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Nonword repetition and phoneme elision in adults who do and do not stutter: Vocal versus nonvocal performance differences

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A R T I C L E I N F O

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A B S T R A C T

Purpose: The purpose of the present study was to enhance our understanding of phonological working memory in adults who stutter through the comparison of nonvocal versus vocal nonword repetition and phoneme elision task performance differences.
Method: For the vocal nonword repetition condition, participants repeated sets of 4- and 7-syllable nonwords ($n = 12$ per set). For the nonvocal nonword repetition condition, participants silently identified each target nonword from a subsequent set of three nonwords. For the vocal phoneme elision condition, participants repeated nonwords with a target phoneme eliminated. For the nonvocal phoneme elision condition, participants silently identified the nonword with the designated target phoneme eliminated from a subsequent set of three nonwords.
Results: Adults who stutter produced significantly fewer accurate initial productions of 7-syllable nonwords compared to adults who do not stutter. There were no talker group differences for the silent identification of nonwords, but both talker groups required significantly more mean number of attempts to accurately silently identify 7-syllable as compared to 4-syllable nonwords. For the vocal phoneme elision condition, adults who stutter were significantly less accurate than adults who do not stutter in their initial production and required a significantly higher mean number of attempts to accurately produce 7-syllable nonwords with a phoneme eliminated. This talker group difference was also significant for the nonvocal phoneme elision condition for both 4- and 7-syllable nonwords.
Conclusion: Present findings suggest phonological working memory may contribute to the difficulties persons who stutter have establishing and/or maintaining fluent speech.

Educational Objectives: (a) Readers can describe the role of phonological working memory in planning for and execution of speech; (b) readers can describe two experimental tasks for exploring the phonological working memory: nonword repetition and phoneme elision; (c) readers can describe how the nonword repetition and phoneme elision skills of adults who stutter differ from their typically fluent peers.

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1. Introduction

Stuttering is largely considered to be a multifactorial disorder (e.g., Bloodstein & Bernstein Ratner, 2008; Conture, 2001; Guitar, 2013; Smith, 1999; Yairi & Seery, 2011). There are significant data to suggest phonological encoding, the process of retrieving the sound segments in words prior to motor programming and execution (Levelt, 1989), is one of the many factors that contribute to the difficulties persons who stutter have establishing and/or maintaining fluent speech (e.g., Aboul Oyoun, El Dessouky, Shohdi, & Fawzy, 2010; Anderson, 2007; Anderson & Byrd, 2008; Bosshardt, 1993; Byrd, Conture, & Ohde, 2007; Byrd, Vallely, Anderson, & Sussman, 2012; cf., Bakhtiar, Ali, & Sadegh, 2007; Hakim & Ratner, 2004; Hennessey, Nang, & Beilby, 2008; Ludlow, Siren, & Zikria, 1997; Melnick, Conture, & Ohde, 2003; Nippold, 2002, 2012; Ntourou, Conture, & Lipsey, 2011; Pelczarski & Yaruss, 2014; Sasisekaran & Byrd, 2013; Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth, & Johnson, 2006; Vincent, Grela, & Gilbert, 2012; Weber-Fox, Spencer, Spruill, & Smith, 2004). For example, of the disorders that co-occur with stuttering, disorders of phonology are among the most frequent (Arndt & Healey, 2001; Louko, Conture, & Edwards, 1999; Yaruss, LaSalle, & Conture, 1998; cf., Nippold, 2001, 2012). Researchers have also suggested that the phonological representations of children who stutter may be underspecified (e.g., Anderson, 2007; Anderson & Byrd, 2008; Anderson & Wagovich, 2010; Anderson, Wagovich, & Hall, 2006; Hakim & Ratner, 2004). Furthermore, the incremental processing abilities of children who stutter do not appear to develop within the same timeframe of their typically fluent peers (Byrd et al., 2007) and the phonological encoding of adults who stutter appears to be uniquely compromised by increased cognitive demands (e.g., Bajaj, 2007; Bosshardt, 1990, 1993; Jones, Fox, & Jacewicz, 2012; Sasisekaran & Weisberg, 2014; Weber-Fox et al., 2004). This reduced speed and accuracy in encoding seen in overt speech tasks have also been revealed during nonvocal speech tasks (e.g., Brocklehurst & Corley, 2011; Postma, Kolk, & Povel, 1990; Sasisekaran, 2013). Thus, together these results suggest that phonological deficits may extend beyond encoding to include other processes distinct to phonological working memory (see Bajaj, 2007 for review of phonological working memory and stuttering). In addition, among the studies that have been completed thus far, vocal indices of phonological working performance have been measured independently of nonvocal indices. The purpose of the present study is to enhance our understanding of the potential contribution of phonological working memory to stuttered speech by comparing nonvocal to vocal responses across tasks that, to date, have been explored with respect to vocal performance or nonvocal performance exclusively, as opposed to the two tasks in tandem.

1.1. Phonological working memory

According to Baddeley (2003) working memory is comprised of the central executive and the three supporting systems: (1) phonological loop, (2) visuospatial sketchpad and (3) the episodic buffer. The function of the central executive and that of the phonological loop are critical to the present study as we are focusing on phonological working memory. The visuospatial sketchpad with its distinct application to the manipulation of visual information is not relevant to the present study and will not be discussed further. Similarly, the episodic buffer will not be discussed as this particular system binds information from various distinct sources into chunks or episodes; an application that was not enacted in the present study. The central executive is thought to support the retrieval and transfer of information from long-term memory to short-term memory and vice versa. The phonological loop is one of the supporting systems to the central executive and is comprised of the following two critical components: a phonological store and a subvocal rehearsal system. The phonological store facilitates the ability to hold material to be remembered in a phonological code. This phonological code is vulnerable to decay over time (i.e., trace will last approximately 2 s), hence the need for the subvocal rehearsal system. The subvocal rehearsal system is a silent verbal repetition process that refreshes the phonologically encoded material, allowing it to be preserved in memory for a longer period of time (>2 s).

If persons who stutter demonstrate slowed initial encoding of phonological information, then the subsequent process of refreshing information would also be decreased as this process can only operate as quickly and efficiently as the information to be refreshed is provided. Alternatively, if there are distinct differences in the selection, programming and subsequent execution of speech (e.g., see Watkins, Smith, Davis, & Howell, 2008 for review of this perspective), then the covert articulatory rehearsal of words may be uniquely compromised in persons who stutter. Yet another consideration is that if persons who stutter have difficulty encoding phonological representations via short-term memory and/or accessing those representations via long-term memory, then perhaps differences reported in previous studies specific to phonological encoding may be reflective of central executive deficiencies.

