reliability of .94 and .96 for males and females, respectively, and a median test-retest reliability of .98 for initial, medial, and final sounds. (pp. 226–227)

2.5 Measurement of Speech Fluency

Participants' speech fluency was measured with respect to frequency, type, and severity of stuttering, to be described in further detail below. These values were derived from a 300-word conversational speech sample—obtained through child-examiner free-play—using a disfluency count sheet (Conture, 2001) in conjunction with the SSI-3.

2.5.1 Types of Disfluencies—Participants' speech disfluencies were categorized as either stuttered or non-stuttered. As with similar, published studies of preschool-age children by the present research group (e.g., Coulter et al., 2009; Richels et al., 2010), stuttered disfluencies included sound/syllable repetitions ([SSR] e.g., "s-s-s-sorry"), single-syllable whole-word repetitions ([WWR] e.g., "the-the-the"),[7] and sound prolongations ([SP] e.g., "ssssorry"). Nonstuttered disfluencies included interjections ([INT] e.g., "um"), phrase repetitions ([PR] e.g., "I want to I want to"), and revisions ([REV] e.g., "I'm going to the store the restaurant").

2.5.2 Frequency of Total, Stuttered and Non-stuttered Disfluencies—Frequency of *total disfluencies* (TD) was calculated by dividing the total number of all speech disfluencies (stuttered + non-stuttered) by the total number of words produced (i.e., TD/TW). Frequency of *stuttered disfluencies* (SD) was measured by dividing the total number of stuttered disfluencies by the total number of words spoken (i.e., SD/TW). Frequency of

[6]For children exhibiting difficulty spontaneously responding to pictures, examiners adhered to the administrative procedures (e.g., providing verbal cues, modeling, assessing stimulability etc..) stipulated in the GFTA-2 manual to elicit production of target sounds.

[7]Single-syllable whole-word repetitions produced "without tension are not counted as stuttering. Repetition of one-syllable words may be stuttering if the word sounds abnormal (shortened, prolonged, staccato, tense, etc.); however, when these single-syllable words are repeated but are otherwise spoken normally, they do not qualify as stuttering using the definition just stated" (Riley, 1994, p. 4). Thus, in accordance with the above quotation from the SSI-3 manual, only perceptually "abnormal (shortened, prolonged, staccato, tense, etc." single-syllable whole-word repetitions were counted as stuttered disfluencies. In the present study, perceptually effortless, non-tense repetitions of single-syllable whole words—such as those produced for emphasis (e.g., the child says, "it was a **big, big** dog," while gesturing how large the dog was)—were *not* counted as stuttered or nonstuttered disfluencies. These non-effortful, non-tense repetitions of single-syllable whole words were excluded from the fluency data used to (1) determine talker group classification, and (2) assess the association between children's articulation scores and frequency of (non)stuttered speech disfluencies. Other stuttering classification schemes—some of which exclude WWRs from the SD category—have been used particularly when assessing older, *school-age* and *adults* who stutter (e.g., Howell et al., 2010; Jiang et al., 2012).

non-stuttered disfluencies (NSD) was measured by dividing the total number of non-stuttered disfluenices per total words (NSD/TW).

2.5.3 Stuttering Severity—Participants' stuttering severity was determined by their overall score on the SSI-3 (Riley, 1994)—a criterion-referenced measure assessing stuttering frequency, duration, and physical concomitants.[8]

2.6 Sound Prolongation Index (SPI)

The sound prolongation index (SPI), a measure empirically shown by Schwartz and Conture (1988) to significantly differentiate among preschool-age CWS, was calculated by dividing the total number of sound prolongations by the total number of stuttered disfluencies (SP/SD) produced during a 300-word conversational sample.

2.7 Procedures

2.7.1 Parent Interview—Data collection for all participants consisted of a parent interview, wherein information was obtained regarding the family's history of speech-language and fluency disorders, as well as caregivers' concerns about their children's speech-language abilities (for further detail pertaining to this interview process, see Conture, 2001). Additionally, information regarding participants' socioeconomic status (SES) was gathered. SES data was classified using the Hollingshead Four-Factor Index of Social Position (Hollingshead, 1975), a protocol assessing SES based on the United States Census. This index takes into account both parents' educational levels, occupation, gender, and marital status. Consistent with Hollingshead's (1975) descriptions for data handling, computed SES scores range on a continuum from eight to 66,[9] with a higher score indicating a higher socioeconomic status. Specifically, a score of eight reflects the lowest possible level of occupational status (e.g., dishwashers) and education (less than 7th grade), whereas a score of 66 reflects the highest level of occupational status (e.g., aeronautical engineer) and educational level (graduate education).

2.8.2 Child Testing—Testing was conducted in a controlled laboratory environment as part of a pre-experimental diagnosis/screening to determine inclusion/exclusion for subsequent experimental research (e.g., Byrd, Conture, & Ohde, 2007; Coulter et al., 2009; Johnson et al., 2010). While one examiner conducted the parent interview, another examiner engaged the child in conversation during free-play, from which measures of speech fluency were obtained (see Measurement of Speech Fluency section above). Participants were then administered a series of standardized speech and language tests in the following, fixed order: the "Sounds in Words" subtest of the Goldman-Fristoe Test of Articulation-2 (GFTA-2; Goldman & Fristoe, 2000), the Peabody Picture Vocabulary Test-Third Edition (PPVT-III; Dunn & Dunn, 1997), the Expressive Vocabulary Test (EVT; Williams, 1997), and the Test of Early Language Development-3 (TELD-3; Hresko, Reid, & Hamill, 1999). These standardized tests assessed children's articulation abilities, receptive and expressive vocabulary, as well as receptive and expressive language skills, respectively. Examiners adhered to the administrative procedures stipulated in the manuals of the abovementioned standardized speech-language measures.

