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Research Article

Veridical and False Recall in Adults Who Stutter

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Purpose: This study used a false memory paradigm to explore the veridical and false recall of adults who stutter.
Method: Twelve adults who stutter and 12 age-matched typically fluent peers listened to and then verbally recalled lists of words that consisted of either semantic or phonological associates or an equal number of semantic and phonological associates (i.e., hybrid condition) of a single, unpresented critical "lure" word. Three parameters of recall performance were measured across these 3 conditions: (a) number of accurately recalled words, (b) order of recall (primacy vs. recency effect), and (c) number of critical lures produced (i.e., false memories).
Results: Significant group differences were noted in recall accuracy specific to list type and also list position as well as relative to critical lure productions.
Conclusions: Results suggest that certain basic memory processes (i.e., recency effect) and the processing of gist semantic information are largely intact in adults who stutter, but recall of verbatim phonological information and subvocal rehearsal may be deficient.

Although the etiology of stuttering requires further investigation, there are data to suggest both motor and linguistic contributions to the difficulties persons who stutter have establishing and/or maintaining fluent speech (for a review of language and stuttering, see Ntourou, Conture, & Lipsey, 2011; cf. Nippold, 2012). Specific to the linguistic contributions, phonological-encoding differences have been demonstrated in children and adults who stutter (e.g., Anderson, 2007; Anderson & Byrd, 2008; Bosshardt, 1993; Byrd, Conture, & Ohde, 2007; Byrd, Vallely, Anderson, & Sussman, 2012; Hakim & Ratner, 2004; Ludlow, Siren, & Zikria, 1997; Melnick, Conture, & Ohde, 2003; Sasisekaran & Byrd, 2013; Sasisekaran & de Nil, 2006; Sasisekaran, de Nil, Smyth, & Johnson, 2006; Weber-Fox, Spencer, Spruill, & Smith, 2004; cf. Bakhtiar, Ali, & Sadegh, 2007; Hennessey, Nang, & Beilby, 2008; Nippold, 2002; Vincent, Grela, & Gilbert, 2012). For example, young children who stutter do not appear to make the shift from holistic to incremental phonological encoding within the expected developmental time frame (Byrd et al., 2007). Phonological disorders are the most frequent concomitant disorder with developmental stuttering (Arndt & Healey, 2001; cf. Nippold, 2001, 2012). Researchers have also posited that the phonological representations of children who stutter may be less specified (e.g., Anderson, 2007; Anderson & Byrd, 2008; Anderson & Wagovich, 2010; Anderson, Wagovich, & Hall, 2006; Hakim & Ratner, 2004). In addition, researchers have suggested that the phonological encoding of adults who stutter may be uniquely compromised by increased cognitive demands (e.g., Bajaj, 2007; Bosshardt, 1990, 1993; Jones, Fox, & Jacewicz, 2012; Weber-Fox et al., 2004). These differences are not limited to overt speech tasks as less rapid and less accurate phonological encoding have also been demonstrated in adults who stutter using nonvocal speech tasks (e.g., Brocklehurst & Corley, 2011; Byrd, McGill, & Usler, in press; Postma, Kolk, & Povel, 1990; Sasisekaran, 2013). More recently, researchers have found that the more complex the phonological representation, the more difficult it is for the persons who stutter to retain the nonword (Sasisekaran & Weisberg, 2014). Taken together, these findings suggest additional exploration is warranted regarding the potential contributions of phonological working memory to difficulties persons who stutter have establishing and/or maintaining fluent speech (see Bajaj, 2007, for review of phonological working memory and stuttering). The purpose of the present study was to investigate phonological working memory by measuring the veridical and false recall of adults who do stutter as compared to adults who do not stutter.

According to Baddeley (2003), working memory is made up of the central executive and three supporting systems: (a) phonological loop, (b) visuospatial sketchpad, and (c) the episodic buffer. The visuospatial sketchpad refers

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to the manipulation of visual information. The episodic buffer binds information from various distinct sources into chunks or episodes. The central executive is thought to support the retrieval and transfer of information from long term to short term and vice versa. The function of the central executive and that of the phonological loop are critical to the present study. However, given the nature of the task (auditory only), the visuospatial sketchpad with its distinct application to the manipulation of visual information is not relevant and as such will not be discussed further. The phonological loop consists 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., the 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 are slowed in their initial encoding of phonological information, then the subsequent process of refreshing information would presumably also be slowed 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 a review of this perspective), then the subvocal rehearsal of words may be uniquely compromised in persons who stutter. Yet another consideration based on previous reports is that phonological differences may be the result of central executive deficiencies. That is, people who stutter may be less efficient in their ability to access phonological representations via long-term to short-term memory, a deficiency that may uniquely compromise their ability to rapidly and fluently support on the fly conversational speech.

There are limited data available within the literature on stuttering with respect to phonological working memory. Of the studies that exist, those that have employed nonword repetition in adults will be reviewed as this task is thought to allow insight into phonological working memory in isolation with minimal influence from long-term storage of phonological and semantic information. Nonword repetition has been shown to differentiate adults who do not stutter from adults who do in a few key ways. Ludlow, Siren, and Zikria (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. 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 one to four 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 one- to four-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 had to repeat 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 (one to four 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 stuttered exhibited more inconsistency in articulatory coordination during the production of longer (i.e., three- and four-syllable length), more phonologically complex nonwords compared to adults who did not stutter, which suggests, according to the authors, that the difficulties persons who stutter have establishing/maintaining fluent speech may be attributed to a critical interplay between phonological encoding and motoric stability.

Byrd et al. (2012) employed a nonword repetition task as well as a phoneme elision task. Fourteen adults who stutter and 14 typically fluent adults listened to 48 nonwords, were provided multiple attempts at production to facilitate accuracy, and then required to repeat them with a sound missing. No difference was found for the phoneme elision task. 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 two- to four-syllable words, but the adults who stutter required a higher mean number of attempts before accurate repetition of seven-syllable words. They attributed the significant finding 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. With respect to the lack of group differences for the phoneme elision task, Byrd and colleagues argued that the task itself may have been too demanding to allow for any detection of differences. They further noted that given the preliminary nature of their data along with the complexity of the task, the null findings for the phoneme elision task coupled with the group differences for the nonword repetition task make it difficult to determine whether phonological working memory contributes to stuttered speech or if perhaps phonological encoding is the distinct contributor.

