Journal of Fluency Disorders 63 (2020) 105745

Contents lists available at ScienceDirect

Journal of Fluency Disorders

journal homepage: www.elsevier.com/locate/jfludis

Nonword repetition and identification skills in Kannada speaking school-aged children who do and do not stutter

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ARTICLE INFO

Keywords:
Nonword repetition
Nonword identification
Phonological working memory
Phonological abilities
Children who stutter

ABSTRACT

Purpose: The present study employed nonword repetition and nonword identification tasks to explore the phonological working memory (PWM) abilities and its interaction with speech motor control in school-aged children who do and do not stutter.
Method: Participants were 17 children who stutter (CWS) (Age range = 7–12) and 17 age and gender-matched children who do not stutter (CWNS). For the nonword repetition task, the participants repeated sets of 2-, 3-, and 4-syllable nonwords (n = 12 per set). The participants silently identified a target nonword from a subsequent set of three nonwords (n = 12 per 2-, 3- and 4-syllable length) for the nonword identification task. The performance of CWS on the nonword repetition task was compared with the CWNS for the mean number of accurate repetitions, number of trials taken, number of accurate repetitions on initial trial, and number of fluent repetitions across the three-syllable conditions for the tasks. For the nonword identification task, the number of nonwords identified accurately by the two groups were subjected to analysis.
Results: CWS were significantly less accurate on the initial production of nonwords and required significantly more number of attempts to repeat the nonword accurately. Further for the nonword identification task, CWS were significantly less accurate than CWNS in correctly identifying the target nonword.
Conclusions: The present findings suggest that, in addition to limitations in PWM capacity, an unstable speech motor control system in CWS may lead to dysfluent speech.

1. Introduction

Stuttering is a multifactorial fluency disorder characterized by disruptions in the forward flow of speech (Bloodstein & Bernstein Ratner, 2008; Conture, 2001; Guitar, 2014; Yairi & Seery, 2011). Approximately 5 % of the preschool children tend to stutter at least once in their lifetime, with roughly 25 % of these children developing chronic stuttering that persists into adulthood (Yairi & Ambrose, 1999). Several theories have been proposed to explain the development of the disorder, with the most accounting for stuttering as a deficit in linguistic, psychological, and sensorimotor control processes (Conture & Walden, 2012; De Nil, 1999; Guitar, 2014; Kalvaram, 2001; Max, Guenther, Gracco, Ghosh, & Wallace, 2004; Neilson & Neilson, 1987; Postma & Kolk, 1993; Smith, 1999; Smith & Kelly, 1997; Vasić & Wijnen, 2005; Webster, 1990; Yairi & Ambrose, 2005). This has led several researchers to take a multifactorial approach to stuttering (Conture, 2001; Smith & Kelly, 1997).

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https://doi.org/10.1016/j.jfludis.2019.105745
Received 17 July 2019; Received in revised form 16 December 2019; Accepted 16 December 2019
Available online 19 December 2019
0094-730X/

The multifactorial framework identifies stuttering as a speech motor disorder that interacts with multiple factors such as cognitive-linguistic processes and emotional systems (Sasisekaran, 2013; Smith & Kelly, 1997). Among the various cognitive-linguistic processes, the role of phonological processing in the manifestation of stuttering has been described extensively by theories such as the Covert Repair Hypothesis (Postma & Kolk, 1993) and model such as the EXPLAN (Howell, 2004). Among the various aspects of phonological processing, phonological working memory (PWM) has been attributed to the difficulties that persons who stutter experience in establishing/ maintaining fluent speech (e.g., Anderson & Wagovich, 2010; Anderson, Wagovich, & Hall, 2006; Byrd, Vallely, Anderson, & Sussman, 2012).

1.1. Phonological Working Memory (PWM)

According to Baddeley (2003), PWM is a neuro-cognitive system that provides temporary storage for incoming linguistic information. Baddeley's model of the PWM system is comprised of four components: (1) central executive, (2) phonological loop, (3) visuospatial sketchpad, and (4) episodic buffer. The central executive constitutes a set of cognitive processes that interact with other components and long-term memory. The central executive is responsible for the transfer of information from the long-term memory to the short-term memory and vice-versa (Bajaj, 2007). The phonological loop is comprised of a phonological store that preserves fleeting phonological codes for approximately two seconds and a sub-vocal rehearsal system that refreshes the phonologically encoded material, thus allowing it to preserve in memory for more than two seconds. The third component of Baddeley's model, the visuospatial sketchpad will not be discussed further as the component is not reported to be involved in the development and persistence of the disorder. Episodic buffer represents another temporary store that transfers information from the short-term memory to the long-term memory and vice-versa (Bajaj, 2007). A disruption in the Baddeley's phonological loop, especially in the phonological working memory can lead to rehearsal of inappropriate phonological code, thus affecting the quality of phonological representations. Children who stutter (CWS) attempt to overcome this disrupted functioning in the phonological loop by relying heavily on the episodic buffer. The access to the pre-existing lexicon through an episodic buffer would not help in nonword repetition performance because the phonological codes for the nonwords do not exist in the lexicon. Thus it is possible that the use of the episodic buffer instead of phonological working memory by CWS as a compensatory strategy leads to poor performance in tasks involving working memory such as nonword repetition (2003, Baddeley, 2000; Bajaj, 2007; Pelczarski & Yaruss, 2016). It is also hypothesized that the PWM supports the developing language processing system during childhood, and those children with better PWM will display an enriched array of words and lengthier utterances in their spontaneous speech than children with reduced PWM abilities (Adams & Gathercole, 1995; Gathercole & Baddeley, 1993).

1.2. Phonological working memory in adults who stutter

Nonword repetition tasks have widely been used to explore the PWM in children and in adults who stutter (AWS). Past studies along this line in AWS have found that these individuals tend to be less successful in repeating nonwords compared to their fluent peers (Byrd et al., 2012; Byrd, McGill, & Usler, 2015; Ludlow, Siren, & Zikria, 1997; Sasisekaran & Weisberg, 2014; Sasisekaran, 2013; Smith, Sadagopan, Walsh, & Weber-Fox, 2010). However, later studies suggested that AWS and adults who do not stutter (AWNS) both exhibit comparable accuracy while repeating nonwords of shorter syllable length and that the working memory deficits in AWS only surface on nonwords of longer syllable lengths. For instance, Byrd et al. (2012) employed a nonword repetition task of 2-, 3-, 4-, and 7-syllables to study the PWM abilities of AWS and AWNS and reported that only 7-syllable nonwords differentiated the two groups. The AWS group were less accurate in their initial attempts to repeat 7-syllable nonwords and required more number of trials to produce nonwords accurately. Research suggests that, while repeating nonwords of shorter syllable lengths, the individuals who stutter benefit from more time for subvocal rehearsal, which in turn increases the likelihood of high accuracy of repetition (Baddeley, Chincotta, Stafford, & Turk, 2002). The findings on reduced accuracy for nonwords of increased syllable length in AWS suggest that the PWM and the subvocal rehearsal systems in these individuals are not efficient in retaining the integrity of the auditory input (Bosshardt, 1990; Byrd et al., 2012; Ludlow et al., 1997).