Standardized testing was followed by the administration of bilateral, pure tone and tympanometric hearing screenings; all audiometric equipment was routinely calibrated. Although testing procedures might have introduced an element of fatigue to some of the

[8]See Howell (2013) for a thorough description and assessment of the SSI-3.

[9]Weighted Family SES scores are calculated by multiplying the occupation scale score by a weight of five and the education scale score by a weight of three, as per Hollingshead's protocol.

later administered tests (e.g., TELD-3), this procedure was a constant one for all participants in both talker groups. Furthermore, the present authors have found that the above procedures maximize the chances that the greatest number of *preschool-age* children will successfully complete all standardized speech-language testing.

2.9 Data Analyses

2.9.1 Talker Group Characteristics

Speech fluency variables: Prior to testing the present study's main hypotheses, generalized linear models (GLM; Nelder & Wedderburn, 1972)[10] were performed to assess between-group differences (i.e., CWS vs. CWNS) in speech fluency (i.e., SSI scores, as well as frequency of stuttered, non-stuttered, and total disfluencies). Given that the speech disfluency data followed a negative binomial distribution,[11] GLM was chosen because it allows for analysis of count data that do not follow a normal distribution. Interested readers are referred to Gardner, Mulvey, and Shaw (1995) for more detailed statistical illustrations/ explanations of GLM and negative binomial distributions.

Demographic and language variables: A series of statistical analyses were performed to better understand the age, gender, SES, language, and vocabulary characteristics of our CWS and CWNS samples. Characteristics that significantly differed between the talker groups were included as covariates in subsequent statistical models to account for competing explanations for possible between-group differences in GFTA-2 scores.

With the exception of gender, all the sample characteristics followed normal distributions and allowed for inferential parametric assessment. A chi-square (χ^2) was performed to assess between-group gender differences given the non-normal categorical nature of the data. A series of analyses of variance (ANOVA) were performed to assess possible between-group differences regarding the other sample characteristics (i.e., age, SES, TELD-3, etc…). Because multiple significance tests may yield false (i.e., "significant") results by chance, we employed a bootstrap re-sampling with replacement procedure (Efron, 1993) for multiple tests with a family wise false discovery rate of p <.05 (Hochberg, 1988; Benjamini & Hochberg, 1995). Re-sampling makes no assumptions about normality or independence. This was done using SAS PROC MULTTEST (Westfall, Tobias et al. 1999).

2.9.2 Hypotheses—To test the present study's *first* hypothesis, generalized estimating equations (GEE)[12] were employed to assess whether there are overall differences between the talker groups' GFTA-2 scores. As will be described below, several covariates were included in the models to prevent misattributing variance in GFTA-2 scores to other talker group differences. To further assess articulation differences between talker groups relative to age, participants were divided into three separate age groups (3-, 4-, and 5-year-olds). Separate GEEs were performed for each age group, with each model containing gender as a covariate and a unique set of additional covariates pertinent to the specified age group. To test the *second* hypothesis, Spearman's Rho correlations assessed the relation between CWS' speech sound abilities and stuttering frequency, severity, and SPI.

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[10]"*Generalized*" linear models allow one to analyze dependent variables that follow various distributions (e.g., binary, Poisson, or negative binomial), including those which are non-normal (Nelder & Wedderburn, 1972). "The GLM should not be confused with the *general* linear model [i.e., ANOVA] described by Cohen (1968)… The latter is a generalization of multivariate and univariate regression with normally distributed errors" (Gardner, Mulvey, & Shaw, 1995, p. 395).

[11]Non-normality of distribution was determined by graphical descriptive analysis of the data (i.e., histogram) as well as results of the Shapiro-Wilk test of normality (p<.001 for all disfluency measures). "Negative binomial" is a type of a Poisson regression with overdispersion (e.g., a long right-hand tail).

[12]GEE were used to assess between-group GFTA-2 differences given the Poisson-like (i.e., non-normal) distribution of participants' speech sound articulation scores.

Present findings were considered significant if their associated *p*-values were .05 or less. Estimates of effect size (ES) were expressed in partial eta squares (η_p^2), Spearman's rho (ρ), beta weights (*β*) or *w* (Cohen, 1988), depending on the statistical/analytical procedure employed. Traditional or recommended interpretations for these effect sizes were assumed (e.g., η_p^2 = .01/.06/.14 ~ small/medium/large effects; *w* =.10/.30/.50 ~ small/medium/large effects [Cohen, 1973, 1988; UCLA: Statistical Consulting Group; Ferguson, 2009; Volker, 2006]).

2.9.3 Statistical power—We performed a Cohen-based power analysis (Cohen, 1988, 1992)—using PASS software (Hintze, 2008)—for a (1) one-way ANOVA with two groups (i.e., the first hypothesis); and (2) within-group correlational analysis (i.e., the second hypothesis). Power was evaluated by estimating the minimum detectable effect size (MDES; Kraemer, Mintz, Noda, Tinklenberg, & Yesavage, 2006). We assumed traditional criteria: $p < .05$ two-tailed, power=80%, and Cohen's effect size guidelines (e.g., *d* = .2/.5/.8 ~ small/med/large effects; r = .1/.3/.5 ~ small/medium/large effects).