Sasisekaran and Weisberg (2014) investigated the nonword repetition accuracy of nonwords that varied specifically by 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 consisted 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 were able to produce the required four to five correct productions needed to be able to complete the kinematic analyses. In addition, the adults who stutter exhibited significant practice effects as measured by reduced movement variability for the three-syllable nonwords but did not demonstrate significant practice effects for the longer four-syllable nonwords; rather, the variability persisted. By comparison, their typically fluent peers easily produced/retained the three-syllable nonwords and also demonstrated reduced movement variability for the three-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 nonword tasks is necessary to understand how these deficits manifest.

The Deese–Roediger–McDermott (DRM) paradigm that we employed in the present study has been used extensively in the memory and language literature to explore the efficiency of phonological working memory, but to date, to our knowledge this paradigm has not been used with persons who stutter. The DRM paradigm was originally developed in a study by Deese (1959) and expanded in a study by Roediger and McDermott (1995). The technique involves using lists made up of words associated with one word that is not on the list (i.e., the "critical lure"). For example, for the critical lure *wet*, the list of semantically related words includes *slippery*, *damp*, *splash*, and *humid.* For the same word, the list of phonologically related words includes *vet*, *watt*, *west*, and *wit.* The corresponding hybrid list would contain half phonologically related words and half semantically related words (Watson, Balota, & Sergent-Marshall, 2001). The DRM technique allows for the exploration of phonological working memory of typical as well as disordered populations.

The fuzzy trace theory (FTT) provides a framework for understanding how the recall of lists of words that are either associated phonologically, semantically, or both might differ. The FTT argues that when presented with a series of items and asked to recall all that were presented, two separate representations are formed: (a) a gist trace and (b) a verbatim trace (Brainerd & Reyna, 2002). In a word list recall task such as what we used in the present study, a gist trace would be defined as the semantic relationship among the words presented. By comparison, the verbatim trace would be the phonological content—the exact phonemic representations of each word on the list. Accordingly, the FTT would suggest that a recall task wherein the lists consists of words that are semantically related would presumably be more likely to result in a higher number of accurately recalled words as the general content of the words or, rather, the gist traces that are in the long-term memory would be activated. In contrast, the number of words recalled on lists that are phonologically related would be significantly less as the person would have to rely more substantially on the verbatim traces of the words or, rather, the short-term memory and, as such, the number of words recalled would be more subject to rapid decay. In addition, the words on the semantic lists are phonologically distinct whereas the words on the phonological lists are phonologically similar. Thus, the phonological list is uniquely challenging to the subvocal rehearsal system as the person is forced to recall words that only differ by individual sound segments (Baddeley, 2003). That is, when faced with a task that requires recall of words that are maximally similar phonologically but are not related semantically, the person will presumably rely more on short-term recall. By comparison, when required to recall a list of words that are semantically related but maximally dissimilar phonologically, the person will presumably be able to use the meaning relationship among the words to access the representations in their long-term store. Or, one could argue that it is not necessarily the meaning connection among the words that results in the difference in recall accuracy, but it is simply the lack of phonological similarity that then leads to the person to rely less on short term and more on long term for their recall of words (Baddeley, 1966). From either perspective, when the words are maximally phonologically similar as compared to dissimilar differences in recall, accuracy is expected.

Another critical consideration when employing a list recall task is that veridical recall also varies as a function of the word's position in a list (Tan & Ward, 2000; Watson et al., 2001). Recall tends to be strongest for those words at the end of the list (the recency effect). In addition, words at the beginning of the list are recalled with higher accuracy (the primacy effect) than words in the middle of the list. Words at the end of the list are the easiest to recall because they are still accessible in short-term memory at the time of recall. Words at the beginning of the list are more easily recalled than words in the middle because of the increased opportunities for rehearsal of these words, rehearsal that could facilitate the transfer of these words to long-term memory. Words in the middle of the list are the most difficult to recall because the likely accessibility in the short-term memory and/or the potential transfer to the long-term memory is significantly reduced.

In addition to veridical recall, the DRM paradigm also allows the examination of false recall as measured by the production of the critical lure, a word that is highly associated with the words on the list either semantically, phonologically, or both, but was not presented to the participant. The production of critical lures appears to be uniquely facilitated by lists that consist of words that are both semantically and phonologically related to the critical lure (i.e., a hybrid list). When completing a list recall task, both the presented words and the nonpresented critical lures are presumed to be activated. Thus, in the case of the hybrid list, there is a converging activation of both phonological and semantic nodes, making it much more challenging to source monitor or rather consciously decipher between

words that were presented versus related words that were not presented. Watson and colleagues (2001) separated participants (N = 182) into three typically fluent adult age groups and two additional groups who presented with Alzheimer's; Watson, Balota, and Roediger (2003) compared false recall of the critical lure using semantic lists, phonological lists, and hybrid lists (N = 66 and 52 for Experiments 1 and 2, respectively; all typically fluent, healthy adults). As predicted, the hybrid list had a superadditive effect: There was a significantly higher production of the critical lure for recall of hybrid lists than there was for recall of semantic or phonological lists. The authors attributed this effect to the act of spreading activation to both the semantic *and* the phonological nodes in this hybrid condition, resulting in an increased likelihood of falsely recalling a word that was in fact not presented but is related to the words on the list. In other words, for the hybrid list, there is a spreading activation of both the meaning and the sounds that are related to the critical lure, making it more likely to result in a false memory that the word was presented within the list of words to recall.

In summary, to revisit Baddeley's (2003) model, veridical recall would be supported by the integrity of the person's phonological storage and retrieval abilities. By comparison, the production of words that are not on the list but are related to the words presented (i.e., false recall/production of critical lure) would reflect both storage and retrieval efficiency as well as central executive functioning as the person has to rely on source monitoring to make the distinction between what they actually heard versus what they thought they might have heard (Johnson, Hashtroudi, & Lindsay, 1993). With respect to the present study, when completing a list recall task, both the presented words and the nonpresented critical lures are presumed to be activated. The listener has to discern the sources of activation for these words. Thus, the production of the critical lure is influenced by both spreading activation and source-monitoring difficulties (Roediger & McDermott, 1995). If the connection among the phonological and semantic nodes is weaker than expected, the predicted converging activation during a list recall task consisting of both phonologically and semantically related words would presumably not occur. Thus, source monitoring difficulties would in turn not arise to such a degree that the person would have significant difficulty discerning what they think they heard from what was actually presented. In this case, one would expect to see relatively intact veridical recall but lower false recall (Weekes, Hamilton, Oakhill, & Holliday, 2008). On the other hand, if a person has unique deficits in the functioning of the central executive particularly with regard to source monitoring, then one would expect relatively preserved veridical recall but atypically high false recall.

