PHONOLOGICAL PROCESSING ABILITIES OF ADULTS WHO STUTTER

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PHONOLOGICAL PROCESSING ABILITIES IN ADULTS WHO STUTTER

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This study investigated phonological awareness, phonological memory and rapid automatic naming abilities of adults who stutter and typically fluent peers. Many theorists posit that a delay or breakdown occurs during "phonological encoding," or the retrieval or construction of phonological segments (Howell & Au-Yeung, 2002; Perkins, Kent & Curlee, 1991; Postma & Kolk, 1993; Wingate 1988). Efficient phonological encoding is predicated upon the ability to segment phonological representations in a rapid, precise manner. According to current theories, a delay or incomplete retrieval of lexical segments could impede the execution of the articulatory plan, thereby resulting in disfluent speech. Unfortunately, the process of phonological encoding is not directly observable and must therefore be explored though alternate processes that reflects its incremental nature. Phonological awareness, phonological memory and rapid automatic naming can be examined to accomplish this task. Several core mechanisms are utilized during phonological processing, and a deficit in any of these mechanisms could account for performance differences in phonological processing tasks. Completion of these tasks is dependent upon the quality of phonological representations in the lexicon, the ability to construct novel phonological codes online, and the ability to maintain phonological representations in memory. The process of redintegration, whereby pre-existing lexical-semantic knowledge is used to supplement decaying or delayed phonological code (Hulme et al., 1997), can also play an important role in the completion of phonological processing tasks.

Participants completed several tasks examining different aspects of their phonological processing abilities. Significant between-group differences were revealed on nonlexical phonological awareness tasks, nonword repetition tasks, and rapid automatic naming tasks that used lexical stimuli. Adults who stutter performed significantly less well than typically fluent adults on tasks that used nonlexical stimuli. Adults who stutter appear to rely heavily on lexical-semantic information (redintegration) to bolster lower performance in other aspects of phonological encoding. Participants in both groups performed equally well on tasks that used lexical stimuli but not on tasks with nonlexical stimuli, indicating that between-group differences in phonological encoding exist. Differences in core mechanisms of phonological processing may reveal subtle linguistic differences that may contribute to an unstable speech system in people who stutter.

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1.0 INTRODUCTION

Stuttering is a communication disorder that is outwardly characterized as a difficulty in the initiation of speech (Bloodstein & Bernstein Ratner, 2008). Surface features of stuttering often involve word- or sound-repetitions (i.e., the first sound of a word is repeated multiple times), prolongations (i.e., the first sound of a word is drawn out before the rest of the word is spoken), or blocks (i.e., the first sound of a word is difficult to initiate). A number of theories of stuttering (Howell & Au-Yeung, 2002; Karniol, 1995; Kolk & Postma, 1997; Perkins, Kent and Curlee, 1991; Postma & Kolk, 1993; Wingate 1988) have suggested that one potential cause for stuttering is a difficulty with the underlying selection and preparation of the sounds that form the words in a speaker's message. Current psycholinguistic theories of typical language formulation refer to this process as "phonological encoding" (Dell, 1986; Dell & O'Seaghdha, 1992; Jansma & Shiller, 2004; Levelt, 1989; Levelt, Roelofs, & Meyer, 1999; Roelofs, 2004; Shattuck-Hufnagel, 1979, 1992). Phonological encoding involves the retrieval of segments of phonological code (i.e., phonemes or syllables of a word) in an incremental, just-in-time manner to allow for efficient construction of phonological words. Although details of the stuttering theories vary, they all hypothesize that a delay or breakdown occurs when phonological words are constructed from individual phonemes (i.e., during the process of phonological encoding). There is evidence to suggest that aspects of phonological encoding may not be as efficient or effective in individuals who stutter, although some of these findings are equivocal (Bosshardt &

Fransen, 1996; Burger & Wijnen, 1999; Hennessey, Nang & Beilby, 2008; Sasisekaran & de Nil, 2006; Sasisekaran, de Nil, Smyth & Johnson, 2006; Weber-Fox, Spencer, Spruill & Smith, 2004; Wijnen & Boers, 1994). Thus, further investigation of the role phonological encoding plays in stuttering is warranted.

Phonological encoding is embedded within the language formulation process, thereby making it difficult to isolate from the rest of the language processes. Although many stuttering theorists suggest that phonological encoding may be a possible contributing factor in stuttering, it is a process that is obscured from direct observation (Coles, Smid, Scheffers, & Otten, 1995; Meyer 1992). Observation of other related processes may provide a window into phonological encoding and provide a parallel form of measurement. Thus, one way to learn about phonological encoding is through the investigation of *phonological processing* abilities. Phonological processing is an “umbrella term” that includes the skills of phonological awareness, phonological memory, and rapid automatic naming (Wagner, Torgesen, & Rashotte, 1999). *Phonological awareness* is an individual’s ability to combine and break apart the individual sounds of words. *Phonological memory* is the ability to maintain phonological and auditory information for short-term retrieval, and *rapid automatic naming* is an individual’s ability to retrieve coded phonetic information rapidly by converting orthographic symbols into a meaningful string of phonemes. Performance on tasks of phonological awareness (that reflect the construction and deconstruction of phonemes, syllables and words) and phonological memory (that help maintain the phonological code while the entirety of a word’s phonological code is retrieved) parallels the processes that occurs during phonological encoding, thus providing a valuable research tool in the investigation of the phonological encoding skills of people who stutter (Acheson & MacDonald, 2009; Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2004; Wijnen & Boers, 1994).