Relative to the *first* hypothesis (i.e., between-group GFTA-2 differences), a one-way ANOVA with two groups (N=277; 128 CWS + 149 CWNS) using a standardized outcome (mean = 0, std = 1) could detect effects as small as Cohen's *d* = 0.34 SDs with 80% power. Relative to the *second* hypothesis (i.e., within-group correlation between GFTA-2 and stuttering behaviors), a correlational analysis with N=128 could detect effects as small as r = 0.24 with 80% power. Given the above MDESs, we concluded that the present study is sufficiently powered to detect small to medium effects (Cohen, 1992). However, it should be noted that non-significant effects might occur if the reported ESs are too weak.

2.10 Inter- and Intra-judge Reliability for Measurement of Speech Disfluencies

Intra-class correlation coefficients (ICC; McGraw & Wong, 1996; Shrout & Fleiss, 1979) using the absolute agreement criterion were calculated to assess inter- and intra-judge reliability for the measurement of stuttered (SD), non-stuttered (NSD), and total disfluencies (TD). Four examiners, trained in assessing stuttering, measured participants' disfluencies in real time while watching video-recorded speech samples (obtained during child-clinician conversations in free-play).

Approximately 12% (*n*=32; 14 CWNS and 18 CWS) of participants' video-recorded speech samples were randomly selected to assess inter-judge reliability. ICCs ranged from .95 to .97 (M=.96), with average measures of .989, p<.001, for identification of SD; from .82 to .89 (M=.86), with average measures of .955, p<.001, for identification of NSD; and from .94 to .97 (M=.96), with average measures of .987, p<.001, for identification of TD. Intra-judge reliability was collected for 11 participants (M=6 CWS; M=5 CWNS). At least 3 months passed between the first and second disfluency counts. ICCs ranged from .95 to .99 (M=.97) for identification of SD, from .88 to .96 (M=.93) for identification of NSD, and from .97 to .98 (M=.97) for identification of TD. The above ICC reliability values exceed the popular criterion of .7 (Yoder & Symons, 2010).

3. Results

3.1 Talker Group Characteristics

Table 2 shows participants' demographic, speech fluency, and language characteristics. It should be noted that these various characteristics were not dependent variables of the present study's main hypotheses, but were assessed to better understand the CWS and CWNS samples.

Speech fluency variables: As would be expected based on talker group classification, preschool-age CWS, when compared to preschool-age CWNS, exhibited (1) a significantly greater mean percentage of total disfluencies (TD), Wald χ^2 (1, 274)=356.63, p < 0.001, β = −1.084; (2) significantly more stuttered disfluencies (SD) per 100 words, Wald χ^2 (1, 274)=641.24, p < 0.001, β=−1.889; and (3) and significantly more non-stuttered disfluencies (NSD) per 100 words, Wald χ^2 (1, 274)=15.1, p < 0.001, β =−.293. Consistent with these findings, CWS exhibited significantly higher mean scores on the SSI-3, Wald χ^2 (1, 274)=630.03, p < 0.001, β=−.96 (Table 2). All of the above β values (an estimate of effect size) indicated strong effects, with the exception of NSD whose β was "minimum [but] 'practically' significant…for social science data" (Ferguson, 2009, Table 1). For CWS, the sound prolongation index (SPI) ranged from 0% to 89.19%, with a mean of 19.13% (*SD*=20.7).

Demographic and language variables: Significant between-group differences were found for chronological age, F (1, 275)=6.986, p=.009 (p=.045, bootstrapped), η_p^2=.025, gender, χ^2 (1)=23.233, p< .001, *w* =.29.[13] EVT, *F*(1, 275)=5.12, *p*=.024 (p=.118, bootstrapped), η_p^2 =.018, and the receptive subtest of the TELD-3, *F*(1, 275)=7.81, *p*=.006 (p=.03, bootstrapped), η_p^2 =.028. The effect sizes (ES) for these variables were small to medium. To control for possible effects of these between-group differences on GFTA scores, these factors (i.e., age, gender, EVT, TELD-3 receptive) were entered in the statistical model as covariates. Further consideration for variables that did not significantly differ between the talker groups (e.g., SES; see Table 2) did not appear warranted.

3.1.2 Hypothesis 1: Overall between-group differences in articulation abilities

—Table 3 provides results of the GEE, which was the statistical model used to assess whether CWS score significantly lower on the GFTA-2 than CWNS (hypothesis 1). Given that the talker-groups significantly differed on a number of demographic and language variables (see Table 2), the GEE model included several covariates and two interaction terms to account for other possible explanations of variation in GFTA-2 scores. Covariates included chronological age, gender, EVT and TELD-3 receptive subscale scores; interactions included talker group X gender and talker group X chronological age.

As shown in Table 3, results of the GEE indicated no significant differences between the speech sound articulation abilities of preschool-age CWS and CWNS, *p* = .312, β=−.06. Of the abovementioned covariates and interactions included in this model, a significant effect was only found for the TELD-3 receptive, Wald χ^2 (1) =4.241, *p* = .039, β =.001; all other variables (age, gender, EVT and the interactions) were non-significant (*p* values ranged from .484 to .06; β ranged from .001 to −.019). Given the small β, further consideration regarding the significant TELD-3 receptive effect did not seem warranted (i.e., as GFTA-2 scores increase by 1 point, TELD-3 receptive scores tend to increase by .001 points, rendering its impact on GFTA-2 performance negligible). For participants in the present study, β values were small for all independent variables and covariates (Ferguson, 2009).