1.2. Nonword repetition in adults who stutter

Relatively few investigations have been completed within the stuttering literature with respect to phonological working memory. Of the studies that exist, those that have employed nonword repetition in adults will be reviewed for two key reasons. First, this particular task is thought to allow valuable insight into phonological working memory in isolation with minimal influence from long-term storage of phonological as well as semantic and lexical information. Second, this present study is a systematic replication of a nonword repetition study that we completed with adults who do and do not stutter (i.e., Byrd et al., 2012). Nonword repetition has been shown to differentiate adults who do not stutter from adults who stutter in a few ways. Ludlow et al. (1997) examined the nonword repetition abilities of adults who do and do not stutter by having the participants (n = 5 per group) repeat two four-syllable nonwords multiple times. Both groups exhibited a practice effect. That is, as both groups repeated the words, production accuracy improved. However, the degree of improvement differed. The percentage of consonants correct was still lower for adults who stutter than that of adults who do not stutter after multiple productions. The reported difference in practice effect lends support to the notion that persons who stutter have less efficient phonological encoding skills than persons who do not stutter. These results also support the perspective that persons who stutter have difficulty learning novel motor speech sequences.

Smith, Sadagopan, Walsh, and Weber-Fox (2010) had 17 adults who do and do not stutter complete a nonword repetition paradigm wherein they first had to produce 16 nonwords, which varied from 1- to 4-syllables in length, from the Nonword Repetition Test (NRT; Dollaghan & Campbell, 1998). Participants from both talker groups did not differ in production accuracy across the 1- to 4-syllable lengths; they were comparably accurate in their productions at each length. Following the completion of the NRT, the adults in the Smith et al. study also repeated a new series of novel words, which were adapted from the NRT so as to include bilabial consonants. The new series of novel words varied in length (1- to 4-syllables) and phonological complexity and were embedded within a carrier phrase. The authors found that the accuracy with which the two groups of participants repeated the nonwords in this task was similar, at least on a descriptive basis. However, the adults who stutter exhibited more inconsistency in articulatory coordination during the production of longer (i.e., 3- and 4-syllable length), more phonologically complex nonwords compared to adults who do not stutter. The authors suggested that there is a critical interplay between phonological encoding and motoric stability in the speech production of adults who stutter.

Byrd et al. (2012) employed a nonword repetition task as well as a phoneme elision task. Fourteen adults who stutter and fourteen adult nonstutterers listened to 48 nonwords, were provided multiple attempts at production to facilitate accuracy, and then were required to repeat the same set of nonwords with a designated sound missing. No difference was found for the phoneme elision task; this task was equally challenging for both talker groups. However, for the nonword repetition task, results showed repetition accuracy was comparable for the adults who do and do not stutter for the repetitions of 2–4 syllable words, but the adults who stutter required a higher mean number of attempts before accurate repetition of 7-syllable words. The authors attributed the significant findings for the nonword repetition task to suggest that there is a deficit in the subvocal rehearsal system of adults who stutter that is highlighted when the required productions are at lengths that are more challenging to recall.

More recently, Sasisekaran and Weisberg (2014) investigated the nonword repetition accuracy of nonwords that varied specific to complexity and phonotactic constraint. Complexity was determined by whether the consonants were considered to be acquired early or late as well as by the number and type of consonant clusters. Four of the eight were considered to be complex; the other four were considered to be simple. Two of the eight were comprised of non-English clusters. The adults who stutter (n = 10) were less accurate in their repetition of these complex nonwords. Sasisekaran and Weisberg also reported that fewer adults who stutter than adults who do not stutter produced the required 4–5 correct productions needed to be able to complete the kinematic analyses. Additionally, the adults who stutter exhibited significant practice effects as measured by reduced movement variability for the 3-syllable nonwords, but did not demonstrate significant practice effects for the longer 4-syllable nonwords, rather the variability persisted. By comparison, their typically fluent peers easily produced/retained the 3-syllable nonwords and also demonstrated reduced movement variability for the 3 syllable words. Taken together, these data across the studies reviewed suggest that deficits in phonological working memory may be associated with the disorder of stuttering, but further exploration beyond production-based tasks is necessary to understand how these deficits manifest.

1.3. Purpose and hypotheses

To date, analyses of nonword repetition performance in adults who stutter have been limited to overt speech tasks; as of yet, there has been no published study of vocal response versus nonvocal response performance differences in adults who stutter. Thus, the potential influence of motor deficits specific to reported findings of significance in nonword repetition performance cannot be ignored. For the present study, we systematically replicated our previous study (Byrd et al., 2012) by adding a nonvocal condition using the same stimuli. In specific, we employed the same vocal nonword repetition and phoneme elision tasks along with the addition of comparable nonvocal response nonword repetition and phoneme elision tasks. Vocal and nonvocal nonword repetition tested the ability of adults who stutter to recall phonological sequences, while vocal and nonvocal phoneme elision tested their ability to recall and manipulate the nonword into a new sequence by eliminating one phoneme. Analysis of performance in the nonvocal response conditions as compared to the vocal response conditions provided valuable insight into the phonological loop and subvocal rehearsal systems of adults who stutter, without the influences of overt motor speech movements. We predicted that if phonological working memory is indeed compromised in adults who stutter, performance differences between adults who stutter and their typically fluent peers will exist for both the nonvocal response and vocal response tasks. Alternatively, if the demands of motor programming and/or execution required for speech output significantly interferes with the ability to retain the integrity of phonological information, we predicted adults who do and do not stutter will perform similarly on nonvocal nonword repetition and phoneme elision tasks with differences emerging only when talker groups are compared on the vocal nonword repetition and phoneme elision tasks.

2. Method

2.1. Participants

Approval for the completion of this study was provided by the first author's university Institutional Review Board and informed consent was obtained for each participant. Participants for the present study had to meet the following inclusionary criteria: (a) native English speaker or an English speaker with native competency; (b) between the ages of 18 and 50 years old; (c) no prior history of speech and/or language disorders (with the exception of stuttering for the adults who stutter); and (d) no neurological, social, emotional, or psychiatric disturbances. One adult who stutters who was initially recruited for participation was excluded because of failure to meet one or more of the aforementioned inclusion criteria. Twenty adults who do ($n=10$; $M=31$ years; range = 21–42; $n=1$ female; $n=9$ males) and do not stutter ($n=10$; $M=31.2$ years; range = 22–43; $n=1$ female; $n=9$ males) matched for age (±3 years), gender, and education-level met the inclusionary criteria for participation in this study.

All 10 of the adults who stutter who participated in the study had reportedly received prior speech therapy for stuttering. Participants who stutter were not excluded from participation based on treatment history for key reasons reported in past research (see Logan, Byrd, Mazzocchi, & Gillam, 2011 for similar arguments regarding the inclusion of children and adults who stutter with a history of treatment). First, there was no reason to suspect that an individual's performance on the experimental tasks would be affected by exposure to fluency treatment. That being said, participants were not observed to employ any fluency facilitating techniques during the single word production vocal response tasks. Second, many adults who stutter report past participation in speech therapy; thus, exclusion of adults who have a history of speech therapy would compromise the ecological validity of this study.