The purpose of the present study is to further investigate the integrity of phonological working memory in adults who stutter through the use of the DRM task. We asked the following three questions: (a) Is the veridical recall of adults who stutter lower than adults who do not stutter? (b) Does the position of the word on the list affect veridical recall for adults who stutter in the same manner as adults who do not stutter? (c) Does false recall differ between adults who do and do not stutter? If phonological working memory is compromised in adults who stutter, then we predict lower recall accuracy as compared to adults who do not stutter regardless of the list type. In addition, given that recall of the verbatim trace has been proven to be more difficult than gist recall, we further predict that both talker groups will accurately recall more words in the semantic than the phonological condition, but that the adults who stutter will have significantly lower veridical recall than adults who do not stutter for phonological lists, in particular, as recall on the phonological list requires the listener to depend solely on the integrity of the verbatim trace. For the list position effect, we predict that both talker groups will demonstrate the recency effect, but that subvocal rehearsal deficits will result in the adults who stutter recalling less words from the beginning and middle parts of the lists than their typically fluent peers across all list types. Finally, specific to critical lure production, we predict that both groups will demonstrate the superadditive effect such that both will produce more critical lures when recalling hybrid lists. In addition, we also predict based on the lack of evidence indicating impaired central executive function and/or reduced spreading activation in the mental lexicon of adults who stutter that there will be no difference in the production of critical lures between the two groups across the list types.

Method

Participants

To qualify for inclusion, participants had to meet the following criteria: (a) native English speaker; (b) between the ages of 18 and 30 years; (c) no past or present speech or language disorders (with the exception of stuttering for the adults who stutter); (d) pass hearing screening per American Speech-Language-Hearing Association guidelines; and (e) no neurological, social, emotional, or psychiatric disturbances. Each participant completed an extensive case history through which they were asked whether or not they had received prior diagnoses and/or treatment for any other speech and/or language disorder in addition to stuttering with explicit questions related to potential history of articulation and/or phonological deficits. Participants were also asked whether they had any prior or present global or specific memory difficulties, including recall of individual words during conversation, and they were asked to report any past neurological, social, emotional, or psychiatric disturbances. In addition, participants were asked to report any medications that they were presently taking. No participant in either group reported past and/or present language, neurological, emotional, or psychiatric diagnoses or treatment. No participant reported past history of diagnosis and/or therapy or any indication of difficulty with articulation, phonology, and/or intelligibility. No participant reported use of medication that would influence performance in the present study. In addition, no

participant in either group reported past or present memory-related deficits. The only report of past diagnosis and/or treatment was that of speech therapy for stuttering among some of the participants who stutter.

In addition to the above stated criteria, participants also had to perform within normal limits on the Peabody Picture Vocabulary Test—Fourth Edition (PPVT–IV; Dunn & Dunn, 2007) and the Expressive Vocabulary Test—Second Edition (EVT–2; Williams, 2007). We administered these two tests to ensure two key issues: (a) that there were no participants in either talker group who had receptive or expressive vocabulary skills that were below normal limits and (b) that we had a similar distribution of linguistic performance between the two talker groups for which we were comparing (see Table 1). Results from independent samples *t* tests demonstrated that the two talker groups did not differ significantly in their performance on the PPVT–IV, $t(22) = -1.423$, $p = .169$, and the EVT–2, $t(22) = 0.306$, $p = .762$. Two adults who stutter who were recruited for participation were excluded because of failure to meet one or more of the aforementioned inclusion criteria. Twenty-four adults who do ($n = 12$; $M = 23$ years; $SD = 2.9$; range = 19–27 years; $n = 3$ women; $n = 9$ men) and do not stutter ($n = 12$; $M = 23$ years; $SD = 2.3$; range = 20–28 years; $n = 3$ women; $n = 9$ men) who were age matched (± 2 years) met these criteria and, thus, participated in the present study.

Speech production and stuttering severity were analyzed from two videos recording 15-min conversational speech samples that occurred just prior to beginning the speech-language testing and experimental tasks. Intelligibility and production of articulation errors and/or phonological errors were informally assessed. No participant in either talker group produced an articulatory or a phonological error.

Severity ratings were exclusively assigned to each of the participants who stutter by the first author using the Stuttering Severity Instrument for Children and Adults–Third Edition (SSI-3; Riley, 1994). Two of the 12 participants received a mild rating, two received a rating of mild–moderate, six received a moderate rating, and two received a severe rating. Interjudge reliability for the severity ratings was assessed by having a graduate student independently complete SSI-3 analyses on four of the 12 samples (33%) that had been previously analyzed and assigned SSI-3 ratings by the first author. Overall, three of the four ratings were identical to the original ratings provided by the first author. For one of the four ratings, there was a difference. The first author reported a mild–moderate score, and the graduate student reported a score of mild. To be clear, the scores between the first and second rater were nearly identical as the mild score was on the highest range, and the mild–moderate score was the lowest possible score within that category.

All 12 of the participants who stutter had reportedly received speech therapy for stuttering. However, to repeat, none of the participants in either talker group reported present or past therapy for articulation, phonology, and/or language. That is, therapy history was exclusive to stuttering for the group of participants who stutter. We chose not to

Table 1. Participant demographic information.

Participant	Age	Talker group	Gender	Severity	PPVT–IV	EVT–2
1	22	AWNS	Male		105	99
2	20	AWNS	Male		112	116
3	21	AWNS	Male		107	101
4	22	AWNS	Male		99	104
5	22	AWNS	Male		112	123
6	21	AWNS	Male		106	110
7	22	AWNS	Male		97	100
8	26	AWNS	Male		109	96
9	28	AWNS	Male		104	112
10	20	AWNS	Female		110	102
11	28	AWNS	Female		121	118
12	25	AWNS	Female		116	121
13	25	AWS	Male	Moderate	115	99
14	22	AWS	Male	Mild	124	118
15	21	AWS	Male	Severe	110	101
16	20	AWS	Male	Severe	115	112
17	23	AWS	Male	Mild	104	99
18	19	AWS	Male	Moderate	117	112
19	27	AWS	Male	Moderate	99	104
20	21	AWS	Male	Mild-mod	121	115
21	22	AWS	Male	Mild-mod	99	97
22	25	AWS	Female	Moderate	110	104
23	24	AWS	Female	Moderate	113	108
24	23	AWS	Female	Moderate	126	120

Note. Peabody Picture Vocabulary Test—Fourth Edition (PPVT–IV): standard score ($M = 100$, $SD = 15$). Expressive Vocabulary Test—Second Edition (EVT–2): standard score ($M = 100$, $SD = 15$). Mean age for both groups = 23 years. AWNS = adults who do not stutter; AWS = adults who stutter; Mild-mod = mild–moderate.

exclude adults on the basis of treatment history for stuttering for two key reasons. First, there was no reason to suspect that exposure to fluency therapy would differentially affect individual performance on the task employed in the study. Second, it is not uncommon for adults who stutter to report participation in fluency therapy, particularly during the school years; thus, inclusion of adults who had participated in therapy adds to the ecological validity of this study.