Age-related between-group differences in articulation abilities: To further assess the possible effects of age and gender on GFTA scores, participants were divided into three age groups: a 3-year-old (57 CWNS, 62 CWS), 4-year-old (58 CWNS, 51 CWS), and 5-year-old age group (34 CWNS, 15 CWS). ANOVAs assessed possible between-group differences, within each age group, on the various standardized language tests (e.g., TELD-3, PPVT-III,

[13]As expected, given gender differences in childhood stuttering (i.e., more boys than girls stutter), the sample presently studied consisted of more males than females who stutter (CWS=27 females and 101 males; CWNS=73 females and 76 males).

EVT). Those found to be significant were included as covariates, in addition to gender, in subsequent statistical analyses.[14]

As shown in Table 3, no significant between-group differences were found for the GFTA-2 for the 3-year-old, 4-year-old, or 5-year-old age groups. Furthermore, no significant gender effects were found for the 3- or 4-year-old groups (p =.943 and .086, respectively; β=.007 and .019, respectively). A significant but small gender effect (as indicated by β; Ferguson, 2009) was found for the 5-year-old age group, with males (*EM*=99.02, *SEE*=1.99) scoring lower on the GFTA-2 than females (*EM*=108.25, *SEE*=2.19), Wald χ^2 (1) =10.304, p = .001, β=−.089. Specifically, 5-year-old CWNS males scored significantly poorer on the GFTA-2 (*EM*=98.29, *SEE*=2.42) than both CWS females (*EM*=109.06, *SEE*=3.52; p=.037) and CWNS females (*EM*=107.45, *SEE*=1.96; p=.001). Likewise, CWS males scored significantly poorer on the GFTA-2 (*EM*=99.76, *SEE*=2.74) than both CWS females (p=.002) and CWNS females (p=.038). However, as previously mentioned, β was quite small for this gender effect (Ferguson, 2009).

3.1.3 Hypothesis 2: Association between CWS' articulation abilities and stuttering behaviors—

Spearman's rho (ρ) correlation was conducted for CWS to test whether an inverse relation exists between their GFTA-2 standard scores and stuttering behaviors. Findings showed no correlations between CWS' GFTA-2 standard scores and TD, SD, and NSD, nor between GFTA-2 standard scores and SSI3 scores or SPI. Rho ranged from .003 to .102, with associated p values ranging from .251 to .975. Effect sizes were small for each of these correlations, as indicated by $\rho < .2$ (Ferguson, 2009).

4. Discussion

4.1 Overall Findings and Implications

The present study resulted in two main findings. First, contrary to hypothesis one, there was no overall significant difference between the articulation abilities of preschool-age CWS and CWNS. Second, contrary to hypothesis two, preschool-age CWS' articulation abilities did not correlate with their stuttering behaviors (i.e., stuttering frequency, severity, and SPI). These findings suggest that for this sample of *preschool-age* children, there is no appreciable association between the diagnosis or behavioral characteristics of stuttering and speech sound articulation, at least when the latter is perceptually measured by a standardized assessment of speech sound articulation.

These findings are curious in light of the relatively high percentage of CWS reported to have co-occurring articulation difficulties (e.g., Blood et al., 2003). However, there are two salient differences between the present study and those reporting the prevalence of co-occurring articulation disorders in CWS. First, whereas the present study assessed the articulation abilities of preschool-age children between 3;0 to 5;11 years of age, some previous studies in this area did not include younger preschool-age children (i.e., Blood et al., 2003; Blood & Seider, 1981). Others studied a wider age-range of CWS, including preschool-age CWS, but reported results for *all* participants without explicating the prevalence of speech sound disorders within particular age groups (e.g., Arndt & Healey, 2001). Second, most of the preschool-age CWS in the present study exhibited within-normal articulation abilities (WNL; based on GFTA-2 scores), whereas other studies (i.e., Arndt & Healey, 2001; Blood et al., 2003; Blood & Seider, 1981) assessed CWS with *identified* articulation *disorders*. Thus, although present findings help clarify the association between

[14]Only the 4-year-old age group required additional covariates, which included the PPVT, EVT, as well as the TELD-3 receptive and expressive subscale scores. However, no significant effects were found for these variables on the GFTA-2 (p values ranged from .342 to .456).

articulation *abilities* and childhood stuttering—in otherwise typically developing preschool-age children—the prevalence of articulation *disorders* exhibited by preschool-age CWS, when compared to their CWNS peers, remains an open empirical question.

Given the above, we propose three possible accounts of the present findings: First, there may be a different association between preschool-age children's stuttering and their articulatory (motoric) versus phonological (linguistic) abilities. Second, there may be a different association between preschool-age children's stuttering and the speed versus accuracy of their speech planning or production. Third, there may be differences in the speech sound abilities of *school-age* versus those of *preschool-age* children. These possibilities are addressed below.