A series of tasks were administered to evaluate short-term memory and phonemic awareness skills in both groups prior to the experimental tasks. Short-term memory span was assessed using the forward and backward digit span tests (Memory Scale; Wechsler, 1997). Phonemic awareness skills, such as perception, conceptualization and manipulation of speech sounds, were also assessed using two subtests of the Lindamood Auditory Conceptualization Test (LAC; Lindamood & Lindamood, 1979). Independent *t*-tests conducted on the mean scores demonstrated that the adults who stutter and adults who do not stutter performances did not significantly differ for the digit, rhyme judgment, or rhyme production tasks. Participants were also matched for education level with education level ranging from some college education to master's degree (see Newman & Bernstein Ratner, 2007, for a similar description of education-level matching criteria).

Stuttering severity was determined from a recorded, 5-min conversational speech sample. Severity ratings were assigned to each participant who stutters by the second author using O'Brian, Packman, Onslow, and O'Brian's (2004) 9-point stuttering severity scale (i.e., 1 = no stuttering, 2 = very mild stuttering, 9 = extremely severe stuttering). The mean rating for all 10 participants who stutter was 3.9 ($SD=2.02$), with six participants receiving ratings of 2 or 3 (corresponding to relatively mild stuttering), three participants receiving ratings of 4, 5, or 6 (corresponding to relatively moderate stuttering), and one participant receiving a rating of 8 (corresponding to relatively severe stuttering). In addition to this rating scale, conversational and reading samples were collected from each participant and analyzed by the second author using the more commonly used measure of stuttering severity, Stuttering Severity Instrument-3 (SSI-3; Riley, 1994). The severity rating results using the SSI-3 replicated the findings reported with the 9-point scale above. Participant descriptive characteristics are summarized in Table 1.

Table 1
Participant characteristics for adults who stutter (AWS) and adults who do not stutter (AWNS).

Participant	Age	Sex	Stuttering severity	Educational level
1	22	Male	N/A	B.A. student
2	23	Male	N/A	B.A. student
3	25	Male	N/A	B.A.
4	25	Male	N/A	B.A.
5	29	Male	N/A	B.A.
6	30	Female	N/A	M.A.
7	38	Male	N/A	M.A.
8	43	Male	N/A	B.A.
9	40	Male	N/A	B.S.
10	37	Male	N/A	M.A.
11	21	Male	5	B.A. student
12	41	Male	2	M.A.
13	42	Male	3	B.A.
14	40	Male	3	B.S.
15	33	Female	2	M.A.
16	26	Male	8	B.A.
17	41	Male	2	M.A.
18	20	Male	6	B.A. student
19	23	Male	3	B.A.
20	23	Male	5	B.S.

Table 2
Vocal nonword repetition task stimuli with the phoneme elision task in parentheses.

Four syllable words	Seven syllable words
1. JIG.VEN.TO.XILE (without the "j")	1. ZOO.BEN.IF.FER.AL.TO.PINE (without the /z/)
2. CAS.TI.PAIL.TY (without the /p/)	2. VAM.PON.TIG.EEZ.I.TRI.CAY (without the /k/)
3. AN.TIS.KOL.DATE (without the /k/)	3. AS.KEN.I.DO.BIS.KU.LATE (without the /d/)
4. DIG.AN.TUL.IN (without the /d/)	4. DAY.BISH.OCK.SIN.ALL.O.BIT (without the "sh")
5. FIN.RAP.TO.KING (without the /k/)	5. FO.MMI.GA.VE.LON.TI.PAN (without the /l/)
6. GUN.DOC.TIP.EEL (without the /d/)	6. GIS.TOR.AK.I.DO.PU.LIN (without the /n/)
7. HISS.Y.DO.GENE (without the /h/)	7. HUN.DI.NO.TER.AL.I.TY (without the /h/)
8. IM.LAC.SO.DOCK (without the /s/)	8. IN.FAS.KO.VI.JI.DE.ENT (without the /t/)
9. VAY.TAW.CHI.DOYP (without the /d/)	9. JED.A.BUL.OS.KER.A.MIC (without the /b/)
10. DA.VON.OY.CHIG (without the /g/)	10. KA.DDEN.I.SO.NO.MA.CY (without the /d/)
11. NY.CHOY.TOW.VUB (without the "ch")	11. SA.CON.IM.BEN.A.LO.PY (without the /l/)
12. TAV.A.CHEE.NYG (without the /g/)	12. UM.PICK.ERR.ANN.I.TI.ZER (without the /z/)

2.2. Stimuli development

2.2.1. Nonword repetition

Twenty-four nonwords consisting of 4- and 7-syllables ($n = 12$ per syllable length category) were selected from the nonword stimulus list developed by Byrd et al. (2012). In an effort to limit any semantic influence, the nonwords were controlled for real wordlikeness, segmental phonotactic probability, biphone phonotactic probability, and phonemic onset as described by Byrd et al. (2012). In specific, nonwords were controlled for phonotactic complexity using the Vitevitch and Luce (2004) web-based method of calculating segmental and biphone phonotactic probabilities. The mean sum of segmental probability was 1.437 for the 4-syllable nonwords and 1.676 for the 7-syllable nonwords. The mean sum of the biphone probabilities was 1.024 for the 4-syllable nonwords and 1.029 for the 7-syllable nonwords. Vitevitch and Luce (1998) defined high phonotactic probability for nonwords as <1. Thus, the segmental and biphone sums for both syllable length categories were low in phonotactic probability. The nonwords were also controlled for real wordlikeness. Twenty adults rated the nonwords according to the wordlikeness scale used by Gathercole (1995). Participants were instructed to rate the spoken nonword on a 5-point scale with 1 indicating "very unlike a real word" and 5 indicating "very like a real word". They were also told that the rating should not be based on comparing the nonword to an existing real word, but on whether the nonword's sound pattern could exist in the English language. Mean wordlikeness ratings of the nonwords were 2.474 for the 4-syllable nonwords and 2.833 for the 7-syllable nonwords. Thus, all words were comparable in their rating of wordlikeness, ranging from "very unlike a real word" to "unlike a real word".

The nonwords were further controlled by ensuring that the phonemic onsets and offsets of the stimuli were consistent across all syllable lengths. Two of the 12 nonwords at the 4-syllable length began with a vowel and three of the 12 nonwords at the 7-syllable length had vowel onsets. Three to six nonwords at each syllable length began with a stop consonant. Three to five nonwords were fricative initiated at each syllable length. Affricate onsets ranged from one to two per syllable length. Regarding offset consistency, for each syllable length, seven to nine of the nonwords ended with a stop consonant, one to two ended in a liquid or glide, and one to four ended in a vowel. Finally, the recorded production of the nonwords consisted of stress placed on the first syllable of each nonword across all syllable lengths.

2.2.2. Phoneme elision

The vocal response phoneme elision task required that participants repeat a nonword with a sound or phoneme missing (Wagner, Torgesen, & Rashotte, 1999). The target nonwords for the phoneme elision tasks were created by requiring the participant to alternately delete the initial consonant sound from the first syllable, the initial consonant from the second through fourth syllables, or the final consonant sound in the same nonwords that were used for the nonword repetition tasks. The end result was that the participant would have to eliminate an initial phoneme at each syllable boundary across both 4-syllable and 7-syllable lengths. Thus, elision was based on location, not on phonological property. For example, the phoneme elision of an initial consonant of a 4-syllable nonword would include the person having to 'say *jigventoxile* without saying "*j*"' with the accurate production being '*igventoxile*'. An example of phoneme elision of a final consonant of a 7-syllable nonword would be for the participant to 'say *infaskovijideent* without saying /t/' resulting in the production of '*infaskovijideen*'.