In a more recent study, Byrd et al. (2015) employed vocal and nonvocal tasks of nonword identification to explore the PWM capacity of AWS. The nonvocal nonword repetition involved the identification of a target nonword from a subsequent set of three nonwords. The findings revealed that AWS were less accurate in repeating nonwords in the initial attempt and required more attempts to accurately repeat nonwords of increased syllable length. However, no difference was noted between AWS and AWNS on nonvocal nonword repetition performance, suggesting that subvocal rehearsal of nonwords in AWS is as efficient as in AWNS. The differences in the performance between these two groups solely on vocal nonword repetition task lends support to the assumption that AWS experience a temporal instability in speech motor programming that results in an inaccurate recall on nonword repetition task (Byrd et al., 2012; Namasivayam & Van Lieshout, 2008; Smith et al., 2010). Additional research is thus warranted to understand the precise source of difficulty in repeating nonwords accurately.

1.3. Phonological working memory in children who stutter

Several studies of nonword repetition performance in CWS have provided evidence for the claim that PWM abilities operate differently in CWS when compared to children who do not stutter (CWNS) (Anderson & Wagovich, 2010; Anderson et al., 2006; Hakim & Ratner, 2004; Oyoun, El Dessouky, Shohdi, & Fawzy, 2010; Pelczarski & Yaruss, 2016). In a preliminary attempt, Hakim and Ratner (2004) compared the nonword repetition ability of CWS aged 4–8 years to age-matched CWNS using the Children's Test of

Nonword Repetition (CNrep; Gathercole, Willis, Baddeley, & Emslie, 1994). The CWS demonstrated fewer correct repetitions and exhibited more phonemic errors than CWNS at the three-syllable level. A floor effect was observed at the two-syllable level with neither group demonstrating difficulty with the task and a ceiling effect at four- and five-syllable level. The authors concluded that the CWS experience subtle PWM deficits and three-syllable nonword level is the breakpoint that differentiates these children from CWNS on working memory capacity.

Studies exploring the PWM abilities of preschool CWS have revealed that compared to older CWS, these children experience difficulty repeating nonwords of even shortest length. Anderson et al. (2006) explored the PWM capacity of CWS and CWNS in the age range 3–5 years and reported that the CWS demonstrated fewer correct productions of nonwords at two- and three-syllable level and significantly more phonemic errors for three-syllable stimuli. Apart from the above finding, it is also reported that the CWS showed a significant correlation between attentional focusing and performance on nonword repetition (Anderson & Wagovich, 2010). The children who were judged by the parents as having greater focused attention repeated nonwords more accurately than those CWS who reported to have less focused attention. However, a similar trend was not observed in CWNS, indicating that the nonword repetition and attention in task performance interact differently in CWS compared to CWNS. Based on the above findings, researchers suggested that CWS have weaker PWM compared to CWNS.

In a recent study on CWS, Pelczarski and Yaruss (2016) studied PWM in 5-6-year-old children using nonwords that ranged from 1 to 7 syllables. The nonword repetition scores of majority of CWS fell within one standard deviation from the standard scores of the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999). Lack of gross difference in nonword repetetion ablities between CWS and CWNS indicate that the PWM skills of CWS are not deficient, but the deficit is more sub-clinical in nature and manifests only when the systems are taxed or overwhelmed. The authors also suggested that these sub-clinical deficits may interact with other systems such as attention, lingustic planning, and speech motor control and manifest as disfluencies of speech (Eggers, De Nil, & van Den Bergh, 2012; Ntourou, Conture, & Lipsey, 2011; Pelczarski & Yaruss, 2014; Smith, Goffman, Sasisekaran, & Weber-Fox, 2012; Weber-Fox, Spruill, Spencer, & Smith, 2008).

In contrast to the aforementioned studies, a few studies have not found performance differences between CWS and CWNS on nonword repetition abilities. For instance, Bakhtiar, Abad Ali, and Sadegh (2007) examined the nonword repetition skills of 5–7 years aged CWS and CWNS, who were native speakers of Persian. Their findings revealed that the two groups were comparable in the speech reaction time for nonword repetition and in the mean phonemic errors. The nonwords used by Bakhtiar and colleagues were newly constructed ones from Farsi language. However, the description of the procedure involved in Farsi nonwords indicates that the nonwords were developed carefully, thus ruling out the chance of word familiarity on task performance. On similar lines, Smith et al. (2012) found no difference between CWNS and CWS without any comorbid conditions on nonword repetition skills. However, CWS with concomitant speech sound disorder demonstrated reduced phoneme accuracy in two-syllable nonwords and CWS with language impairment repeated one-, two-, and three-syllable nonwords with significantly lower accuracy.

Furthermore, Smith et al. (2010) explored the phonological and speech motor control processes that contribute to nonword repetition using behavioural and kinematic measures. The behavioural accuracy of CWS in repeating nonwords was comparable to that of CWNS. However, CWS demonstrated higher lip aperture variability compared to CWNS on kinematic measure indicating a maturational lag of speech motor control in these children. Based on the above observations, the authors suggested that the performance difference between the two groups on nonword repetition tasks may be specific to speech motor difficulties and not due to the PWM constraints.

While the majority of the studies in the stuttering literature used the accuracy of nonword repetition tasks to assess the PWM abilities in persons who stutter, a few studies also attempted to explore how limited working memory is contributing to speech disfluencies by studying the effect of nonword syllable length on speech fluency. For instance, Hakim and Ratner (2004) compared the fluency of nonword repetitions by CWS across 2-, 3-, 4-, and 5-syllable length conditions. The findings revealed a decline in fluency in a few participants with an increase in syllable length, whereas the fluency of the remaining participants was not sensitive to an increase in syllable length. In contrast to the above findings, Anderson et al. (2006) reported that the difficulty CWS experienced in repeating 2- and 3-syllable nonwords did not manifest in children's fluency of production. Recently, Sasisekaran and Weathers (2019) reported a systematic effect of nonword length on speech fluency in young CWS between 8 and 15 years. On nonword repetition task, CWS exhibited nearly twice the percentage of disfluencies at 6-syllable level compared to 3- and 4-syllable levels. The findings of comparable rates of disfluencies between 3- and 4-syllable nonwords confirm Anderson et al. (2006) findings of lack of systematic effect of nonword syllable length on fluency in repeating nonwords of these lengths. The findings were interpreted as repeating 6-syllable nonwords places a higher demand on speech planning and production units in CWS (Logan & Conture, 1995; Logan & LaSalle, 1999; Sawyer, Chon, & Ambrose, 2008; Weiss & Zebrowski, 1992).

From this review, it is clear that the underlying processes that contribute to the difficulty CWS experience in accurately repeating nonwords are not well understood, and the available findings are mixed in nature. It is also possible that speech motor control deficits in stuttering might be contributing to the disfluent speech in children and adults who stutter. Hence, the observed group difference in nonword repetition cannot be attributed solely to the PWM (Sasisekaran & Weisberg, 2014; Sasisekaran, Smith, Sadagopan, & Weber-Fox, 2010; Smith et al., 2010). Studies that examined the relationship between nonword repetition and fluency in CWS have reported that even though these children experience greater difficulty in repeating nonword of increased syllable length, the increase in task complexity of nonword repetition did not reflect on the fluency during repetition (Anderson et al., 2006; Hakim & Ratner, 2004; Oyoun et al., 2010). Hence, it is possible that the nonword repetition task performance may be impacted by multiple speech output processes, and it is necessary to explore whether which one among these processes contributes significantly to the performance difference in CWS.