4.1.1 Articulation versus Phonology—As mentioned above, speech sound articulation is often considered to be a motoric process involved in the execution or production of speech, whereas phonology is a cognitive/linguistic process involved in how speech sound information is represented/organized, stored, planned and retrieved (Bauman-Waengler, 2004; Gierut, 1998). One might consider that even if there is no relation between preschool-age CWS' speech fluency and their perceived number of articulation errors (when the latter is perceptually measured using the GFTA-2), the possibility remains that there is an association between preschool-age children's speech fluency and the quantity or quality of their phonological processes (i.e., typical or atypical patterns of rule-based speech sound errors, such as cluster reduction, gliding, and stopping). To date, however, there are equivocal findings regarding between-group differences in the number or types of phonological processes.

For instance, some have reported that preschool-age CWS exhibit a greater number of disordered or atypical phonological processes than preschool-age CWNS (e.g., Louko, Edwards, & Conture, 1990), whereas others reported no such differences (e.g., Yaruss, LaSalle, & Conture, 1998). Additionally, some have found no significant relations between the number or types of CWS' phonological processes and their stuttering behaviors (e.g., stuttering frequency and duration, SPI; Louko et al., 1990; Yaruss et al., 1998), whereas others reported that preschool-age CWS with disordered phonology, compared to those without, exhibited significantly more sound prolongations (Wolk, Edwards, & Conture, 1993). Taken together, further empirical study is warranted to better understand between-group differences in phonological versus articulatory abilities, particularly in preschool-age CWS versus their CWNS peers. Implications of such studies should provide insight into the association between childhood stuttering and linguistic versus motoric processes associated with speech-language planning and production.

4.1.2 Accuracy versus Speed of Speech Processing, Planning, or Production —Perhaps differences between the articulation abilities of preschool-age CWS and CWNS are not apparent with respect to *accuracy* but rather in *speed* or temporal aspects of speech processing, planning or production. In other words, even if GFTA-2 scores (essentially a measure of articulatory accuracy) of preschool-age CWS do not differ from those of CWNS, the speed with which the talker groups' process, plan and produce speech sounds might differ. This possibility could not be investigated using the present study's methodology. However, such speculation is consistent with extant reports of between-group differences in (non)speech reaction times (RT) in children and adults who do versus those who do not stutter (e.g., Jones, Fox, & Jacewicz, 2012; Melnick, Conture, & Ohde, 2003; Weber-Fox, Spencer, Spruill, & Smith, 2004).

For instance, in a phonological priming study examining preschool-age children exhibiting WNL articulation abilities, Melnick et al. (2003) found that preschool-age CWNS with higher GFTA scores exhibited faster speech reaction times (SRT) than those with lower GFTA scores. For preschool-age CWS, however, no relations were found between GFTA scores and reaction times. These findings led the authors to conclude that "even after removing children with apparent and/or clinically significant articulatory difficulties, it would appear that the articulatory systems of CWS are less well-developed or organized than those of their normally fluent peers" (p. 1439).

Similarly, several studies examined the phonological processing abilities of adults who do (AWS) and do not stutter (AWNS) during non-speech tasks (e.g., rhyme judgment tasks). Findings indicated that compared to AWNS, AWS demonstrated longer delays and slower RTs especially during cognitively loaded (non)speech tasks (Jones et al., 2012; Weber-Fox et al., 2004). These results were taken to suggest that "the phonological processing system of AWS, compared to AWNS, are slower and more vulnerable to delays…especially when the cognitive load increased" (Jones et al., 2012).

The above suggests that *temporal* aspects of speech processing, planning or production may moderate/mediate the association between speech sound articulation and childhood stuttering. However, support or refutation for such possibilities must await future empirical investigation employing different methodologies than those used in the present study.

4.1.3 Articulation Abilities in Preschool- Versus School-age Children—It is also possible that the association between childhood stuttering and articulation is more apparent in *school-age* rather than in *preschool-age* children. Such speculations seem reasonable since children typically continue to develop and refine their speech sound productions until 6 to 9 years of age (Shriberg, Gruberg, Kwiatkowski, 1994; Shriberg, Kwiatkowski, & Gruber, 1994; Table 7, Smit, Hand, Freilinger, Bernthal, & Bird, 1990). Thus, it is fairly common for preschool-age children to exhibit speech sound errors that would be considered typical/acceptable. However, errors that persist beyond the typical age of acquisition would be considered more problematic. Additionally, there have been reports of typically developing children exhibiting reversals of previously acquired speech sounds, particularly of /s/ and /z/ productions (e.g., Smit et al., 1990). In other words, there are children who have acquired correct production of speech sounds "early in development and then adopt an error variant for a time before reverting to an acceptable production" (e.g., Smit et al., 1990, p.791).

Related to the above, Ryan (1992, 2001) found no significant differences between the articulation scores of preschool-age CWS and CWNS. However, he reported that five of the CWS (25% of the CWS sample), but none of the CWNS, later required therapy to correct "residual" speech sound errors. Residual errors are typically considered to be distortions of fricatives or liquids (e.g., /s/, /r/, and /l/) that persist in children ages 9 years and above (Shriberg & Kwiatkowski, 1994). Taken together, future research in this area may benefit from longitudinal studies of articulation in preschool-age children as they progress into school-age years, or replication and extension of the present study using both preschool- and school-age CWS and CWNS.