With exception of the sixth syllable, initial and final consonants were removed from all syllables at least once, as consistently as possible, and in random order to create the foils for the nonvocal nonword repetition and phoneme elision stimuli. The sixth syllable exception related to the construction of the nonwords with the sixth syllable rarely, if ever, containing a final consonant that could be eliminated. Thus, the foil stimuli for both the nonvocal nonword repetition and phoneme elision tasks were variations of the target nonword with a different phoneme deleted. See Table 2 for a complete list of stimuli used in the nonvocal and vocal conditions for the nonword repetition and phoneme elision tasks.

2.3. Stimuli recording

Stimuli was recorded by a female native speaker of Standard American English on a Dell computer using Computerized Speech Lab equipment in a sound-treated room with a microphone placed approximately six inches from the speaker.

2.4. Procedure

The experimental nonword repetition and phoneme elision conditions were completed in two separate testing sessions, on average 5–7 days apart. Each session lasted approximately 40–50 min. Each participant completed the two experimental testing sessions in random order, with half of the participants completing the nonword repetition condition before completing the phoneme elision condition. The order of tasks (vocal or nonvocal stimuli presentations) within the nonword and phoneme elision condition was also counterbalanced across participants in both groups. In every task, twelve 4-syllable nonwords were attempted before the more challenging 7-syllable nonwords.

The experimental stimuli were presented using Windows Media Player software through headphones to all participants with the exception of Participant 15 who requested presentation of the stimuli through loud speakers. Stimuli presentation order was randomized within each syllable class using Microsoft Excel. Participant responses were recorded with a digital video camera and Olympus digital voice recorder, and scored as either correct or incorrect by hand during the presentation on a nonword repetition and phoneme elision score sheet.

A pilot study with one AWNS (female; age 33) and one AWS (female; age 27) was completed before the 20 participants completed the experimental tasks. Neither of the participants in the pilot study were included as participants in the experimental study. The pilot study allowed us to determine the length of the experimental sessions. Both pilot participants completed the vocal and nonvocal conditions during one session lasting approximately 120 min. However, pilot participant feedback regarding the length of the experimental tasks was used to determine the need to administer the experimental tasks over two, shorter sessions instead of one, longer session. The pilot study also enabled us to confirm the number of presentations the participants needed in order to accurately produce a given nonword. Both pilot study participants required less than four attempts to accurately produce each of the nonwords. Based on these pilot data, all participants in the experimental tasks were allowed a maximum of four trials to listen to and attempt to produce each of the nonwords during the verbal nonword repetition task.

2.5. Nonword repetition task

The nonword repetition task consisted of a vocal response and a nonvocal response condition. Prior to completion of either condition, participants completed four practice trials.

2.5.1. Vocal condition

For the vocal nonword repetition condition, participants were instructed to *verbally repeat* two sets of nonwords: twelve 4-syllable nonwords and twelve 7-syllable nonwords ($N = 24$ total nonwords). Participants were instructed, "You are about to hear a series of nonwords. You are required to listen to the nonword and verbally repeat it as accurately as you can. Once you have made what you consider to be your best effort to repeat the nonword accurately, we will move on to the next nonword. Let's practice." Participants were given a maximum of four attempts to listen to and accurately repeat the nonword before advancing to the next stimulus item. Once the participant repeated the nonword correctly or after the participant had listened and incorrectly produced the nonword four times, the following nonword stimulus was presented. Presentation timing for the vocal response nonword repetition task including the carrier phrase "Say. . ." was, on average, 2.09 s for 4-syllable words and 2.62 s for 7-syllable words.

2.5.2. Nonvocal condition

For the nonvocal condition of the nonword repetition task, participants were instructed to *listen* to the initial target nonword and then *silently identify* the target nonword from a subsequent set of three nonwords. One of the three nonwords played was identical to the initial target nonword, the other two nonwords were not. After each presentation set, consisting of the target nonword and three additional nonwords, the participant pressed a button "1," "2," or "3" to indicate selection of the first, second, or third additional nonword, respectively. In specific, participants were instructed: "You are about to hear a nonword and this nonword will be followed by three (one identical and two contrasting) additional nonwords. After you listen to the target nonword and three additional nonwords, you must choose the one identical to the target by pressing button "1," "2," or "3" for the identical first, second, or third additional nonword, respectively. You will have one opportunity to identify the accurate target word. Let's practice." Unlike the vocal nonword repetition condition, each stimulus item in the nonvocal identification condition was administered only once. Presentation timing for the nonvocal nonword repetition condition including the target nonword, the three subsequent stimuli, and pauses between each word was, on average, 10.21 s for 4-syllable words and 11.37 s for 7-syllable words.

2.6. Phoneme elision task

The phoneme elision task also consisted of vocal and nonvocal conditions. Similar to the nonword repetition task, participants completed four practice trials prior to completion of the phoneme elision experimental tasks.

2.6.1. Vocal condition

The vocal phoneme elision condition required the participants to vocally complete a phoneme elision task with a given nonword from the aforementioned stimuli set. Recall that phoneme elision tasks require the participant to *repeat* a nonword with a sound or phoneme missing (Wagner et al., 1999). For example, "*Kaddenisonomacy* without the /d/." Participants were instructed to "listen to the nonword and verbally repeat it the best you can with a designated sound eliminated, as instructed by the recording. Each new nonword will have only one correct pronunciation. Once you feel as though you have produced the target nonword accurately and/or to the best of your ability, we will move on to the next nonword. Let's practice." Participants were given a maximum of four attempts to accurately repeat the nonword with a designated sound eliminated before advancing to the next stimulus item. Once the participant produced an accurate vocal response to the phoneme elision task or after the participant had incorrectly produced the nonword four times, the following phoneme elision stimulus was presented. Presentation timing for the vocal response phoneme elision task including the carrier phrase was, on average, 4.6 s for 4-syllable words and 5.23 s for 7-syllable words.

2.6.2. Nonvocal condition

For this condition, the participant was asked to *silently identify* which of the following three auditorily presented nonwords (one accurate and two inaccurate) matched the target nonword with the designated phoneme eliminated. The following directions were presented prior to the start of the nonvocal phoneme elision condition: "Listen to the nonword and the specific instructions regarding which phoneme to eliminate within that nonword. This production of the nonword and the related phoneme elision instructions will be followed by three nonword presentations (one accurate and two inaccurate). After you listen to the stimuli production and three additional nonwords, you must choose the one nonword that matches the correct response to the phoneme elision stimuli instructions by pressing button "1," "2," or "3" for the identical first, second, or third additional nonword, respectively. You will have one opportunity to listen to each set of nonwords and nonverbally select the identical choice. Let's practice." Each stimulus item in the nonvocal phoneme elision condition was administered once. Presentation timing for the nonvocal phoneme elision condition including the target nonword, the three subsequent stimuli, and pauses between each word was, on average, 10.68 s for 4-syllable words and 13.06 s for 7-syllable words.