Approval for the completion of this study was provided by the first and second authors' university institutional review board, and informed consent was obtained for each participant. All participants were provided monetary compensation for their participation. Participant characteristics and performance on standardized test measures are summarized in Table 1.

Materials

Target word lists. Word lists were selected from Watson et al. (2001). Forty-eight lists were used, each with 12 words. Lists were centered on 12 different critical lure words. For each word, four lists of 12 words each were developed: 12 phonological associates for the phonological condition, 12 semantic associates for the semantic condition, and six semantic and six phonological associates for the hybrid lists. Two hybrid lists for each lure word were used. There was one hybrid list in which the first word was a phonological associate and the second word was a semantic associate and so on in alternating order. In the second hybrid list, the first word was a semantic associate and the second was a phonological associate, and this pattern was repeated within that list. The two types of hybrid lists were alternated between participants such that each participant heard only one type of hybrid list. In total, there were three different sets of lists of semantic associates, three different sets of lists of phonological associates, three different sets of lists of hybrid associates beginning with a semantic associate, and three different sets of lists of hybrid associates beginning with a phonological associate. Each set contained four lists of 12 words (see the Appendix for the stimuli list).

Stimuli recording. A female, native English speaker with a standard American accent recorded the stimuli using a digital Zoom H4 recorder in a soundproof booth. The recording was segmented into individual sound files, each containing one word list. Intelligibility of the spoken words was verified by asking three research assistants blind to the purpose of the study to listen to and write down all the words from the 48 lists. All three research assistants correctly identified all 576 list words (see Appendix).

Procedure

Participants were tested individually in a quiet room. Each list was presented in auditory form using Windows Media Player through the built-in stereo speakers of a 24-in. Apple iMac with model number A1225. During administration of the task, the participant was seated in a chair facing the speakers, which were approximately 4 ft away. The examiner sat directly in front of the computer screen and faced it.

Prior to the presentation of the experimental lists, participants were presented with one trial list of 12 unrelated words to ensure they understood the nature and requirements of the experimental task. Participants were told that after each individual list was presented, they would be asked to verbally repeat all of the presented words they could remember in any order. For the experimental task, participants were presented with 12 lists of words that consisted of 12 words each, four lists in each condition (semantic, phonological, hybrid). The order of the sets of lists was counterbalanced across the participants. The examiner marked the presented words on the score sheet in the order they were recalled, as well as the lure word, and also wrote in any other false memories produced as the participant said them aloud. After the participant stated that he or she could not recall any more items for that particular list, the next list was presented. Time to complete the experimental task was approximately 20 to 30 min maximum.

The task was audio-recorded on a Sony ICD-MX20 digital voice recorder for subsequent intra- as well as interrater review of coding. After the in-session recordings of the results, the examiner listened to the audio recordings for each participant to verify that there were no discrepancies in what the participant recalled and what was documented. This intrarater review was followed by two additional graduate students blind to the purpose of the study who listened to the recordings of all the participants and verified the recorded productions with the documented productions completed by the examiner. No discrepancies in the audio and the associated written recordings of the words that were recalled were noted by either of the two interrater reviewers.

Results

To address our specific research questions, two main analyses were performed. The first analysis explored recall accuracy across the phonological, semantic, and hybrid conditions with respect to the three different list positions. The second analysis explored the production of the critical lure across the three conditions.

Veridical Recall

To determine whether recall accuracy differed depending on the position of the word in the list, a repeated measures analysis of variance (ANOVA) using a Huynh–Feldt correction was completed with the between-subjects factor of Fluency Group (adults who stutter vs. adults who do not stutter) and the within-subjects factors of List Type (semantic, phonological, and hybrid) and List Position (i.e., first four, middle four, last four words; Huynh & Feldt, 1976). The dependent variable was the number of words accurately recalled. Each participant had to recall four lists of 12 words for each list type resulting in 48 words presented

in the first four positions, 48 in the middle four positions, and 48 in the last four positions.

Results revealed a significant main effect for List Type, $F(2, 44) = 43.297$, $p < .0001$, $\eta_p^2 = .663$, with higher veridical recall for words on the semantic list than on the phonological or hybrid lists. There was also a significant main effect for List Position, $F(1.679, 36.942) = 794.597$, $p < .0001$, $\eta_p^2 = .973$, with more words at the end being accurately recalled as compared to the beginning or the middle of the lists and more words accurately recalled from the beginning than the middle. There was no significant between-subjects effect for Fluency Group, $F(1, 22) = 3.855$, $p = .062$, $\eta_p^2 = .149$, but there was a significant three-way interaction between List Type by List Position by Fluency Group, $F(3.130, 68.859) = 6.716$, $p < .0001$, $\eta_p^2 = .234$ (see Figures 1–3).

Given that the purpose of the present study was to explore talker group differences in recall specific to list type and position, follow-up analyses were completed with respect to between-group differences specific to the list type and list position. A series of one-way ANOVAs with a Bonferroni adjustment revealed significant between-group differences for the words recalled at the beginning of the list for the phonological list, $F(1, 23) = 63.073$, $p < .0001$, and the hybrid list, $F(1, 23) = 17.078$, $p < .0001$, with the adults who stutter recalling significantly fewer words than the adults who do not stutter. No other between-group differences were noted across the list position and type.

Production of Critical Lure

To investigate the production of the critical lure between groups and also across conditions, a repeated measures ANOVA was conducted with the between-subjects factor of Fluency Group and a within-subject factor of List Type. The dependent variable was the mean number of critical lures produced. There was a significant main effect for the within-subject factor of List Type, $F(2, 44) = 22.200$, $p < .0001$, $\eta_p^2 = .502$, with more critical lures produced in the hybrid condition ($M = 2.38$, $SD = 1.1$) than the semantic ($M = 0.58$, $SD = 0.72$) or the phonological condition ($M = 1.17$, $SD = 0.92$) and no difference in production between the semantic versus the phonological condition. There was also a significant between-subjects effect for

Figure 1. Mean and standard error for number of words accurately recalled from the first, middle, and last part of the lists in the semantic condition for adults who stutter (AWS) versus adults who do not stutter (AWNS).