4.2 Ancillary Findings: Articulation Abilities Relative to Gender

A gender effect for the GFTA-2 was found for the 5-year-old age group, with girls generally outperforming boys, regardless of talker group. However, inferences regarding gender should be made with caution, given the relatively small effect size and sample of female CWS in this study, particularly in the 5-year-old age group. With that caveat in mind, present findings suggest that in the general population, older preschool-age girls tend to exhibit stronger articulation abilities than older preschool-age boys, a finding consistent with those indicating that typically developing girls generally exhibit better articulation abilities than boys (Kenney & Prather, 1986; Kenney, Prather, Mooney, & Jeruzal, 1984; Smit et al., 1990; Templin, 1957). Similarly, Blood et al. (2003) reported that 5- to 18-year-old CWS males exhibited a greater percentage of co-occurring articulation disorders than 5- to 18-year-old CWS females. However, it should be noted that the above studies did not report gender differences relative to specific age groups. Thus, further investigations, employing large sample sizes, are warranted to determine whether *preschool-age* males present with more articulation disorders/difficulties than *preschool-age* females—both in the general and stuttering populations—within specific age groups (i.e., 3-, 4-, and 5-year-olds).

5. Caveats

One limitation of the present study is that articulation was assessed using a standardized measure eliciting speech sounds in single-word responses. Some children might perform fairly well in single-word responses, but display poor sound production in conversational speech (Morrison & Shriberg, 1992). Perhaps a multi-method approach, including both formal and informal measures of speech sound development across varying speaking contexts, would provide a more comprehensive assessment of the association between articulation abilities and childhood stuttering.

A second limitation is that the GFTA-2 and similar standardized measures of articulation represent but *one* method of assessing children's speech sound production—a method involving *perceptual* judgments of the (in)accuracy with which children produce speech sounds at the word level. Such perceptual, standardized methods are certainly salient to a comprehensive understanding of the association between articulation and stuttering. However, based on the overall results of such methods (e.g., standard scores), it could be difficult to determine whether speech sound errors were phonological/phonemic (i.e., cognitively or linguistically based) or phonetic (i.e., motorically based) in nature (Bauman-Waengler, 2004; Gierut, 1998). Therefore, other available means of measuring children's speech sound abilities (e.g., acoustic, physiological, kinematic, etc.) should be explored to assess the relation between various facets of articulation and childhood stuttering.

A third limitation is that the vast majority (94%) of participants scored within (WNL) or above the normal limits (ANL) on the GFTA-2 (e.g., 122 CWS scored W/ANL, 6 scored BNL). Thus, our findings might not be generalizable to populations of preschool-age children exhibiting disordered articulation. Certainly, our findings do not rule out the possibility of a subgroup of preschool-age CWS with clinically significant or frank articulation disorders (Blood & Seider, 1981; Van Riper, 1971), for whom results might differ. For this subgroup, it is possible that a stronger relation exists between articulation and characteristics of their stuttering (e.g., frequency and severity).

6. Conclusion

Equivocal findings have been reported regarding differences between the articulation abilities of CWS and CWNS. Such equivocation relates, at least in part, to between-study differences in sample characteristics and methodologies. In the present investigation, we addressed these sample and methodological concerns by studying a relatively large sample of *preschool-age* children using standardized, replicable methodology. In doing so, we examined (1) between-group articulation differences, and (2) the association between articulation and stuttering behaviors within CWS.

Present findings indicated that preschool-age CWS do not appear to differ from their non-stuttering peers, at least on the basis of one standardized test of speech sound articulation (i.e., GFTA-2). Furthermore, results showed no significant correlation between preschool-age CWS' articulation abilities and their stuttering frequency and severity, or SPI. We, therefore, concluded that for this sample of *preschool-age* children, there is no apparent association between childhood stuttering and speech sound articulation abilities when the latter is assessed by the GFTA-2 (a standardized, perceptual measure of consonant production at the word level).

Given the developmental nature of stuttering and the possibility that chronological age impacts speech sound articulation (the latter indicated by Shriberg et al. [1994] and others), one might suggest that both articulation abilities and childhood stuttering change over time. These changes may contribute to different interactions among chronological age, gender, speech sound articulation and childhood stuttering across the preschool- and school-age years. Therefore, such interactions should be further considered in subsequent theoretical accounts, narrative and meta-analytical reviews, as well as empirical studies of the association between speech sound articulation and childhood stuttering.

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Highlights

- The GFTA-2 assessed preschool-age CWS' and CWNS' articulation abilities.
- No articulation differences were found between preschool-age CWS and CWNS.
- CWS' articulation scores did not correlate with measures of stuttering.
- Articulation—measured by the GFTA-2—and stuttering are not related in preschoolers.

Table 1

Summary of *selected* studies comparing the *articulation* abilities of preschool-age CWS and CWNS. Studies were not included in this table if they analyzed children's phonological processes (e.g., Louko, Edwards, & Conture, 1990) or if they did not include control groups (e.g., Blood & Seider, 1981; Blood, Ridenour, Qualls, & Hammer, 2003). *N/A* = data was not reported; *WNL* = within normal limits.