2.7. Data scoring

One of the authors (i.e., second or third) and trained research assistants performed all of the data scoring. The participant responses to the vocal nonword repetition and phoneme elision conditions were scored as either correct or incorrect. If the response was incorrect, a phonetic transcription of the response was recorded. For the present study, we measured both mean number of attempts prior to accurate production and we also measured the accuracy of the initial attempt. If a participant failed to vocally produce a given nonword after four attempts, that participant's number of production attempts was not included in the overall analysis of the mean number of attempts. However, the initial production attempt for that nonword was included in the data corpus for analysis for accuracy of initial attempt. The incorrect responses of each participant were also reviewed offline by the primary scorer and also by the second or third author at least two times to ensure accuracy in transcription. Any discrepancies were resolved through discussion resulting in 100% agreement in transcription. In both vocal response tasks, productions with disfluencies, such as sound/syllable repetitions and prolongations were included as correct responses. The participant responses to the nonvocal nonword repetition and phoneme elision conditions were scored as either correct or incorrect. Coding of these responses were also checked and re-checked by the primary coder as well as the second and/or third author to again allow for 100% agreement in coding.

3. Results

To review, the purpose of the present study was to explore phonological working memory of adults who do and do not stutter using four experimental conditions: vocal nonword repetition, nonvocal nonword repetition, vocal phoneme elision, and a nonvocal phoneme elision.

4. Nonword repetition task

4.1. Vocal condition

Data from the vocal nonword repetition condition were analyzed for accuracy of the first production across both 4-syllable and 7-syllable lengths as well as the mean number of production attempts required to accurately produce the nonword across both syllable lengths.

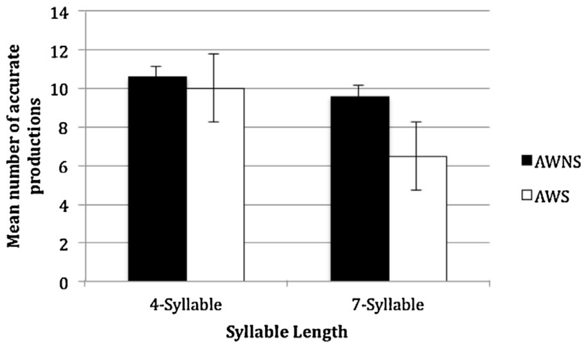

Fig. 1. The mean number of accurate productions on the first attempt to repeat the nonword during the vocal nonword repetition condition at each syllable length for adults who stutter (AWS) and adults who do not stutter (AWNS).

4.1.1. *Accuracy of initial production*

Accuracy of the initial production was analyzed using a Repeated Measures ANOVA with the between-subjects factor of Talker Group (AWS, AWNS) and a within-subjects variable of syllable length (4- and 7-syllable nonwords). The dependent variable was the mean number of accurate initial productions of the nonword. Results revealed a main effect for Syllable Length $F(1,18) = 36.09$, $p \leq .0001$, partial $\eta^2 = .667$. There was no significant between-subjects effect $F(1,18) = 3.384$, $p = .082$, partial $\eta^2 = .158$, but there was a significant interaction between Talker Group and Syllable Length $F(1,18) = 11.139$, $p = .004$, partial $\eta^2 = .382$. Decomposition of the interaction between Syllable Length and Talker Group using estimated marginal means with the Bonferroni adjustment revealed there was not a significant difference between adults who stutter and adults who do not stutter for the 4-syllable length $F(1,18) = .555$, $p = .466$, partial $\eta^2 = .03$. However, there was a significant difference between talker groups at the 7-syllable length; $F(1,18) = 5.809$, $p = .027$, partial $\eta^2 = .244$. Adults who do not stutter produced significantly more accurate initial productions of 7-syllable nonwords than the adults who stutter, as displayed in Fig. 1.

4.1.2. *Mean number of attempts*

To analyze the mean number of production attempts required prior to an accurate production, a Repeated Measures ANOVA was conducted with the between-subjects factor of Talker Group (AWS, AWNS) and a within-subjects factor of syllable length (4- and 7-syllable nonwords). There was a significant main effect for Syllable Length $F(1,18) = 8.211$, $p = .01$, partial $\eta^2 = .313$. The between-subjects effect for Talker Group $F(1,18) = 4.293$, $p = .053$, partial $\eta^2 = .193$ approached but was not significant. An interaction approaching significance was also noted between Talker Group and Syllable Length, $F(1,18) = 4.367$, $p = .051$, partial $\eta^2 = .195$. Although these differences were not significant, as seen in Fig. 2, adults who stutter required more attempts to accurately produce the nonword than adults who do not stutter at the 7-syllable length.

4.2. *Nonvocal condition*

Recall that participants were provided only one attempt to accurately complete the nonvocal nonword repetition condition. A Repeated Measures ANOVA was conducted with the between-subjects factor of Talker Group (AWS, AWNS) and a within-subjects factor of syllable length (4- and 7-syllable nonwords). The dependent variable was mean number of accurate responses on the nonvocal nonword repetition task. Results revealed a significant main effect for Syllable Length $F(1,18) = 4.500$, $p = .048$, partial $\eta^2 = .200$, but no significant between-subjects effect for Talker Group $F(1,18) = .600$, $p = .449$,

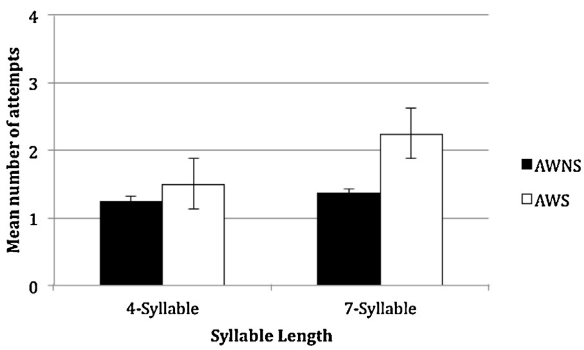

Fig. 2. The mean number of total attempts needed to accurately repeat the target nonwords during the vocal nonword repetition condition at each syllable length for adults who stutter (AWS) and adults who do not stutter (AWNS).

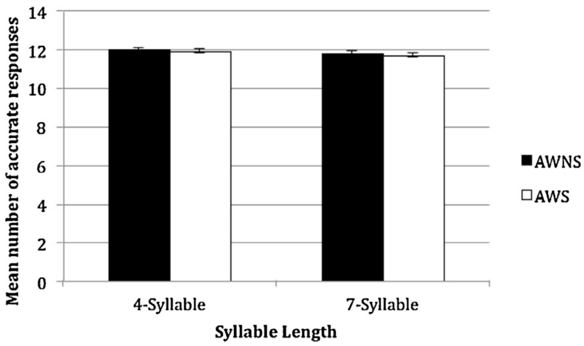

Fig. 3. The mean number of accurate silent identifications in the nonvocal nonword repetition condition across syllable lengths for adults who stutter (AWS) and adults who do not stutter (AWNS).

partial $\eta^2 = .032$. In addition, no significant interaction between Syllable Length and Talker Group $F(1,18) = .000$, $p = 1.00$, partial $\eta^2 < .0001$ was found. Thus, both talker groups were significantly less accurate in completion of the nonvocal nonword repetition task at the 7-syllable word length compared to the 4-syllable length (see Fig. 3).