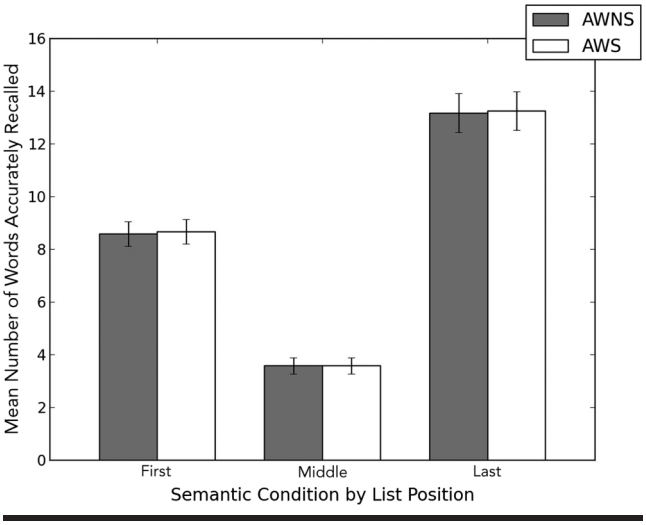


Figure 2. Mean and standard error for number of words accurately recalled from the first, middle, and last part of the lists in the phonological condition for adults who stutter (AWS) versus adults who do not stutter (AWNS). *$p \leq .0001$.

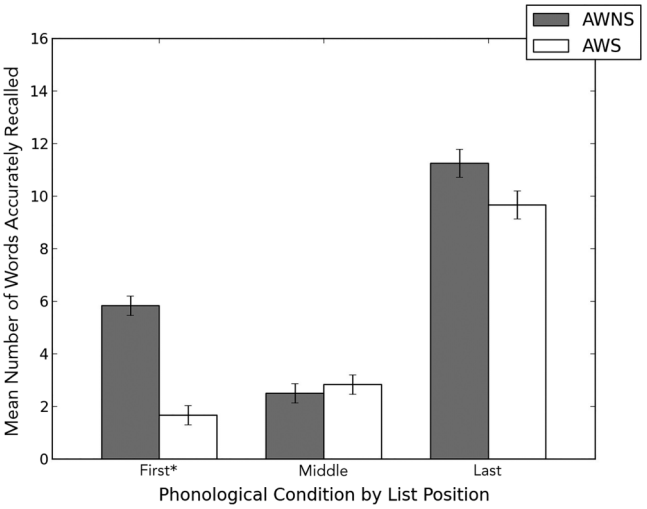
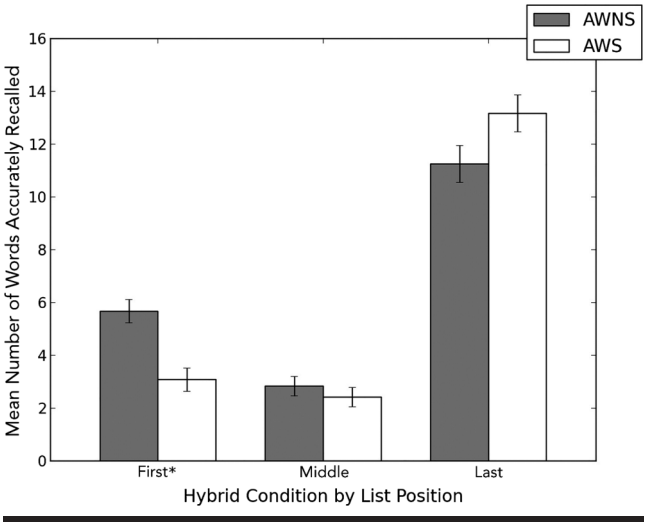


Figure 3. Mean and standard error for number of words accurately recalled from the first, middle, and last part of the lists in the hybrid condition for adults who stutter (AWS) versus adults who do not stutter (AWNS). *$p \leq .0001$.



Fluency Group, $F(1, 22) = 8.360$, $p = .008$, $\eta_p^2 = .275$, with the adults who stutter ($M = 1.11$, $SD = 0.93$) producing an overall lower level of critical lures across all three list types than the adults who do not stutter ($M = 1.64$, $SD = 0.92$). There was not a significant interaction between List Type and Fluency Group, $F(2, 44) = 0.477$, $p = .624$, $\eta_p^2 = .021$.

Discussion

In the present study, we set out to further enhance our understanding of phonological working memory of adults who stutter. We employed the DRM paradigm, a task that was developed to allow exploration of memory differences using semantic, phonological, or both semantic and phonological routes. We specifically selected this paradigm as we wanted to determine whether adults who stutter differed from adults who do not stutter in their recall accuracy, in the list position effect on their recall accuracy, and in their production of false memories (i.e., critical lures) across lists of words that rely on gist and verbatim traces to a different extent.

Veridical Recall

To review, we hypothesized that if phonological working memory of adults who stutter is uniquely compromised, then their recall accuracy should be significantly lower than their fluent peers across all lists, but that the difference between the two groups would be greatest for the words on the phonological lists. We further hypothesized that veridical recall would be highest for the semantic lists for both groups as compared to the other two list types. Contrary to our predictions, there was no difference in overall recall accuracy between the two talker groups, but, as predicted, veridical recall was highest for the semantic list across all participants. In addition, and in accord with our predictions, the adults who stutter recalled significantly fewer words than the adults who do not stutter for those words presented at the beginning of the phonological lists. Finally, the adults who stutter also recalled fewer words from the beginning of the list in the hybrid condition, a finding that was not predicted but is not surprising upon further consideration of the nature of the task employed.

Baddeley (2003) suggests that verbatim phonological traces are subject to rapid decay in the absence of rehearsal and that phonological similarities among words cause interferences in rehearsal. In fact, Baddeley (1966) previously demonstrated that immediate recall of maximally phonologically similar word lists is significantly more difficult than is the recall of word lists that are maximally phonologically dissimilar. Thus, the higher veridical recall of semantic list words in the present study was expected because (a) the gist traces are reinforced by the common thematic relationships among the words and (b) the verbatim traces are maximally distinct and minimally mutually interfering due to the lack of phonological overlap among the words. In contrast, the lists consisting of words that are phonologically related were expected to be more challenging as it is presumably more difficult to distinguish target words from each other since their verbatim traces are highly similar.