Early **empirical investigations employing *informal* or *non-standardized* measures of articulation**

Study	Method of Articulation Assessment	Inclusion Criteria: Articulation Abilities	Participants: *N* Total CWS (*n* girls)	Participants: *N* Total CWNS (*n* girls)	Participants: Age (years;months) Overall Range	Age Mean (SD) *CWS*	Age Mean (SD) *CWNS*	Findings
McDowell (1928)	Sentence repetition task	Freely varying	33[1]	33[1]	7–12 years	N/A	N/A	CWS exhibited a greater number of incorrect (articulatory) responses than CWNS
Morley (1957)	Single word productions	Freely varying	37	114	Each child examined at ages 3;9, 4;9, and 6;6 years	N/A	N/A	CWS produced more articulation errors than CWNS at 6;6 years of age, but not at the younger ages.
Schindler (1955)	Spontaneous responses on the "speech articulation tests"[2]	N/A	126	252	1st–12th grade	N/A[3]	N/A[3]	Significantly more CWS than CWNS "made some type of articulation error on the speech articulation tests" (Schindler, 1955, p. 355)
Williams & Silverman (1968)	Story-telling, sentence imitation, and reading tasks	N/A	115[4]	115[4]	Kindergarten-9th grade	N/A	N/A	More CWS than CWNS exhibited at least one consistent articulation error, particularly in the younger grades. No statistical analyses were performed to determine significance.

Recent **empirical investigations employing *formal* or *standardized* measures of articulation**

Study	Method of Articulation Assessment	Inclusion Criteria: Articulation Abilities	Participants: *N* Total CWS (*n* girls)	Participants: *N* Total CWNS (*n* girls)	Participants: Age (years;months) Overall Range	Age Mean (SD) *CWS*	Age Mean (SD) *CWNS*	Findings
Anderson & Conture (2000)	GFTA	All scored WNL	20 (4 girls)	20 (4 girls)	3;0–5;5 years	3;10 (9.8 mos)[5]	3;11 (9.6 mos)[5]	CWS exhibited significantly poorer GFTA scores than CWNS

Recent empirical investigations employing _formal_ or _standardized_ measures of articulation

Study	Method of Articulation Assessment	Inclusion Criteria: Articulation Abilities	Participants: N — Total CWS (n girls)	Participants: N — Total CWNS (n girls)	Participants: Age (years;months) — Overall Range	Participants: Age — Mean (SD) — CWS	Participants: Age — Mean (SD) — CWNS	Findings
Anderson & Conture (2004)	GFTA-2	All scored WNL	16 (4 girls)	16 (4 girls)	3;3–5;5 years	4;5 (N/A)	4;4 (N/A)	No significant group difference
Anderson, Pellowski, & Conture (2005)	GFTA-2	CWS freely varied; CWNS scored WNL	45 (16 girls)	45 (16 girls)	3;0–5;11 years	4;1 (N/A)	4;1 (N/A)	No significant group difference
Arnold, Conture, & Ohde (2005)	GFTA	All scored WNL	9 (4 girls)	9 (4 girls)	3;0–5;11 years 3-year-old age group	N/A[3]	N/A[3]	No significant group difference
Byrd, Conture, & Ohde (2007)	GFTA	All scored WNL	26[6] (N/A)	26[6] (N/A)	5-year-old age group	N/A[3]	N/A[3]	No significant group difference (3- and 5-year-old age groups were combined so that all CWS were compared to all CWNS)
Coulter, Anderson, & Conture (2009)[7]	GFTA-2	CWS freely varied; CWNS scored WNL	40 (15 girls)	40 (15 girls)	3;0–5;8 years	3;11 (9.7 mos)	4;0 (9.4 mos)	No significant group difference
Pellowski & Conture (2005)	GFTA-2	All scored WNL	23 (2 girls)	23 (5 girls)	3;0–5;11 years	4;6 (9 mos)	4;6 (9 mos)	No significant group difference
Pellowski, Conture, Anderson, & Ohde (2001)	GFTA	All scored WNL	25 (5 girls)	25 (5 girls)	3;0–6;3 years	N/A[3]	N/A[3]	CWS exhibited significantly poorer GFTA scores than CWNS
Ryan (1992)	AAPS	N/A	20 (5 girls)	20 (5 girls)	2;10–5;9 years	4;4 (8.7 mos) *Moderate* 12;7 (N/A)	4;1 (9.1 mos)	No significant group difference
St. Louis & Hinzman (1988)	GFTA-Experimental; data obtained from a national survey	Unclear	48 (10 girls)	24 (12 girls)	6–20 years	*Severe* 12;5 (N/A)	12;5 (N/A)	CWS produced significantly more articulation errors than CWNS

[1] CWS and CWNS participants were matched for chronological and mental age, intelligence, sex, language and racial background.

[2] The exact title and nature of the speech articulation tests were not specified in the report.

[3] Participants were matched for age. However, M age and SD for each talker-group was not provided.

[4] Gender ratio was reported to be approximately 4:1 males to females in each talker group. Participants were analyzed in four groups: kindergarten through first grade (N=25), second through third grade (N=32), fourth through sixth grade (N=34), and seventh through ninth grade (N=24).

[5] Standard deviations (SD) were calculated by the present authors based on the data reported by Anderson and Conture (2000, Table 1).

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[6]Each talker group consisted of 13 3-year-olds and 13 5-year-olds. Participants were matched for gender. However, specific gender information was not provided.

[7]Coulter, Anderson, and Conture (2009) reported Study 1 and Study 2 results. However, because Study 2 includes participants from Anderson, Pellowski, and Conture (2005), we only reported results for Study 1 in the present table.

Note: For many of the above studies, analyses of children's articulation were done as part of a larger, overall purpose (e.g., phonological or lexical priming). Arizona Articulation Proficiency Scale (AAPS; Barker, 1973); Goldman-Fristoe Test of Articulation-Experimental (GFTA-experimental; Goldman & Fristoe, 1968); Goldman-Fristoe Test of Articulation (GFTA; Goldman & Fristoe, 1986); Goldman-Fristoe Test of Articulation-2nd edition (GFTA-2; Goldman & Fristoe, 2000).