5. Phoneme elision task

5.1. Vocal condition

Similar to the vocal nonword repetition condition, data from the vocal phoneme elision condition were analyzed for accuracy of the first production across both 4-syllable and 7-syllable lengths as well as the mean number of production attempts required to accurately produce the nonword across both syllable lengths.

5.1.1. Accuracy of initial production

Accuracy of the initial phoneme elision production was analyzed using a Repeated Measures ANOVA with the between-subjects factor of Talker Group (AWS, AWNS) and a within-subjects factor of syllable length (4- and 7-syllable nonwords). The dependent variable was the mean number of times the participant was able to produce the phoneme elision accurately on the first attempt across trials. Results revealed a significant main effect for Syllable Length $F(1,18) = 31.304$, $p \leq .0001$, partial $\eta^2 = .635$. No significant between-subjects effects were observed $F(1,18) = 3.283$, $p = .087$, partial $\eta^2 = .154$. However, a significant interaction was noted between Syllable Length and Talker Group $F(1,18) = 7.826$, $p = .012$, partial $\eta^2 = .303$. A decomposition of the interaction between Talker Group and Syllable Length using estimated marginal means with the Bonferroni adjustment revealed a significant difference between the adults who stutter ($M = 4.9$, $SD = 3.57$) and the adults who do not stutter ($M = 8.2$; $SD = 2.35$) at the 7-syllable length $F(1,18) = 5.958$, $p = .025$, partial $\eta^2 = .249$. As seen in Fig. 4, adults who stutter were significantly less accurate during the initial phoneme elision production at the 7-syllable length than adults who do not stutter. No significant differences were found at the 4-syllable length $F(1,18) = 1.024$, $p = .325$, partial $\eta^2 = .054$.

5.1.2. Mean number of attempts

In addition to analyzing the mean number of accurate initial productions, the mean number of attempts required to accurately complete the vocal phoneme elision condition was analyzed using a Repeated Measures ANOVA with the between-subjects factor of Talker Group (AWS, AWNS) and a within-subjects factor of syllable length (4- and 7-syllable nonwords). A

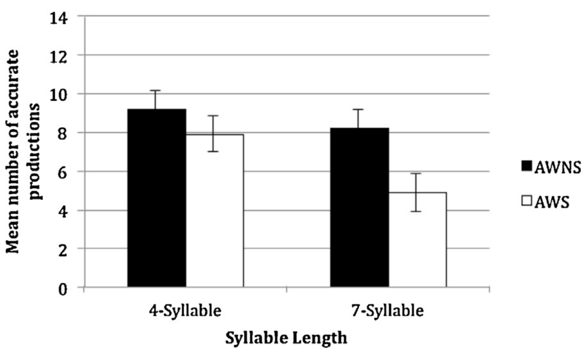

Fig. 4. The mean number of accurate productions on the first attempt of the vocal phoneme elision condition for adults who stutter (AWS) and adults who do not stutter (AWNS).

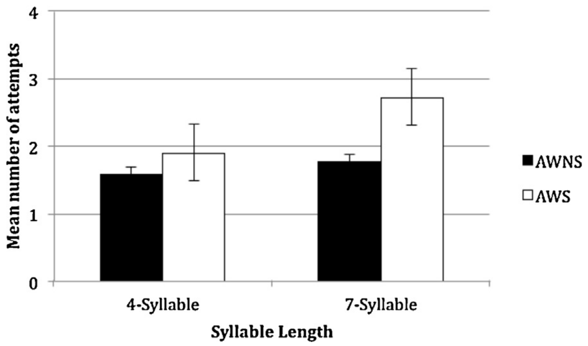

Fig. 5. The mean number of attempts needed to accurately complete the nonvocal phoneme elision condition for each nonword across syllable lengths for adults who stutter (AWS) and adults who do not stutter (AWNS).

significant main effect for Syllable Length was observed $F(1,18) = 15.808$, $p = .001$, partial $\eta^2 = .468$. There was no significant between-subjects effect $F(1,18) = 2.456$, $p = .134$, partial $\eta^2 = .120$, but there was a significant interaction between Syllable Length and Talker Group $F(1,18) = 6.335$, $p = .021$, partial $\eta^2 = .261$. Decomposition of the interaction between Syllable Length and Talker Group using estimated marginal means with the Bonferroni adjustment indicated that the adults who stutter required significantly more attempts at accurate phoneme elision completion at the 7-syllable length ($M = 2.73$, $SD = .334$) than at the 4-syllable length ($M = 1.89$, $SD = .256$), $F(1,18) = 21.205$, $p \leq .0001$ (see Fig. 5).

5.2. Nonvocal condition

Similar to the nonvocal nonword repetition condition, participants were provided one attempt per trial. A Repeated Measures ANOVA was conducted with the between-subjects factor of Talker Group (AWS, AWNS) and a within-subjects factor of syllable length (4- and 7-syllable nonwords). The dependent variable was mean number of accurate responses. Results revealed a significant main effect for Syllable Length $F(1,18) = 48.077$, $p \leq .001$, partial $\eta^2 = .728$ and a significant interaction between Syllable Length and Talker Group $F(1,18) = 33.923$, $p \leq .001$, partial $\eta^2 = .653$ was also found. Additionally, there was a significant between-groups effect for Talker Group $F(1,18) = 30.64$, $p = .001$, partial $\eta^2 = .630$. Decomposition of the interaction between Syllable Length and Talker Group using estimated marginal means with the Bonferroni adjustment revealed a significant difference between the adults who stutter and adults who do not stutter at both the 4-syllable, $F(1,18) = 16.647$, $p = .001$, partial $\eta^2 = .274$, and 7-syllable lengths $F(1,18) = 9.894$, $p = .006$, partial $\eta^2 = .362$. Adults who stutter produced significantly fewer accurate responses than their fluent peers during the nonvocal phoneme elision condition across both syllable lengths (see Fig. 6).

6. Discussion

To review, the purpose of the present study was to extend past research that suggests phonological working memory as a contributor to stuttered speech by comparing vocal versus nonvocal nonword repetition and phoneme elision abilities in adults who do and do not stutter. We completed a systematic replication of our previous nonword repetition and phoneme elision study wherein we added the comparison of nonvocal performance differences. Results revealed performance differences in phonological working memory tasks are not exclusive to vocal output. Results will be discussed with respect to theoretical as well as clinical implications.