1.4. Purpose of the present study

Analysis of the PWM in AWS using vocal and nonvocal nonword repetitions has revealed that these individuals exhibit difficulty only when vocal production of the nonword is required and not during silent identification of the words (Byrd et al., 2015). The current study is a partial replication of that of Byrd and colleagues, on school-aged CWS using nonword repetition and nonword identification tasks. The nonword identification task requires the participants to store the novel words in the working memory and activation of subvocal rehearsal to allow the phonologically coded material to be stored in the memory for an extended period. Apart from the storage and silent rehearsal of nonwords, the nonword repetition task demands additional processes such as constructing a precise articulatory plan for the nonword sequence and execution of the motor plan. Any difference in the two task performances will contribute to the current understanding of the role of PWM and speech motor control in the difficulty CWS experience in establishing and maintaining fluent speech production.

The primary objective was to examine the nonword repetition abilities of school-aged CWS. The CWS and CWNS groups were compared for the number of accurate repetitions, the number of trials taken to repeat the nonwords accurately, the effect of nonword syllable length on fluency of repetition. The research question was whether CWS differ from CWNS in accuracy and number of trials in the nonword repetition task of different syllable length. Based on past findings, we hypothesized that CWS would show reduced accuracy in the nonword repetition task as there is supporting evidence that adults who stutter and at least a subgroup of children demonstrate difficulty in repeating nonwords accurately (Anderson et al., 2006; Byrd et al., 2015; Pelczarski & Yaruss, 2016).We further hypothesized that reduced accuracy in CWS is likely to be accompanied by more number of trials required to repeat the nonwords accurately, reduced accuracy in the initial attempt, and progressive decline in fluency with an increase in nonword syllable length.

The second objective was to investigate the group differences in accuracy in identifying nonwords. The research question addressed was whether CWS demonstrate reduced accuracy in only nonword repetition task or in both nonword repetition and nonword identification tasks. It is hypothesized that if the PWM is compromised in CWS, the group difference observed in previous studies will be evident on both vocal and nonvocal tasks. Alternatively, if the poorer performance of CWS on nonword repetition, as reported in the literature is due to speech motor planning and execution deficits, we predict both CWS and CWNS will perform similarly on nonword identification tasks and differences between the groups will only emerge on nonword repetition task.

2. Method

2.1. Participants

Participants were 17 CWS (16 males, age range = 7–12, Mean age = 11.06 years, SD = 0.77) and 17 age and gender-matched CWNS (age range 7–12, Mean age = 11.28 years, SD = 0.63). CWS participants were recruited from the Department of Clinical Services, All India Institute of Speech & Hearing, Mysore, India. The normally fluent controls (children who do not stutter; CWNS) were recruited from regular schools in Mysore. All the participants were right-handed as determined by the Edinburgh Inventory for assessment of handedness (Oldfield, 1971). The participants' demographic details were documented through a self-reported questionnaire. All the participants passed a binaural hearing screening test conducted at 20 dB HL at 500, 1000, 2000, 4000, and 8000 Hz (American Speech & Hearing Association, 1990). The mother's level of education was recorded as an index of the child's socio-economic status, and the two groups were matched for the same (Hollingshead, 1975; Smith et al., 2012).

To qualify for the inclusion, the participants had to meet the following criteria: (a) native speakers of Kannada language; (b) no history of neurological, language, speech, sensory, and motor impairment (with the exception of stuttering for CWS), (c) no social, emotional, or psychiatric disturbances, and (d) not taking any medications that affect the outcome of the experiment. All CWS were reported to have begun stuttering during early childhood and had a history of the persistence of stuttering beyond 36 months post-onset (Ambrose, Cox, & Yairi, 1997). Out of the 17 CWS, nine children had received intervention for stuttering. CWS who had positive treatment history were not excluded from the study due to key reasons reported in past research (Byrd et al., 2015; Logan, Byrd, Mazzocchi, & Gillam, 2011). The current study and consent form documentation was approved by the institutional review board of All India Institute of Speech and Hearing, Mysore, India.

2.2. Stuttering diagnosis

The participants were classified as CWS if all the three criteria developed by Yairi and Ambrose (1999) were met: (1) the child was regarded as having stuttering by an experienced speech-language pathologist; (2) the child's stuttering severity was rated as 2 or higher on an eight-point severity scale by the parent (3) the child exhibited at least three stuttering-like disfluencies (SLDs) per 100 syllables of spontaneous speech. Spontaneous speech and reading or picture description samples of all the CWS participants were video recorded using Sony HDR-PJ340 handy cam recorder to asses the stuttering severity. A minimum of 300 syllables speech sample was elicited from each participant, and the stuttering severity of the CWS group was assessed using the Stuttering Severity Instrument-4 (SSI-4) (Gregg & Sawyer, 2015; Riley, 2009). Out of the 17 CWS, two received a score of 'mild,' eight received a score of 'moderate,' six received a score of 'severe,' and the remaining one received a score of 'very severe' stuttering.

Table 1
Participant characteristics for CWS.

Participants	Age	Gender	Language score	Articulation score	SSI score	Severity	Forward digit span score	Backward digit span score
1	10;8	M	258	114	19	Mild	9	6
2	11;3	M	278	114	30	Severe	8	6
3	8;9	M	254	114	29	Severe	7	7
4	10;2	M	261	114	27	Moderate	7	6
5	11;8	M	278	114	29	Severe	8	6
6	11,10	M	285	114	30	Severe	9	7
7	11;7	M	280	114	25	Moderate	7	6
8	11;3	M	276	114	26	Moderate	8	7
9	11;3	F	280	114	27	Moderate	9	7
10	11;9	M	278	114	27	Moderate	8	7
11	11;2	M	273	114	28	Severe	7	6
12	11;0	M	276	114	18	mild	9	6
13	10;8	M	280	114	29	moderate	7	7
14	11;5	M	285	114	28	Severe	9	7
15	12; 0	M	282	114	23	moderate	7	6
16	11;1	M	275	114	36	Very severe	8	7
17	10;11	M	258	114	26	moderate	6	5

2.3. Language, articulation, and short term memory

A series of tests were administered to explore the language abilities, articulation, and short term memory in both the groups. The receptive and expressive vocabularies were tested using the Kannada Language Test (KLT; Suchithra & Karanth, 1990, 2007). Articulation skills were tested using the Kannada Diagnostic Photo Articulation Test (KDPAT; Deepa & Savithri, 2010). The short term memory span was assessed using forward and backward digit span tests (Weschler's Memory scale; Wechsler, 1997). Results suggest that there was no statistically significant difference between the two groups in the language abilities {CWS ($M = 274.47$, $SD = 9.16$) and CWNS ($M = 276.53$, $SD = 6.05$) [$t(32) = -0.773$, $p = 0.221$]}, articulation skills (the articulation scores of CWS and CWNS were not subjected to statistical analysis as all the participants achieved maximum score on articulation test), forward digit span {CWS ($M = 5.59$, $SD = 0.94$) and CWNS ($M = 6.12$, $SD = 0.86$) [$t(32) = -1.716$, $p = 0.096$]}, and backward digit span {CWS ($M = 4.43$, $SD = 0.51$) and CWNS ($M = 4.41$, $SD = 0.51$) [$t(20) = -.671$, $p = 0.550$]}. The demographic characteristics of the individual participants are provided in Table 1.