Table 2

Demographic, speech fluency, and language characteristics of preschool-age children who do (CWS, n = 128, 101 boys) and do not stutter (CWNS, n = 149, 76 boys) with freely varying articulation scores. *N/A* = Not applicable to a particular analytical procedure.

	Mean (Standard Deviation)						
	CWS	***CWNS***	***F(df)***	***Wald*** χ^2***(df)***	***p* (bootstrapped)**[c]	η_p^2	β
Demographic Information							
Chronological Age (in months)	48.26 (9.01)	51.23 (9.58)	6.99 (1, 275)	*N/A*	.009 (.045)	.025	*N/A*
Gender[a]	*N/A*	*N/A*	*N/A*	*N/A*	< .001	*N/A*	*N/A*
SES[b]	43.19 (11.69)	46.34 (10.45)	3.68 (1, 246)	*N/A*	.056 (.248)	.015	*N/A*
Speech Fluency Measures							
Total Disfluencies (%TD)	12.28 (5.86)	4.21 (2.16)	*N/A*	356.63 (1, 274)	< .001	*N/A*	−1.084
Stuttered Disfluencies (%SD)	8.41 (5.52)	1.29 (.71)	*N/A*	641.24 (1, 274)	< .001	*N/A*	−1.889
Non-Stuttered Disfluencies (%NSD)	3.85 (2.41)	2.88 (1.86)	*N/A*	15.1 (1, 274)	< .001	*N/A*	−.293
SSI-3 Total Score	18.32 (5.73)	7.01 (1.58)	*N/A*	630.03 (1, 274)	< .001	*N/A*	−.960
Language Measures							
PPVT-III	105.5 (14.23)	108.66 (13.68)	3.55 (1, 275)	*N/A*	.061 (.264)	.013	*N/A*
EVT	108.77 (12.84)	112.38 (13.57)	5.12 (1, 275)	*N/A*	.024 (.118)	.018	*N/A*
TELD – 3 Receptive	108.74 (17.34)	114.09 (14.54)	7.81 (1, 275)	*N/A*	.006 (.03)	.028	*N/A*
TELD – 3 Expressive	103.67 (14.37)	105.07 (13.61)	0.69 (1, 275)	*N/A*	.408 (.922)	.002	*N/A*

Note. As described in the *Data Analyses* section of the text (section 2.9), ANOVAs were performed to assess between-group differences in chronological age, SES and standardized measures of language (e.g., TELD-3, PPVT-III, EVT); a chi-square was performed to assess between-group gender differences. Therefore, *Wald* χ^2 and β values were *N/A* for these measures. Additionally, GLM assessed between-group differences on the speech fluency measures (i.e., SSI-3 scores, as well as frequency of stuttered, non-stuttered, and total disfluencies). For these measures, F and η_p^2 values are *N/A*.

[a] A chi-square analysis assessed between-group gender differences, which provided frequencies of boys and girls per talker group, rather than M, SD, or F. Thus, results of the chi-square were not included in Table 2. As discussed in the Methods and Results sections, chi-square results indicated that the present sample consisted of more boys than girls who stutter (CWS=27 females and 101 males; CWNS=73 females and 76 males), χ^2 (1)=23.233, p< .001, w =.29. Such findings are expected, given the gender differences in childhood stuttering (i.e., more boys than girls stutter).

[b] SES information was available for 248 of the 277 total participants (132 CWNS, 116 CWS).

[c] As described in the Methods, a bootstrap re-sampling procedure was employed when appropriate to control for false discovery rates.

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Table 3

Descriptive (mean [M], standard deviation [SD]) and *inferential* statistics (estimated marginal means [EM], standard estimated error values [SEE]) related to GFTA-2 standard scores for preschool-age children who do (CWS, $n = 128$) and do not stutter (CWNS, $n = 149$). It should be noted that EM and SEE values were derived from the generalized estimating equations models (GEE). These derived EM and SEE values, which correspond with the reported Wald χ^2, p, and β, represent adjusted M and SD that account for covariates included in the statistical models (e.g., gender) described in *Results* (Section 3).

	Overall Between-Group Differences		**Between-Group Differences Stratified by Age**					
			3 year-olds		***4 year-olds***		***5 year-olds***	
Talker Group	CWS	CWNS	CWS	CWNS	CWS	CWNS	CWS	CWNS
N	128	149	62	57	51	58	15	34
Gender								
Male	101	76	45	27	43	28	13	21
Female	27	73	17	30	8	30	2	13
GFTA-2 Standard Score								
Descriptive Statistics								
M (SD)	105.06 (11.45)	106.32 (12.92)	108.34 (9.64)	107.6 (13.86)	102.27 (12.63)	107.72 (12.28)	101 (11.02)	101.79 (11.59)
Inferential Statistics								
EM (SEE)	105.61 (1.06)	105.87 (1.06)	108.38 (1.30)	107.59 (1.82)	104.63 (1.77)	106.60 (1.59)	104.31 (2.77)	102.77 (1.71)
Wald χ^2 (*df*)	1.02 (1)		.12 (1)		.666 (1)		.20 (1)	
p	.312		.729		.415		.655	
β	−.06		−.007		.019		−.015	