The significantly lower veridical recall of the words at the beginning of the hybrid lists was not predicted but is plausible, as arguably the hybrid lists are more similar to the phonological lists than are the semantic lists. That is, the potential for interference among similar sound sequences is not as high as is the case in the phonological lists, but it is certainly higher than in the semantic list. These findings suggest that for the words on the semantically related lists, the adults who do and do not stutter were both able to efficiently determine the gist trace that connected the words across the list and were able to use that gist trace within their long-term store to facilitate short-term recall of those words. In contrast, words on the phonological lists were not bound by thematic cohesiveness, and the sounds that comprised the words were maximally similar, leaving the participants to rely on the verbatim traces for short-term recall. Although there were talker group differences for words at the beginning of the hybrid lists, recall accuracy for words on the phonological lists appeared to be more challenging for the adults who stutter. That is, the adults who stutter recalled even fewer words from the beginning of phonological lists than their typically fluent peers. Thus, taken together, these findings suggest that recall of the verbatim trace particularly when there are multiple competing phonemic targets that exist across all the words within the list (as opposed to only half of the words as was the case for the hybrid list and none of the words as in the semantic list) may be uniquely challenging for adults who stutter. In other words, when the entire list consists of words that are maximally phonologically similar, adults who stutter appear to have the most reduced recall as compared to their typically fluent peers, lending further support to the notion that differences in phonological working memory are most notable in those tasks where there is an increased cognitive load. This argument has been made by other researchers with respect to nonvocal performance differences in adults who do and do not stutter.

Specifically, Weber-Fox et al. (2004) compared the nonverbal 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 the present findings, the authors further suggested that the phonological-encoding skills of adults who stutter may be uniquely vulnerable to decreased efficiency as the required cognitive load increases. For the present study, recall accuracy was increasingly lower when the words were maximally phonologically similar as

compared to the semantic condition where the words were maximally phonologically dissimilar.

Moreover, the comparable performance of the adults who stutter with respect to their recall of semantic lists suggests that their ability to rely on their long-term store to facilitate short-term recall is similar to that of their typically fluent peers. However, when persons who stutter have to recall the verbatim trace of multiple words that are maximally phonologically similar, their recall accuracy is significantly lower than adults who do not stutter. In the case of the phonological lists and to a lesser degree the hybrid lists, recall of words requires that the person rely on their phonological loop to store and refresh the verbatim trace. In other words, recall of words from the beginning of lists that are nearly identical in the phonemic structure but are not related semantically requires that the person rely on subvocal rehearsal to maintain the integrity of the verbatim trace. Perhaps, the subvocal rehearsal of these words was difficult not only because they were phonologically similar but also because they were motorically similar. It seems plausible that the more motorically similar the words are the more the person has to finely distinguish and recall the distinct movements required for each individual production. This maximum similarity both phonologically and motorically may have rendered the phonological list and, to a lesser degree, the hybrid list significantly more challenging for the adults who stutter to recall.

On the other hand, the differences seen may not be attributed exclusively to subvocal rehearsal as there may have been an interaction between the actual production of the words that were recalled and the person's attempt to refresh the remaining words that were to be recalled. That is, for the person who stutters in particular, producing words from lists that are maximally phonologically similar may have been more motorically challenging. For example, they would have had to finely discriminate and program the motor movements required for words on the list, and then they would have to execute those movements while at the same time refreshing the remaining words to be produced. We did not time the participant's production of the words on the lists, and we also did not analyze the phonetic complexity of the words to be produced. It may be the case that the persons who stutter took longer to initiate and also produce the words from the phonological lists, a difference in timing of producing these words that would make the remaining words to be produced more vulnerable to decay. It is also possible that there were particular words that were more motorically challenging to produce. Future explorations should consider these factors in the development and related analyses of lists to be recalled.

List Position

To review, recall accuracy is mediated by the position of the word within the lists. Researchers have reported that words presented at the end of the list are recalled with the greatest accuracy (the recency effect; e.g., Tan & Ward, 2000; Watson et al., 2001). In addition, words in the initial position are recalled with higher accuracy (the primacy effect) than those in the middle of the list. Words presented at the end of lists are thought to be easily recalled because these words are still accessible in short-term memory at the time of recall. The list-initial recall advantage is attributed to the increased opportunities to apply rehearsal strategies, which may result in the transfer of these words to long-term memory. Words in the middle of the list are considered to be more difficult to recall because neither the accessibility nor the rehearsal benefit is available.

For the list position effect, we predicted that the adults who stutter would be comparable in their ability to recall words at the end of the list as compared to their typically fluent peers but that they would recall significantly less from the beginning and middle of the list regardless of list type. Results partially supported our prediction with respect to the hybrid and the phonological list but the recall of words at the beginning of the list was comparable between talker groups for the words at the beginning of the semantic list. Our prediction that words located in the middle of lists would be recalled with greater accuracy by adults who do not stutter was not supported across any of the lists. We had made this prediction based on the assumption that phonological working memory of persons who stutter would be less efficient than persons who do not stutter regardless of the nature of the recall task. However, both talker groups recalled the least number of words from the middle list position, suggesting that words from that part of the list are the most vulnerable to decay. This finding coupled with the lack of talker group differences in recall for the semantic lists across all positions indicates that the recall differences noted between talker groups was uniquely mitigated by the types of lists the persons were attempting to recall. Perhaps, for the phonological and the hybrid lists, the subvocal rehearsal strategies were not employed as effectively by the adults who stutter, leaving them less able to recall words at the beginning of the list, particularly when those words are maximally phonologically and/or motorically similar.

To recall words at the beginning of the list, a person would presumably have to subvocally rehearse those words to keep them refreshed within the phonological store. In addition, recalling words from the beginning of lists of maximally phonemically similar words theoretically forces the listener to rely more heavily upon subvocal rehearsal when attempting to recall these types of lists. Such reliance on subvocal rehearsal is not thought to be critical to the recall of words that are semantically related as it is theorized that the listener is able to use the meaning connection or rather thematic gist among the words and can rely more heavily on their long-term store to assist in their ability to remember those words. The fact that the adults who stutter recalled significantly fewer words than their typically fluent peers from the beginning of lists that were phonologically related but no such talker group differences were found for the semantically related lists suggests that the subvocal rehearsal abilities of persons who stutter may be uniquely compromised.

Subvocal rehearsal deficits in adults who stutter is supported by past research (e.g., Bosshardt, 1990, 1993;

Byrd et al., 2012; Sasisekaran & De Nil, 2006; Sasisekaran et al., 2006). 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 consonant–vowel–consonant nonwords. That being said, the potential motor implications cannot be ignored. Perhaps, the adults who stutter had more difficulty recalling the words that were phonologically related because the motor movements across the words that they had to recall needed to be more precise within that list. In other words, the increased distinction among the words in the semantic list may have made motor programming and subsequent production less challenging than the more fine-grained programming required for distinction among the maximally similar words in the phonological list. 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 (1 day vs. ≥ 1 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, coherence of the movements between the required articulators did not increase in adults who stutter in the manner in which it did for adults who do not stutter. 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 (2008) stated that their data demonstrate adults who stutter are compromised in their motor learning of novel sound sequences. Findings from the present study could suggest that when presented with a series of words that differ by only minimal motor movements, persons who stutter may have to process each one as a novel sequence, which would make the accurate recall of each word significantly more challenging. To further explore this possibility, list recall tasks employing nonwords with maximally similar versus maximally dissimilar motor movements is warranted.