2.4. Nonword stimuli

For the nonword repetition and nonword identification tasks, 144 nonwords were constructed (48 nonwords in each syllable length conditions) by substituting the consonant-vowel combinations of real Kannada words. Three speech-language pathologists (SLPs), who are native speakers of Kannada rated the newly constructed nonwords for real word unlikeliness on a 5-point rating scale (1 indicates very unlike a Kannada real word, and 5 indicates very like a Kannada real word) (Gathercole, 1995; Byrd et al., 2015) and phonotactic rules violations while constructing nonwords. The syllables of the nonwords rated as very likely to be a Kannada real word and intermediate were subjected to another round of syllable substitution to ensure that the real word likeliness was reduced. The final stimulus list contained only nonwords rated as very unlikely to be a Kannada real word. The phoneme sequences in each nonword adhered to the phonotactic rules of Kannada (Gathercole et al., 1994). Thirty-six nonwords consisting of 2-, 3-, and 4-syllable nonwords served as the stimuli for nonword repetition (n = 12 for each syllable length category).

The stimulus list of the nonword identification task consisted of 108 nonwords of 2-, 3-, and 4-syllable lengths (n = 36 for each syllable length category). The nonword sets for the identification task were constructed by substituting CV combinations in the final position of 2-syllable target nonwords and CVCV combinations in the medial and final positions of 3- and 4-syllable target nonwords. The nonwords for both the tasks were produced by a male speaker and were audio-recorded using CSL software and digitized using PRAAT software (Boersma & Weenink, 2016) at a rate of 22.5KHZ. The list of nonwords used for nonword repetition and nonword identification tasks in the current study are provided in Tables 2 and 3 respectively.

2.5. Experiments

The participants completed both the tasks in a quiet room over one session lasting for 40 min. The participants completed four practice trials before the commencement of both nonword repetition and nonword identification tasks. Both the tasks were counterbalanced across the participants in both groups. Half of the participants in each group completed the nonword identification task before completing the nonword repetition task. In both the tasks, the participants attempted 2- and 3- syllable nonwords before the more challenging 4-syllable words.

Table 2
Stimuli for nonword repetition task.

Bisyllabic nonwords	Trisyllabic nonwords	Four syllabic nonwords
|pe:cha|	|t̪ipa:tʃa|	|sunnuvut̪i|
|vikka|	|ku:lud̪a|	|ṛinnad̪etʃe|
|t̪ela|	|ʃad̪ila|	|ka:ṇigitʃtʃe|
|t̪a:mu|	|dʒabava|	|va:bhaṋu:ra|
|dʒa:ta|	|ait̪uva|	|laṭṭuṇe:ba|
|ḷa:ko|	|ke:balu|	|mindeka:be|
|tʃeka|	|lit̪uppa|	|maḷuṋega|
|rit̪ra|	|ḍenali|	|nuḍḍadava|
|veḍa|	|burigu|	|kiṛava:ʃa|
|suste|	|ṛangava|	|mabiluga|
|dʒu:stʃe|	|lukast̪a|	|va:samo:ṛa|
|ʃunta|	|ḍe:joḍi|	|ʃuvuḍuko|

Table 3
Stimuli for nonword identification task.

Bi-syllabic nonwords		Trisyllabic nonwords		Four syllabic nonwords	
Target nonword	Nonword sets	Target nonword	Nonword sets	Target nonword	Nonword sets
|kuppa|	|kemma||kuppa||kammu|	|takiki|	|takiki||tikita||takita|	|d̪unnuvut̪i|	|d̪unnuvat̪e||d̪unnuvut̪i| |d̪unnuvuʃi|
|t̪ela|	|t̪ela|t̪ed̪e|| t̪eke|	|pikada|	|paludi||pabala||pabala|	|raka:t̪ari|	|raka:t̪ema||raka:t̪ari| |raka:t̪aka|
|bija|	|buja||beja||bija|	|kebalu|	|kebalu||ke:galu||kigava|	|niva:ʃara|	|niva:ʃara||niva:ʃalu| |niva:ʃaka|
|su:gu|	|su:gu| |sume| |sata|	|genali|	|genali ||gedura||galudi|	|karasaka|	|karasalu||karasaka| |karasama|
|ṛube|	|ṛube| |ṛussa||ṛessi|	|labat̪a|	|lit̪uppa||lagava||labat̪a|	|maḷuṋega|	|maḷuṋalu||maḷuṋega ||maḷuṋeba |
|guma|	|gusa| |guma| |gega|	|naluvi|	|naluvi||na:gevi||nebalu|	|pad̪i:galu|	|padigetʃe| |padi:gaʃa||pad̪i:galu|
|pecha|	|pe:ssa| |pecha| |pebe|	|had̪ila|	|had̪ila||habat̪a|| had̪ura|	|indeka:be|	|indeka:ra||indeka:be| |indeka:ta|
|vika|	|vika| |ve:si| |vike|	|sabava|	|saluvi||sabava||sakiki|	|gabi:luga|	|gabi:luga||gabi:latʃi| |gabi:luko|
|nuga|	|nena| |nuga| |negu|	|ʃad̪ila|	|ʃad̪ila||ʃagevi||ʃabava|	|garasaga|	|garasa:ra||garasaga| |garasuʃa|
|d̪u:gu|	|d̪e:t̪a| |d̪u:gu| |d̪u:gu|	|dʒait̪uva|	|dʒangava||dʒtaka||dʒait̪uva|	|kaḷuṋega|	|kaḷuṋara||kaḷuno:ṛa| |kaḷuṋega|
|kuma|	|kupa| |kuga| |kuma|	|burigu|	|bedura||bubila||burigu|	|ediga:ra|	|ediga:ra||ediga:be| |edina:ra|
|dipe|	|diga| |mipe| |disi|	|gubila|	|gubila| |pukast̪a| |ṛejodi|	|laḷugara|	|laḷugara||laḷugema| | laḷugiba|

2.6. Nonword repetition task

For the nonword repetition task, the recorded nonword stimuli were presented using windows media player software through insert earphones at the level of 70 dBHL. The participants were instructed as follows: "Now you will listen to a few funny words. You are required to listen to the words carefully and verbally repeat them as accurately as you can. Once you have made your best effort to repeat one funny word, we will move on to the next word. Let's start." (Sasisekaran & Byrd, 2013) (Fig. 1).