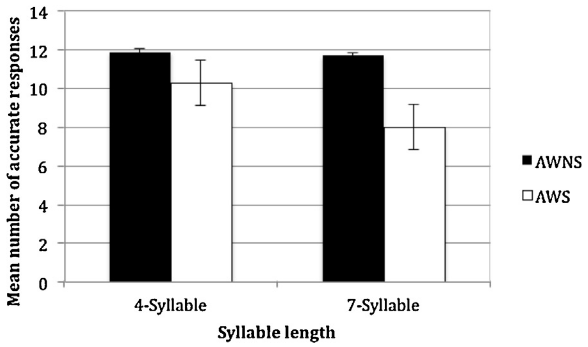

Fig. 6. The mean number of accurate silent identifications of the nonword with the designated phoneme eliminated across syllable lengths for adults who stutter (AWS) and adults who do not stutter (AWNS).

6.1. Vocal performance differences

In the present study, the adults who stutter produced significantly fewer accurate initial attempts of the 7-syllable nonwords than the typically fluent controls. The differences in the mean number of attempts prior to accurate production of 7-syllable nonwords between adults who do and do not stutter approached but was not significant ($p = .053$). An interaction approaching significance was also noted in the present study between talker group and syllable length ($p = .051$). In our previous study (Byrd et al., 2012), similar to present findings, the adults who stutter were significantly less accurate than adults who do not stutter in their initial repetition of the 7-syllable nonwords. When analyzing the mean number of attempts prior to accurate production, in our 2012 study the adults who stutter required significantly more attempts than adults who do not stutter to accurately produce 7-syllable nonwords. Together, our past and present data demonstrate adults who stutter require more attempts than typically fluent speakers to accurately produce nonwords of increased length.

With respect to the phoneme elision task, in our previous study, both the adults who stutter and the adults who do not stutter performed significantly worse when completing phoneme elision productions on 7-syllable words, but there were no talker group differences. In the present systematic replication of our prior study, the adults who stutter were significantly less accurate during the production of the 4- syllable and the 7-syllable words. These data suggest that phoneme elision is a task that is hard for both typically fluent speakers and persons who stutter. The significant differences noted between talker groups in the present study that were not present in the previous study also lend support to assumption that there are, at least, subgroups of persons who stutter who appear to have distinct difficulty maintaining and simultaneously manipulating novel phonological strings in the phonological loop.

Research shows that for typically fluent speakers the subvocal rehearsal system is critical to the accurate recall and production of longer words (Baddeley, Chincotta, Stafford, & Turk, 2002). Our present as well as past nonword repetition data suggest that the subvocal rehearsal abilities of adults who stutter may not be as robust as adults who do not stutter. This assumption is also supported in our present results for the vocal phoneme elision condition. The adults who stutter were significantly less accurate in their initial production and also required a significantly higher mean number of attempts when repeating words with a target phoneme eliminated. The apparent increased difficulty for adults who stutter as compared to their typically fluent peers in the repetition of the nonword with a phoneme eliminated suggests that their subvocal rehearsal system is not as efficient at retaining the integrity of the auditory input. Subvocal rehearsal deficits in persons who stutter have been suggested by other researchers. For example, Bosshardt (1990, 1993) found that adults who stutter not only articulated more slowly than fluent peers, but that this slowed rate of articulation was associated with a significantly decreased ability to accurately recall strings of CVC nonwords. He interpreted these findings to be related to subvocal rehearsal deficiencies. That being said, motor implications are also plausible.

Perhaps, the adults who stutter had more difficulty manipulating and then producing (as in the phoneme elision task) the longer nonwords because the related motor programming and movements were more challenging. Support for this possibility is found in a study by Namasivayam and Van Lieshout (2008). Five adults who do and do not stutter repeated one 2-syllable nonword multiple times at fast versus typical speech rates over one of two different time periods (one day versus $\geq$one week). The variability in coordination of movements required to produce the nonword did not decrease in adults who stutter to the same degree as in adults who do not stutter. In addition, unlike in their fluent peers, articulatory variability did not increase in adults who stutter during fast speech, suggesting that their speech motor systems were less adaptive to increasing speech demands. Results further revealed that the adults who stutter did not retain the integrity of the production over time as did the adults who do not stutter across both the fast and typical speech rates. Namasivayam and Van Lieshout stated that their data demonstrate adults who stutter are compromised in their motor learning of novel sound sequences. This assumption seems reasonable upon consideration of the present findings with respect to the comparable nonword repetition performance in nonvocal condition across talker groups. However, this assumption is weakened by the nonvocal performance differences that were found for both the 4-syllable and 7-syllable nonwords in the nonvocal phoneme elision task.

6.2. Nonvocal performance differences

Our previous study did not include nonvocal performance tasks. Therefore, no direct comparisons between our present and past study can be made with respect to the nonvocal performance findings. Recall no differences were noted in nonvocal nonword repetition performance, suggesting that the encoding and retention of nonwords of increased length was as efficient in adults who stutter as adults who do not, at least when no vocal production and/or no manipulation of the nonword required. To the former point, in the nonvocal nonword repetition task, the holding and subsequent matching of nonwords of 4- and 7-syllable lengths did not require motor execution. However, to retain the word, both talker groups still likely employed subvocal rehearsal to recall the word to be identified. To retain the integrity of the verbatim trace, subvocal rehearsal is theorized to be enacted within 2 s of the initial stimulus presentation. For the nonvocal nonword repetition task, the entire length of the task from initial stimulus presentation to the presentation of the subsequent 3 nonwords was approximately 10 s for the 4-syllable nonwords and approximately 12 s for the 7-syllable nonwords suggesting that subvocal rehearsal would have been necessary. From a theoretical perspective, the fact that there were no talker group differences for the nonword repetition nonvocal task condition but there were differences for the phoneme elision nonvocal task condition calls into question our previous statements regarding whether or not the subvocal rehearsal system in fact is deficient or if perhaps subvocal rehearsal deficiencies only emerge when the system is taxed.

For the nonvocal phoneme elision task, the participants had to rely on subvocal rehearsal in order to be able to retain the integrity of the initial stimulus while attempting to eliminate the target phoneme and, successively, match the revised nonword with one of the three following nonwords. Whether or not the subvocal rehearsal system is less efficient in persons who stutter warrants further investigation. Nevertheless, the absence of talker group differences for the nonvocal nonword repetition task but presence of differences for the nonvocal phoneme elision task lends support to the notion that phonological differences in persons who stutter only emerge when the demand on the phonological working memory system increases. This argument has been made by other researchers with respect to nonvocal performance differences in adults who do and do not stutter (Weber-Fox et al., 2004).

Weber-Fox et al. (2004) compared the nonvocal rhyming accuracy abilities of adults who do and do not stutter ($n = 11$ per group). Participants selected a "yes" or "no" button to indicate if the two visually presented words rhymed. The only condition for which there were talker group differences was the condition considered to be the most phonologically challenging. In this particular condition, participants were presented with two words that were orthographically similar but did not rhyme (e.g., "move" and "love"). Weber-Fox et al. (2004) concluded that phonological encoding abilities are relatively comparable between adults who stutter and their typically fluent peers. However, as is supported by present findings, the authors further suggested that the phonological encoding skills of adults who stutter may be particularly vulnerable to decreased efficiency as the required cognitive load increases compared to fluent controls. Perhaps, as suggested by Smith and colleagues (e.g., Smith et al., 2010), there is a critical interplay between phonological encoding and motor programming in adults who stutter. Such interplay would presumably lead to subgroup differences across tasks that tap into these processes. That is, if there is an interplay we would have to assume that it differs for each person who stutters; consequently, some would perform better than others on tasks that require use of phonological encoding and the related motor programming.