Production of Critical Lure

To review, the production of a critical lure occurs because of the activation of the word based on its close relationship to the words in the list. The participant thinks that he or she heard that word (i.e., has a false memory of the word being presented) because of an inability to distinguish between the item-specific information he or she encoded initially and the highly activated word (Watson et al., 2001, 2003). We hypothesized that both the adults who do and do not stutter would produce the superadditive effect. That is, we thought both groups would demonstrate a spreading activation among words that were actually presented on the hybrid list and words that are semantically and phonologically related to those words. The present results support our prediction, at least in part. The adults who stutter (as well as the adults who do not stutter) produced significantly more critical lures when recalling words from the hybrid lists than when recalling words from either the semantic or the phonological lists. However, despite presenting this superadditive effect, the adults who stutter still produced significantly fewer critical lures across the conditions than the adults who do not stutter, which was in contrast to what we had predicted, as again, we did not predict group differences.

The demonstration of the superadditive effect in both the adults who do and do not stutter appears to suggest that spreading activation among the phonological and semantic representations did occur to such a degree that both talker groups had difficulty discerning what they actually heard from what they thought they heard. That is, the converging activation of semantic and phonological modes made it more challenging for all participants to source monitor veridical from false recall. However, the adults who stutter produced significantly less critical lures than the adults who do not stutter. There are at least a few plausible explanations for this difference in critical lure production.

First, the semantic and phonological connection among words in the mental lexicon may not be as strong for adults who stutter. As a result, the spreading activation among the phonological and semantic nodes may not be as efficient. This interpretation lends support to the notion that persons who stutter require more than the expected time prior to execution in order to allow for appropriate selection of the target phoneme among competing associated phonemes (i.e., see Brocklehurst & Corley, 2011, for review of evidence for and against the Covert Repair Hypothesis). More direct support of less efficient lexical organization has been demonstrated in other studies requiring verbal production (e.g., Newman & Ratner, 2007); however, like the present one, additional research is needed to determine the contributor(s) to the differences observed.

Yet another consideration is that the connection among semantic and phonological nodes is comparable across talker groups and spreading activation is equally efficient but the two groups differ with respect to source monitoring. Recall that to avoid producing the critical lure, the person has to be able to decipher what they actually heard from what was activated in their mental lexicon. Perhaps, persons who stutter are simply better at source monitoring than persons who do not stutter. If that is the case, this would lend further support to the perspective that any differences in recall can be attributed to the phonological loop rather than the central executive. That is, persons who stutter can exclude what they heard from what was activated, but retaining and then rehearsing those words they heard in the short-term memory may be uniquely compromised.

An alternative perspective is that persons who stutter may have had the same source-monitoring difficulties during this task as persons who do not stutter but produced less false recalls because they as a group were more reticent to produce words that they were not as sure about whether or not they were actually produced. We did not ask participants to provide any confidence rating with respect to whether or not they were positive the words they recalled

were actually words that were presented. Given this difference in the production of the critical lure, future investigations of false versus veridical recall should consider including this type of recall confidence rating.

The decreased production of the critical lure may also be explained from a motor perspective, but the question remains as to whether or not this perspective can be explained by conscious or subconscious processing or, perhaps, both. For example, if the programming of the speech motor control movements is less efficient for persons who stutter, their resources during this recall task may have been subconsciously allocated to subvocal rehearsal. As such, persons who stutter may have spent more time programming and, subsequently, rehearsing the production of each individual word. This does not suggest that spreading activation did not occur, but from a top-down perspective, once that activation occurred and they began to prepare to produce what they recalled, the time spent during subvocal rehearsal may have contributed to the fewer false and also fewer veridical recalls produced by persons who stutter.

From a conscious motoric perspective, participants in the present study were not asked whether or not they considered the production complexity of the words as they were listening to them and preparing for recall. Yet, it is possible that as persons who stutter listened to the words from the lists and prepared for recall their initial thought process was the motoric complexity and/or production similarity of the words. One could even argue that there may have been specific words on the lists that might have been more likely to trigger conscious concerns about production and would result in the person who stutters as opposed to the person who does not stutter possibly being more likely to focus on the production aspect given their distinct history of speech fluency difficulties. One could further argue that the order in which the words were presented within the list across participants may have differed with respect to potential motor complexity. However, this particular argument is weakened when one also considers that the presentation of lists were counterbalanced, but the words within the list were presented in the same order across all participants. Thus, any differences noted between groups cannot be explained by the order in which the words were presented as the words were presented in the same order for all participants. Nevertheless, future research would benefit from asking participants what strategies if any they employed to assist in recall as this may allow for a better understanding of the differences in recall observed.

One final important consideration with respect to the critical lure findings is that the overall production of critical lures per list type was reduced to a possible range of zero to four per list type. Thus, the between-group difference may be intricately related to the limited opportunities for production. That is, had the participants been exposed to more lists, there would have been more opportunities to produce a critical lure and that in and of itself may have resulted in a comparable production of critical lures between the two groups. That being said, the present data do not support the notion that persons who stutter may have unique deficits in the functioning of the central executive, at least, not with respect to employing source monitoring to distinguish what they actually heard from what they thought they heard (i.e., source-monitoring deficits). However, future research efforts should focus on employing paradigms that facilitate increased opportunities to produce the critical lure to determine if the significantly fewer productions among persons who stutter in the present study were related to the limited productions allowed by the nature of the task or if perhaps persons who stutter as a group produce less critical lures for any of the one reasons previously discussed.

Conclusion

The present findings suggest that adults who stutter may have distinct difficulty with the information carried in the verbatim trace. This difficulty appears to be limited to the subvocal rehearsal system as indicated by the list-position effect, with the adults who stutter showing deficient recall for words in the initial position for both phonological and hybrid lists. The presence of the superadditive effect for both talker groups coupled with significantly lower production of critical lures by adults who stutter can be interpreted from different perspectives, including, but not limited to, spreading activation, source monitoring, and subconscious as well as conscious recall strategies. Additional investigation that would allow for increased critical lure production across both talker groups is needed to determine which potential explanation(s) is/are most plausible. Taken together, the present findings suggest that certain basic memory processes (i.e., recency effect) and the processing of gist semantic information are largely intact in adults who stutter, but recall of verbatim phonological information and subvocal rehearsal may be deficient.