The nonword repetition performance of the participants was video recorded using a digital video camera. The participants were given a maximum of four trials to repeat each nonword accurately before advancing to the next stimulus item (Byrd et al., 2015). The nonwords were presented again in case a participant failed to repeat the word correctly in the initial attempt. Once the participant repeated the nonwords correctly or failed to repeat nonwords correctly over four trials, the subsequent nonword was presented. The

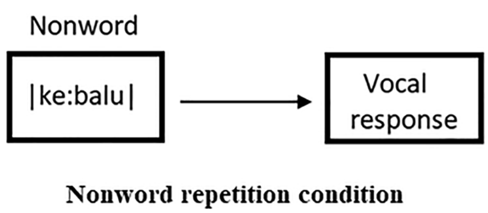

Fig. 1. Illustration of the events in each trial of the nonword repetition task.

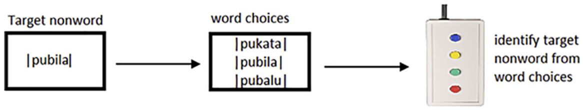

Fig. 2. Illustration of the events in each trial of nonword identification task.

responses of the participants for the nonword repetition condition were scored as either phonologically correct or incorrect. A production was considered accurate if all phonemes in the target nonword were produced correctly. Any response with a dialectal variation of Kannada or a consistently misarticulated phoneme or disfluent utterances influencing the acoustic output resulting in a slight distortion of a phoneme was considered correct (Anderson et al., 2006; Edwards & Lahey, 1998). The accuracy of initial response and the mean number of attempts prior to accurate production was also subjected to analysis. In addition to the above measures, the responses by CWS were judged as fluent or disfluent. A repeated utterance was considered disfluent if it contained one or more stuttering like disfluencies or other disfluencies like polysyllabic word and phrase repetitions, revisions, and interjections. The number of fluent utterances produced for the three-syllable length conditions was subjected to analysis (Anderson et al., 2006).

2.7. Nonword identification task

The nonword identification task involved listening to a target nonword followed by the identification of the target nonword from a subsequent set of three nonwords presented auditorily. The participants selected the button'1', '2', or '3' in the response pad to identify the target nonword. For the nonword identification task, the following instructions were presented: "Now you will hear a funny word, and the funny word will be followed by three additional funny words. After you listen to the initial word and three additional words, you have to choose the one that is identical to the initial word by pressing the 1, 2, and 3 buttons to indicate first, second, and third funny words, respectively. You will have only a single chance to identify the word. Let's begin."(Fig. 2)

The stimuli for the nonword identification task were presented through E-prime software version 2 (Schneider, Eschman, & Zuccolotto, 2002) at a level of 70 dBHL via insert earphones. The participant responses to the nonword identification condition were scored as correct and incorrect using E-prime software.

2.8. Data scoring and statistical analysis

The first author performed the scoring of data, which was verified by the second author. The participants' correct attempts to vocally produce the words for the nonword repetition task and accurate identification of the target nonword in the nonword identification task were scored as '1,' and the wrong attempts were scored as '0'. For the nonword repetition task, the dependent variables measured were the number of accurate repetitions, the number of trials taken to repeat the nonwords correctly, and the accuracy of initial trials. The effect of task load on the fluency in CWS was also subjected to analysis. For the nonword identification task, the responses were scored as either correct or incorrect. Any discrepancies in scoring between the first and the second author were subjected to combined analysis and resulted in 100 % agreement in scoring. The obtained data for both the tasks were analyzed using IBM SPSS Statistics: Version 23 (IBM Corp., 2011). A significance level of 0.05 was used for all statistical analyses.

3. Results

3.1. Nonword repetition task

The mean scores achieved by CWS and CWNS for the number of accurate repetitions, the number of trials taken, the accuracy of repetition on the initial trial, and the effect of nonword syllable length on the fluency of repetition of nonword repetition task is depicted in Table 4.

3.1.1. Number of accurate repetitions

A repeated-measures ANOVA with the between-subjects factor of group (CWS vs. CWNS) and a within-subjects factor of nonword syllable length (2-, 3- and 4-syllables), was conducted. The dependent variable was the mean number of nonwords repeated correctly. Mauchly's test of sphericity revealed $p < 0.01$; therefore, Greenhouse-Geiser corrected p-values are reported. The results revealed a significant effect of talker group on task performance [$F(1, 32) = 6.509$, $p < .05$, $\eta^2p = .169$]. The mean number of nonwords repeated correctly was significantly lower for the CWS than the CWNS, as depicted in Fig. 3. There was also a significant main effect of nonword length [$F(1.594, 51.011) = 15.670$, $p < .001$, $\eta^2p = .329$] on the task performance. However, there was no significant interaction between the talker group and nonword syllable length ($p = .140$). Post hoc comparisons of all pairs of the within-subject factor (2-syllable vs. 3-syllable, 3-syllable vs. 4-syllable, 2-syllable vs. 4-syllable) were conducted using Bonferroni correction. It was observed that the number of nonwords repeated correctly for 3-syllable and 4-syllable nonwords were significantly ($p < .001$) lower compared to 2-syllable words. However, the difference in mean number of nonwords repeated correctly between 3- and 4-syllable nonwords was not statistically significant ($p = .170$).

Table 4
The mean number of accurate repetitions, number of trials taken, accuracy of repetition on the initial trial, and effect of nonword syllable length on the fluency of repetition of CWS and CWNS for the nonword repetition task. Standard deviations and ranges are in italics and in parentheses.

Task	CWS			CWNS		
	Mean	SD	Range	Mean	SD	Range
Number of accurate repetitions						
2-syllable	11.53	*(1.00)*	*(9–12)*	12.00	*(0.00)*	*(12-12)*
3-syllable	10.47	*(1.46)*	*(7–12)*	11.71	*(.588)*	*(10–12)*
4-syllable	10.24	*(2.04)*	*(5–12)*	11.18	*(.951)*	*(9–12)*
Number of trials taken						
2-syllable	1.09	*(.090)*	*(1.00–1.25)*	1.01	*(.038)*	*(1.00–1.16)*
3-syllable	1.11	*(.125)*	*(1.00–1.43)*	1.02	*(.035)*	*(1.00–1.09)*
4-syllable	1.11	*(.137)*	*(1.00–1.45)*	1.05	*(.077)*	*(1.00–1.20)*
Accuracy of repetition on the initial trial						
2-syllable	10.71	*(1.26)*	*(8–12)*	11.82	*(.529)*	*(10–12)*
3-syllable	9.59	*(1.73)*	*(5–12)*	11.53	*(.717)*	*(10–12)*
4-syllable	9.35	*(2.23)*	*(4–12)*	10.82	*(1.01)*	*(9–12)*
Effect of nonword syllable length on the fluency of repetition						
2-syllable	9.59	*(3.57)*	*(2–12)*	n/a	n/a	n/a
3-syllable	9.12	*(3.29)*	*(2–12)*	n/a	n/a	n/a
4-syllable	7.59	*(4.01)*	*(0–12)*	n/a	n/a	n/a

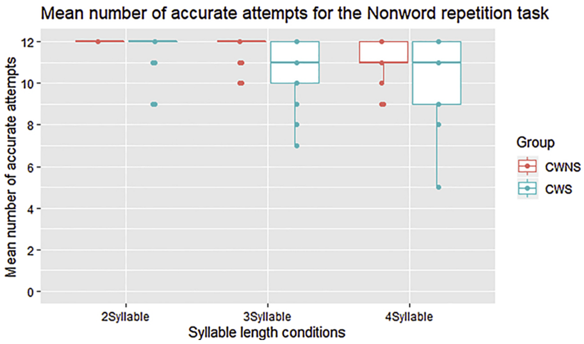

Fig. 3. Comparison of the mean number of accurate repetitions for the nonword between CWS and CWNS for the nonword repetition task (error bars indicate standard deviation values). A ceiling effect was demonstrated by CWS at the 2-syllable condition and CWNS at 2- and 3-syllable conditions.