6.3. *Additional considerations*

The difference in the number of attempts needed to be able to produce the nonword accurately corroborate previous findings that suggest the repeated exposure to the auditory presentation of the word as well as repeated attempts at production is distinctively more beneficial for adults who do not stutter than adults who stutter (Ludlow et al., 1997; Namasivayam & Van Lieshout, 2008; Smith et al., 2010). Nevertheless, it still remains unclear how this difference(s) in phonological working memory contributes to stuttered speech (see Bajaj, 2007 for discussion). Although nonword repetition clearly places a premium on storage and retrieval abilities, factors associated with auditory-perceptual, phonological, and motor planning processes also influence the quality of phonological representations in short-term memory (Gathercole, 2006). Thus, the precise source of difficulty for adults who stutter in their ability to accurately repeat novel words is still less than clear, and warrants further investigation.

To plan and execute the correct articulatory movements for the target nonword, the person has to be able to accurately encode and then internally refresh the novel phonological string through subvocal rehearsal such that the representation is maintained long enough to allow for accurate programming. However, the factors that influence the integrity of the phonological representation cannot be limited exclusively to the phonological encoding of the auditory input. That is, while it may be true that phonological information that is presented in an auditory manner is subject to a more rapid rate of decay in persons who stutter, it is also possible that a temporal instability in motor programming is occurring to such a degree that the resultant program is faulty and the subsequent recall is inaccurate (Byrd et al., 2012; Namasivayam & Van Lieshout, 2008; Smith et al., 2010). Present findings of comparable nonword repetition in the nonvocal condition but reduced accuracy in the vocal condition lend further support to this assumption. Additional research investigating phonological working memory in nonvocal versus vocal tasks that are identical in nature as in the present study will enable us to better understand the potential interplay between phonological encoding and motor programming (Smith et al., 2010).

Yet another consideration is that the participants may have varied in the strategies that they employed when completing these tasks. For example, Donkin and Nosofsky (2012) provide an interesting overview of scanning procedures that persons may employ when engaged in a short-term recall task. It is difficult to know whether or not these strategies were employed in the present study but the possibilities are worth consideration. Specifically, participants may have employed a more global matching strategy or perhaps they may have employed a sequential strategy and only listened for sound differences among the subsequent words in comparison to the initially presented word. Furthermore, the differences in performance noted between our present and past study may be attributed to differences in short-term memory strategies employed across the participants in these studies. Future research that would allow closer examination of short-term memory scanning patterns is warranted.

Finally, when completing these types of controlled experiments we have to consider how far removed these tasks are from conversational speech – the precise location where stuttering is most likely to occur. What does this difference in storage and manipulation of novel phonological strings of increasing length mean with respect to the breakdowns in speech that are characteristic of stuttering? Although, the phonological loop and more specifically subvocal rehearsal are presumed to support the on-the-fly, automatic speech that is critical to fluent conversational output, future research that investigates the phonological loop and subvocal rehearsal using more real word tasks would enhance the ecological validity of our findings.

7. Conclusion

Previous research suggests that phonological working memory may contribute to the difficulties persons who stutter have establishing and/or maintaining fluent speech (see Bajaj, 2007; cf. Nippold, 2012). To understand this potential contribution, several researchers have explored phonological working memory in adults who stutter using a nonword repetition task (e.g., Byrd et al., 2012; Sasisekaran & Weisberg, 2014). The present study demonstrated that the differences previously reported in nonword performance extend to nonvocal abilities; that is, they are not intricately tied to production-based tasks. However, as with past research nonvocal differences in phonological tasks were only apparent in those tasks that were particularly challenging (i.e. phoneme elision). Thus, results lend further support to the notion that differences in phonological working memory may uniquely compromise the speech fluency of persons who stutter but additional research is warranted to better understand the various systems or subsystems involved.

CONTINUING EDUCATION

Nonword repetition and phoneme elision in adults who do and do not stutter: Vocal versus nonvocal performance differences

QUESTIONS

1. Which of the following is an accurate statement regarding phonological working memory?
   a. There are two components of the phonological loop in working memory: a phonological store and a subvocal rehearsal system.
   b. Phonological working memory capacity decreases with age.
   c. Nonword repetition and phoneme elision tasks are not effective tasks for exploring phonological working memory abilities.
   d. There are no data to suggest that the phonological encoding abilities of adults who stutter are not as efficient as adults who do not stutter.
   e. The visual spatial system is the major aspect of phonological working memory that contributes to recall accuracy of novel words.
2. Which of the following is an accurate description of a phoneme elision task?
   a. A phoneme elision task requires that a person repeat a nonsense word accurately.
   b. A phoneme elision task requires that a person repeat a word with an additional sound or phoneme.
   c. A phoneme elision task requires that a person repeat a word with a sound, or phoneme, missing.
   d. A phoneme elision task requires that a person repeat a word backwards.
   e. A phoneme elision task requires that the person repeat the first sound in a word.
3. Which of the following is an example of a non-word repetition and phoneme elision task, as used in the present study?
   a. Say umpickerrannitizer. Now say umpickerrannitizer with a /d/ at the beginning.
   b. Say kentaid. Now say pentaid.
   c. Say zoobeniferaltopine. Now say zoobeniferaltopine without saying /z/.
   d. Say aftyss. Now say aftyss backwards.
   e. Say kentaid. Now say the first sound in kentaid.
4. Results from the present study revealed which of the following findings related to vocal nonword repetition abilities for adults who stutter versus adults who do not stutter?
   a. Adults who stutter required more repetitions than adults who do not stutter to accurately repeat the nonwords at the 7-syllable length category only.
   b. Adults who stutter were less accurate than adults who do not stutter in their nonverbal identification of 7-syllable length nonwords.
   c. Adults who stutter were less accurate in their nonverbal identification of the 4-syllable length nonwords.
   d. Adults who stutter and adults who do not stutter demonstrated comparable accuracy on both vocal and nonvocal nonword repetition tasks.
   e. Adults who stutter required fewer repetitions than adults who do not stutter to accurately repeat 7-syllable nonwords.
5. Results from the present study revealed which of the following findings related to the phoneme elision abilities for adults who stutter versus adults who do not stutter?
   a. Adults who stutter produced more accurate phoneme elision responses at the 7-syllable length than adults who do not stutter.
   b. Adults who stutter were comparable to adults who do not stutter in their production accuracy in the phoneme elision tasks at all syllable lengths.
   c. Adults who stutter were less accurate than adults who do not stutter in their nonverbal identification of nonwords with target phonemes eliminated.
   d. Adults who stutter produced more inaccurate vocal phoneme elision responses at both the 4-syllable and 7-syllable lengths than adults who do not stutter.
   e. Adults who do not stutter required more production attempts to accurately complete the vocal response portion of the phoneme elision condition at the 4-syllable length.

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