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Lists of Presented Words for Each Critical Lure

BAD				BALL			
SEM	**PHO**	**HSP**	**HPS**	**SEM**	**PHO**	**HSP**	**HPS**
Goo	Had	Good	Had	Bounce	Doll	Bounce	Doll
Rotten	Lad	Lad	Rotten	Throw	Bile	Bile	Throw
Harmful	Bat	Harmful	Bat	Basket	Bail	Basket	Bail
Worse	Bag	Bag	Worse	Bowling	Balk	Balk	Bowling
Villain	Bud	Villain	Bud	Golf	Wall	Golf	Wall
Severe	Band	Band	Severe	Play	Fall	Fall	Play
Trouble	Dad	Trouble	Dad	Tennis	Bald	Tennis	Bald
Awful	Bide	Bide	Awful	Soccer	Pall	Pall	Soccer
Terrible	Bid	Terrible	Bid	Round	Tall	Round	Tall
Evil	Pad	Pad	Evil	Catch	Bill	Bill	Catch
Corrupt	Ad	Corrupt	Ad	Pitch	Bell	Pitch	Bell
Horrible	Bed	Bed	Horrible	Moth	All	All	Moth

CAR				DOG			
SEM	**PHO**	**HSP**	**HPS**	**SEM**	**PHO**	**HSP**	**HPS**
Auto	Char	Auto	Char	Hound	Log	Hound	Log
Drive	Call	Call	Drive	Puppy	Dodge	Dodge	Puppy
Engine	Care	Engine	Care	Bite	Dug	Bite	Dug
Wreck	Are	Are	Wreck	Mutt	Hog	Hog	Mutt
Garage	Card	Garage	Card	Pet	Bog	Pet	Bog
Motor	Carp	Carp	Motor	Beware	Doff	Doff	Beware
Van	Cot	Van	Cot	Bone	Daub	Bone	Daub
Truck	Core	Core	Truck	Tail	Cog	Cog	Tail
Crash	Par	Crash	Par	Cat	Dock	Cat	Dock
Accident	Scar	Scar	Accident	Animal	Dawn	Dawn	Animal
Trunk	Cart	Trunk	Cart	Paw	Fog	Paw	Fog
Tire	Far	Far	Tire	Poodle	Dig	Dig	Poodle

FACE				MAIL			
SEM	**PHO**	**HSP**	**HPS**	**SEM**	**PHO**	**HSP**	**HPS**
Mouth	Fake	Mouth	Fake	Stamp	Meal	Stamp	Meal
Expression	Vase	Vase	Expression	Deliver	Nail	Nail	Deliver
Nose	Fuss	Nose	Fuss	Receive	Mate	Receive	Mate
Eyes	Faith	Faith	Eyes	Bills	Mile	Mile	Bills
Frown	Lace	Frown	Lace	Letters	Hail	Letters	Hail
Wrinkle	Fail	Fail	Wrinkle	Send	Make	Make	Send
Makeup	Fain	Makeup	Fain	Fax	Mall	Fax	Mall
Cheek	Ace	Ace	Cheek	Express	Sail	Sail	Express
Head	Case	Head	Case	Post	Veil	Post	Veil
Mask	Fate	Fate	Mask	Zip	Mill	Mill	Zip
Moustache	Fame	Moustache	Fame	Address	Mole	Address	Mole
Beard	Race	Race	Beard	Envelope	Maid	Maid	Envelope

MAN				PEN			
SEM	**PHO**	**HSP**	**HPS**	**SEM**	**PHO**	**HSP**	**HPS**
Woman	Can	Woman	Can	Ink	Pan	Ink	Pan
Guy	Moon	Moon	Guy	Paper	Then	Then	Paper
Sir	Main	Sir	Main	Marker	Hen	Marker	Hen
Boss	Fan	Fan	Boss	Eraser	Ken	Ken	Eraser
Super	Tan	Super	Tan	Pencil	Pawn	Pencil	Pawn
Lady	Pan	Pan	Lady	Writing	Pain	Pain	Writing
Person	Mean	Person	Mean	Notebook	Fen	Notebook	Fen
Fellow	Map	Map	Fellow	Bic	Peg	Peg	Bic
Mister	Van	Mister	Van	Point	When	Point	When
Bachelor	Ran	Ran	Bachelor	Mark	Ben	Ben	Mark
Uncle	Mat	Uncle	Mat	Scribble	Pine	Scribble	Pine
Con	Mad	Mad	Con	Pal	Pun	Pun	Pal

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Lists of Presented Words for Each Critical Lure

RAIN				RIGHT			
SEM	**PHO**	**HSP**	**HPS**	**SEM**	**PHO**	**HSP**	**HPS**
Umbrella	Train	Umbrella	Train	Correct	Tight	Correct	Tight
Drench	Main	Main	Drench	Perfect	Rye	Rye	Perfect
Weather	Ran	Weather	Ran	Equal	Rife	Equal	Rife
Hail	Wren	Wren	Hail	Accurate	Night	Night	Accurate
Cloud	Pain	Cloud	Pain	Fair	Bright	Fair	Bright
Dew	Rave	Rave	Dew	Justify	Rile	Rile	Justify
Pour	Raise	Pour	Raise	Left	Ripe	Left	Ripe
Storm	Brain	Brain	Storm	Turn	Bite	Bite	Turn
Thunder	Bane	Thunder	Bane	Angle	Rat	Angle	Rat
Wind	Raid	Raid	Wind	Answer	Rot	Rot	Answer
Puddle	Rate	Puddle	Rate	Mistake	White	Mistake	White
Acid	Range	Range	Acid	Wrong	Rice	Rice	Wrong
TOP				**WET**			
SEM	**PHO**	**HSP**	**HPS**	**SEM**	**PHO**	**HSP**	**HPS**
Bottom	Mop	Bottom	Mop	Slippery	Vet	Slippery	Vet
Peak	Stop	Stop	Peak	Damp	Watt	Watt	Damp
Hill	Tap	Hill	Tap	Paint	Wheat	Paint	Wheat
Over	Tup	Tup	Over	Splash	Pet	Pet	Splash
Roof	Chop	Roof	Chop	Dry	West	Dry	West
Summit	Bop	Bop	Summit	Humid	Bet	Bet	Humid
Pinnacle	Tock	Pinnacle	Tock	Water	Wed	Water	Wed
Zenith	Cop	Cop	Zenith	Dripping	Well	Well	Dripping
Apex	Hop	Apex	Hop	Soak	Net	Soak	Net
Spin	Tape	Tape	Spin	Moist	Let	Let	Moist
Above	Taupe	Above	Taupe	Saturate	Welt	Saturate	Welt
Ceiling	Pop	Pop	Ceiling	Sponge	Wit	Wit	Sponge

Note. SEM = semantic lists; PHO = phonological lists; HSP = hybrid semantic–phonological lists; HPS = hybrid phonological–semantic lists.