3.1.2. Number of trials taken

A second repeated-measures ANOVA was conducted to investigate whether CWS and CWNS differed in the number of trials taken to repeat the nonwords accurately. The mean number of trials taken as the dependent variable, whereas the talker group (CWS, CNS) was the between-subject variable, while nonword length (2-, 3- and 4-syllable) was the within-subject variable. There was a significant between-subject effect for the talker group [$F(1, 32) = 13.519$, $p < .005$, $\eta^2 p = .297$]. However, no main effect of nonword syllable length on the number of trials taken [$F(2, 64) = 1.682$, $p = .194$] and no significant interaction effect between talker groups and syllable length was noted [$F(2, 64) = .314$, $p = .734$]. The mean number of trials required to produce the nonwords accurately was significantly higher for CWS than CWNS, as depicted in Fig. 4.

3.1.3. Accuracy of repetition on the initial trial

CWS produced significantly less accurate repetitions on the initial trial than CWNS, as displayed in Fig. 5. Repeated-measures ANOVA, with the between-subjects factor of talker group (CWS vs. CWNS) and a within-subjects factor of nonword syllable length (2-, 3-, and 4-syllables) was conducted. The dependent measure was the mean number of accurate productions on the first trial. Results revealed significant main effect of the talker groups [$F(1, 32) = 14.295$, $p < .005$, $\eta^2 p = .309$] and also a significant main effect of nonword syllable length [$F(2, 64) = 14.509$, $p < .001$, $\eta^2 p = .312$]. However, there was no interaction between talker groups and nonword syllable length ($p = .179$).

A pairwise comparison of all syllable length conditions was conducted using Bonferroni correction. The analysis revealed that the differences among 2- and 3-syllable ($p < .05$) and 2- and 4-syllable ($p < .001$) conditions were statistically significant, with reduced accuracy of nonword repetition on the first trial for the 3- and 4- syllable levels compared to 2-syllable nonwords. The task performance difference between 3- and 4-syllable nonwords was not significant ($p = .08$).

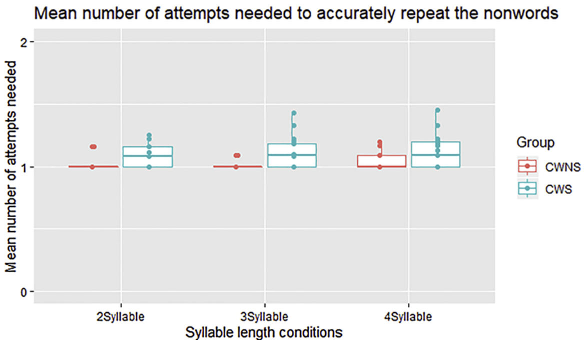

Fig. 4. Comparison of the mean number of trials taken for accurate repetition of nonwords between CWS and CWNS for the nonword repetition task (error bars indicate standard deviation values). A ceiling effect was demonstrated by CWNS at 2- and 3-syllable conditions.

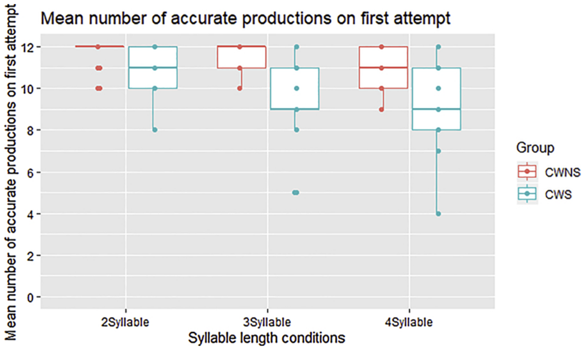

Fig. 5. Comparison of the mean number of accurate repetitions between CWS and CWNS on the initial trial of nonword repetition task (error bars indicate standard deviation values). A ceiling effect was demonstrated by CWNS at 2-syllable condition.

3.1.4. Effect of nonword syllable length on the fluency of repetition

The effect of nonword syllable length on the fluency in CWS was analyzed using one way repeated measures ANOVA with syllable length as the within-subject factor. The dependent variable was the mean number of fluent repetitions. Greenhouse-Geiser corrected p values are reported as sphericity was violated. The results revealed a significant main effect of syllable length on the fluency of nonword repetitions [$F(1, 32) = 21.415$, $p < .001$, $\eta^2p = .572$].

Post hoc comparison of all the pairs was conducted using Bonferroni correction with estimated marginal means. The results revealed that the difference between all the pairs (2-syllable vs. 3-syllable, 3-syllable vs. 4-syllable, 2-syllable vs. 4-syllable) was statistically significant ($p < .01$). That is, CWS were progressively less fluent while repeating nonwords of 2-,3- and 4-syllable length with least fluent at longest word syllable length (Fig. 6).

3.2. Nonword identification

A repeated-measures ANOVA was conducted with the talker group (CWS, CWNS) as the between-subjects factor and syllable length (2-, 3-, and 4-syllable nonwords) as a within-subject factor to analyze the accuracy of nonword identification. The dependent

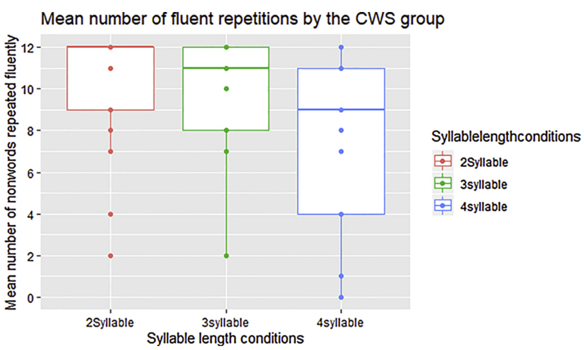

Fig. 6. The mean number of fluent repetitions for the CWS group for the nonword repetition task (error bars indicate standard deviation values).

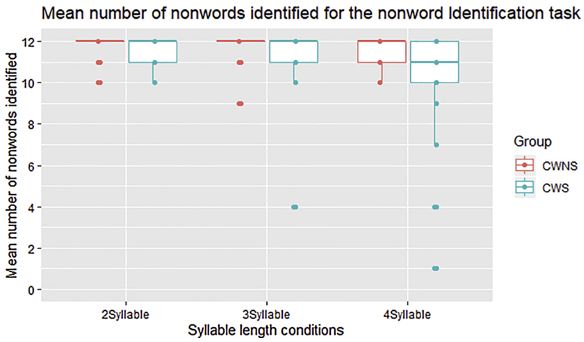

Fig. 7. Comparison of the mean number of nonwords identified correctly between CWS and CWNS for the nonword identification task (error bars indicate standard deviation values). A ceiling effect was demonstrated by CWNS at 2- and 3-syllable conditions.

variable was the number of nonwords correctly identified. The results revealed a significant main effect for the talker group [$F(1, 32) = 4.662$, $p < .05$, $\eta^2 p = .127$]. The mean number of nonwords correctly identified was significantly fewer for the CWS than CWNS (Fig. 7). The mean number of nonwords correctly identified by CWS and CWNS is depicted in Table 5.

In addition to the group effect, there was a significant main effect of nonword syllable length [$F(1.461, 46.759) = 5.139$, $p < .01$, $\eta^2 p = .138$] and interaction between nonword syllable length and talker group [$F(1.461, 46.759) = 4.062$, $p < .05$, $\eta^2 p = .113$]. A decomposition of interaction between nonword length and talker group was carried out using one way repeated measures ANOVA with syllable length as within-subject factor. The results indicated a significant main effect of nonword syllable length on CWS [$F(1.341, 21.456) = 5.198$, $p < .05$, $\eta^2 p = .245$] but not on CWNS [$F(2, 32) = .142$, $p = .868$].

Further, the effect of talker groups on the number of nonwords identified correctly was examined using the independent t-test. The findings revealed that CWS identified fewer nonwords than CWNS at 4-syllable condition [$t(38) = -2.473$, $p < .01$]. The accuracy difference between CWS and CWNS at 2-syllable and 3-syllable levels did not reach significance (for 2-syllable, $p = .516$, and 3-syllable, $p = .280$).

4. Discussion

The present study investigated specific aspects of phonological working memory (nonword repetition and nonword identification abilities) in Kannada speaking school-aged children who do and do not stutter. Both groups of children were carefully matched for chronological age, language abilities, socioeconomic status, which have previously been reported to influence the performance on phonological working memory tasks. Based on the earlier report of poor nonword repetition performance attributed to the PWM deficits (Anderson et al., 2006; Anderson & Wagovich, 2010; Hakim & Ratner, 2004), it was hypothesized that CWS would show difficulty in both repeating and identifying nonwords compared to CWNS. The following findings were revealed (1) CWS performed as well as CWNS on test of language, articulation, and forward and backward digit span tests; (2) CWS performed significantly poorer compared to CWNS in repeating nonwords of all the three-syllable lengths; (3) CWS demonstrated difficulty identifying nonwords of 4-syllable length in contrast to the previous findings of no difference in performance between AWS and AWNS in identifying nonwords of even longest syllable length.

4.1. Group performance in nonword repetition

In the current study, the CWS group performed consistently poorer compared to CWNS on the nonword repetition task. CWS accurately repeated fewer items at every nonword length compared to CWNS. In addition to reduced accuracy, CWS also required a higher number of attempts to repeat the nonwords accurately and were less accurate in the initial trial at all the three-syllable length conditions. The current findings corroborate earlier reports of lower phonemic accuracy for two-syllable nonwords in preschool CWS

Table 5
The mean number of nonwords correctly identified by CWS and CWNS for the nonword identification task. Standard deviations and ranges are in italics and in parentheses.

Task	CWS			CWNS		
	Mean	SD	Range	Mean	SD	Range
Number of nonwords identified accurately						
2-syllable	11.59	*(.712)*	*(10–12)*	11.71	*(.686)*	*(10–12)*
3-syllable	11.06	*(1.91)*	*(4–12)*	11.65	*(.786)*	*(9–12)*
4-syllable	9.71	*(3.05)*	*(1–12)*	11.59	*(.712)*	*(10–12)*

(Anderson & Wagovich, 2010; Anderson et al., 2006) and school-aged CWS (Hakim & Ratner, 2004; Sasisekaran & Byrd, 2013). Furthermore, Byrd et al. (2012) reported that AWS were less accurate than AWNS in their initial repetition and require more attempts for the accurate production of 7-syllable nonwords. The trend suggests that difficulty in repeating nonwords in preschool CWS may persist throughout the development period into adulthood. Similar to the findings on AWS by Byrd et al. (2012), a higher number of attempts were needed by CWS to repeat the nonwords accurately. This suggests that the group benefits less from repeated exposure to the stimuli as well as repeated attempts at production (Byrd et al., 2012; Ludlow et al., 1997; Namasivayam & Van Lieshout, 2008; Smith et al., 2010).

One of the possible explanations for reduced accuracy in nonword repetition in CWS is a disruption in the Baddeley's phonological loop (Bajaj, 2007; Pelczarski & Yaruss, 2016). A limited phonological working memory capacity may have lead to difficulty in holding the phonological code in memory temporarily, resulting in the rehearsal of an inaccurate articulatory code, thus affecting the quality of phonological representation. Another possible explanation for a significantly poorer performance of CWS group in repeating nonwords is that the retrieval and rehearsal of articulatory code may be intact. However, a disruption at the motor planning and execution might have resulted in inaccurate repetition of the nonwords (Smith et al., 2010, 2012).

On the surface, the current results appear to be in conflict with that of Smith et al. (2012) who reported that CWS aged 4–5 years who were free of language and phonological deficits demonstrated comparable performance on nonword repetition whereas CWS who scored below the expected levels on language and phonological tests produced fewer nonwords accurately. The findings of Smith et al. suggest that the ability to repeat nonwords accurately is influenced by language and not by the fluency status of these children. Incontast to the above finding, the CWS group without language and phonological deficits exhibited higher lip aperture variability on the kinematic measure of nonword repetition suggesting a deficit more at the speech motor programming and execution level. The difficulty in repeating and identifying nonwords in a CWS group without any associated language or articulation deficits as demonstrated in the current findings provide strong evidence against Smith et al. (2012) findings that CWS who do not have a comorbid language disorder perform similar to CWNS on nonword repetition tasks. Similarly, the findings from a different cohort of AWS and AWNS indicate that the performance of the two groups was comparable while repeating simpler nonwords, but the kinematic measures of nonword reading differentiated the two groups with AWS exhibiting greater movement variability while reading nonwords of longer syllable lengths (Sasisekaran, 2013). The above findings indicate that even though nonword repetition places a demand on the PWM, factors associated with motor planning and execution may also influence the quality of phonological representations in the short term memory (Byrd et al., 2012; Gathercole, 2006). Thus, the precise source of reduced ability in accurate repetition of nonwords and how the deficits in PWM contributes to disfluent speech remains unclear and warrants further investigation.

4.1.1. Digit span task performance

The present study findings revealed a comparable performance of CWS and CWNS on forward and backward digit span tests is congruent with the findings of several studies on similar lines (Pelczarski & Yaruss, 2016; Smith et al., 2012; Spencer & Weber-Fox, 2014). One of the possible reasons for comparable group performance is that, even though repeating back strings of digits requires storage and rehearsal of the digits in the phonological working memory, the task involves backward repetition of phonologically simple numbers that places reduced articulatory demand allowing the CWS to perform on par with CWNS. Accurate repetition of nonwords requires storage, rehearsal and motor planning and execution of novel phonological segments that place additional demand on phonological working memory. Hence, digit span requires less storage capacity in the phonological loop resulting in concealing the subtle deficits present in CWS and comparable performance between the groups (Pelczarski & Yaruss, 2016).

4.1.2. Fluency of nonword repetitions

The study also attempted to explore the fluency of repetitions by the CWS group as the nonwords increased in syllable length. The number of disfluencies across the three-syllable length conditions when compared showed a significant decline in the fluency as the nonwords increased in length. Thus, it would appear that the increased difficulty of CWS in repeating nonwords of 3- and 4-syllable lengths manifested in the children's fluency as well. The current findings are in consensus with the existing stuttering literature reports that the length of speech production units is a contributing factor to stuttering. Schlesinger, Melkman, and Levy (1966) reported that school-aged CWS demonstrated an increase in disfluency with increases in syllable length. Similar findings have been reported in younger CWS between 2 and 7 years (Logan & Conture, 1995; Logan & LaSalle, 1999; Sawyer et al., 2008). More recently, Sasisekaran and Weather (2019) reported twice the percentage of disfluencies in CWS while repeating nonwords of 6-syllable levels compared to 3-syllable level. The findings suggest that increase in nonword syllable length places a higher demand on both PWM and speech motor control that may be contributing to the observed differences (Logan & Conture, 1995; Sasisekaran & Weather, 2019; Smith et al., 2010). However, the present findings are not in agreement with the findings of existing studies on nonword repetition that the difficulty CWS experience in accurately repeating nonwords does not manifest in children's fluency (Anderson et al., 2006; Hakim & Ratner, 2004; Oyoun et al., 2010). The current finding is particularly interesting in light of the fact that the majority of the participants in the current study were of moderate to very severe degree of stuttering whereas the existing literature findings were based on performance of CWS in the mild to moderate category. It is possible that in individuals who may have more severe stuttering, increase in task demand may heighten the probability of speech motor system failure leading to higher probability of disfluencies. Hence, additional research is warranted to better understand the systems that contribute to decline in nonword repetition performance with increase in syllable length.

4.2. Nonword identification performance differences

In the present study, in addition to a vocal nonword repetition task, the participants were compared in a nonvocal nonword identification task. It was assumed that nonword identification would rule out the possibility of motor speech deficits in stuttering influencing the task performance as in nonword repetition task and provides insight into the phonological store capacity of the CWS. Both CWS and CWNS exhibited comparable accuracy at 2- and 3-syllable word lengths. However, identifying 4-syllable nonwords was proved to be significantly more difficult for CWS compared to CWNS. The duration of nonword identification tasks including target nonword and the three subsequent stimuli in the current study was approximately 7.8 s for 2-syllable, 8.2 s for 3-syllable, and 8.5 s for 4-syllable nonwords. According to Baddeley (2003), any acoustic speech event that is to be retained for more than 2 s requires the activation of the subvocal rehearsal system (Bajaj, 2007). Hence, the current findings of CWS experiencing difficulty in identifying nonwords of only 4-syllable length support the notion that the PWM may be a source of difficulty for CWS. But these deficits may manifest only when the system is taxed.

Since the present study is a preliminary attempt towards exploring the nonword identification abilities in CWS, a direct comparison of the obtained results with existing literature on CWS is unremarkable. However, assessment of nonword identification abilities of AWS and AWNS by Byrd et al. (2015) revealed that AWS exhibited significant ceiling effects on the task even at the 7-syllable level, and the task performance does not differentiate the groups. Taken together the two study findings, it is suggested that school-aged children experience difficulty in storage and subvocal rehearsal of nonwords of 4-syllable length, whereas AWS does not exhibit phonological working memory deficits even at 7-syllable length. The comparable performance between AWS and AWNS in repeating nonwords as reported by Byrd et al. may be attributed to the task is not sufficient enough to tap the subtle PWM defícts in AWS. Yet another possibility is that these defícts being subclinical in nature, AWS may recover from the PWM defícts with age, thus resulted in comparable performance with AWNS. Further research that would allow to closely examine the effect of developmetal changes on PWM in both CWS and AWS and its effect on disfluencies is warranted.

It is also observed that CWS exhibited reduced accuracy in repeating nonwords of all syllable lengths, whereas, for nonword identification task, the performance of the group significantly deteriorated only at 4-syllable nonword level. Given that the nonword repetition task involves additional motor planning and execution, the observed performance difference across the two tasks by the CWS indicates that in addition to the PWM deficits, shortfalls in motor planning and execution also limit the performance of the group in the nonword repetition task. Smith et al. (2010) suggest that there is a critical interplay between phonological processing and motor programming in CWS. Such interplay can lead to subgroups within the CWS population, leading to performance differences on tasks of PWM as reported by the literature (Bakhtiar et al., 2007). Hence, the present study provides strong evidence against theories of stuttering that posit phonological processing deficits as the causative factor of the disorder (Postma & Kolk, 1993). The current findings indicate that both PWM and speech motor planning ability is equally compromised in CWS even though the extent of interaction between these deficits is still unclear.

4.3. Study limitations

An inevitable limitation while investigating the phonological working memory in children who stutter using nonword repetition and nonword identification task is the difficulty in fully separating the effect of faulty phonological encoding on the phonological working memory tasks. Although the nonword identification task rules out the influence of motor planning and execution deficits, and it appears clear that CWS demonstrates subtle deficits in tasks involving phonological working memory, the findings may have been influenced by phonological encoding deficits. Studies exploring the phonological encoding in children and adults who stutter provide evidence to suggest that the phonological encoding abilities in these populations are different from those in nonstuttering children and adults (Sasisekaran & Byrd, 2013; Sasisekaran, Luc, Smyth, & Johnson, 2006). The two processes, phonological encoding, and phonological working memory being equally attributable to each other, it still remains unclear, which among these processes contribute to nonword identification performance difference in CWS to a greater extent. Hence is it is too early to draw the conclusion that a limited phonological working memory capacity is the core casual factor of disfluent speech in CWS. Rather, we would conclude from the current findings and earlier studies (reviewed in Sasisekaran & Byrd, 2013; Smith et al., 2012) that CWS group was challenged by phonological encoding and working memory deficits during nonword identification task and additional speech motor programming and execution deficits while repeating nonwords. Additional research is warranted to study the role of other processes involved in disfluent speech and their interaction with phonological working memory to obtain a better understanding of the multifactorial nature of the disorder.

5. Conclusion

The present findings indicate that Kannada speaking school-age children who stutter are less accurate in both repeating and identifying nonwords, and this reduced accuracy most likely reflects a limited phonological working memory. Further, it was observed that there was increased difficulty in identifying nonwords of increased syllable length. The current findings suggest that differences in PWM in these children may not appear until the system is sufficiently challenged. In contrast to the non-word identification task, the performance of children who stutter on nonword repetition demonstrated additional difficulties in performing, which was at par with fluent peers. Thus, the findings indicate that children who stutter demonstrate additional deficits in speech motor planning and execution, which might have added to the existing PWM deficits. Additional research is warranted to study the extent of interaction between the PWM and speech motor control and the combined contribution to the difficulty CWS experience in establishing and maintaining fluent speech.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

Authors report no conflict of interest.

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