Despite the interest in phonological encoding in theories of stuttering, there is little published research that explicitly examines the phonological processing skills of individuals who stutter. Some evidence exists that children who stutter perform differently on phonological processing tasks as compared to their non-stuttering peers (Anderson, Wagovich, & Hall, 2006; Arnold, Conture, Byrd, Key, Mathiesen, & Coulter, 2006; Byrd, Conture, & Ohde, 2007; Hakim & Bernstein Ratner, 2004; Pelczarski & Yaruss, 2008; Seery, Watkins, Ambrose & Throneburg, 2006; Weber-Fox, Spruill, Spencer & Smith, 2008). Few studies have investigated these same processes in adults who stutter. This is surprising considering that the theoretical models of stuttering are nearly all based on the fully-specified adult speech system (Howell & Au-Yeung, 2002; Kolk & Postma, 1997; Perkins et al., 1991; Postma & Kolk, 1993; Wingate 1988; cf. Karniol, 1995). Thus, it would be beneficial to investigate the phonological processing skills of adults who stutter to be able to equate the results directly with the theoretical models of stuttering.

Exploration of the individual aspects of phonological processing may help identify specific factors that influence phonological encoding. Potential differences in phonological encoding may be the result of phonological awareness difficulties (suggesting that any difficulties may lie in the incremental retrieval process of phonological encoding), phonological memory difficulties (suggesting that short-term memory may be impaired in terms of maintaining the phonological code during phonological encoding), or rapid automatic naming (suggesting that the ability to rapidly decode symbols of the language may influence phonological encoding). These differences may further inform what is known about phonological encoding in people who stutter and provide additional information about linguistic factors that influence stuttering in both children and adults. Understanding these linguistic factors can help direct future evidence-based clinical treatments by allowing clinicians to treat areas of weakness or utilize strengths in the phonological encoding system. Thus, this study investigates the phonological processing abilities of adults who stutter, while examining the individual components of phonological processing and how they interact in adults who stutter.

2.0 LITERATURE REVIEW

Thorough investigation of the phonological processing skills of adults who stutter requires review of a number of different literatures. First, a model of typical language planning is presented to provide an overview of how language is formulated and the role phonological encoding plays in that process. Many theories of stuttering implicate phonological encoding as a possible locus for stuttering which suggests that closer examination of a more specified model of phonological processing is warranted. Ramus, Peperkamp, Christophe, Jacquemot, Kouider, & Dupoux (2010) provide such a model and it is reviewed in the context of phonological processing skills. A model of phonological memory (Baddeley & Hitch, 1974; Baddeley, 2000) is presented to provide a theoretical framework for understanding the contribution of both short- and long-term memory stores to phonological processing. Next, a review of the phonological processing literature provides some background on how phonological awareness, phonological memory, and rapid automatic naming skills present in typically fluent individuals. The recent research on the phonological processing skills of adults who stutter is presented next and discussed within a theoretical framework. Finally, six research questions are offered as an outline of the goals of the current study. Review of this evidence will allow for a clear understanding of the importance of phonological processing in adults who stutter and how examination of phonological processing skills will aid in furthering our understanding as to whether adults who stutter possess different phonological encoding skills.

2.1 TYPICAL LANGUAGE FORMULATION

WEAVER++, a model of lexical access developed by Levelt and colleagues, is one of the most often-cited and fully specified theories of typical language formulation (Cholin, Levelt & Schiller, 2006; Cholin, Schiller, & Levelt, 2004; Jansma & Shiller, 2004; Levelt, 1989; Levelt et al., 1999; Roelofs, 1997a; 1997b; 1999; 2004). The current version of the model consists of four general processing stages: 1) conceptualization, 2) lexical selection, 3) formulation, and 4) articulation (Figure 1). The first stage of language formulation begins with a thought or idea at the level of the *conceptualizer*. It is during this process that the conceptualizer generates the content of a speaker's intended message. Each entry in the mental lexicon is represented by a *lemma* that contains an item's specific meaning and syntactic information, while the phonological form of the item is contained within the *lexeme*. The lexicon is considered a long-term memory store for this information (Gathercole, 1995). The *formulation* stage of WEAVER++ uses the information stored in both the lemma and lexeme to facilitate two encoding processes: grammatical encoding and phonological encoding. *Grammatical encoding* is a process that utilizes the information from the lemma to select appropriate syntactic structures to create grammatically correct utterances. The process of *phonological encoding*, on the other hand, retrieves the phonological code from the selected lexemes to assemble the phonetic form

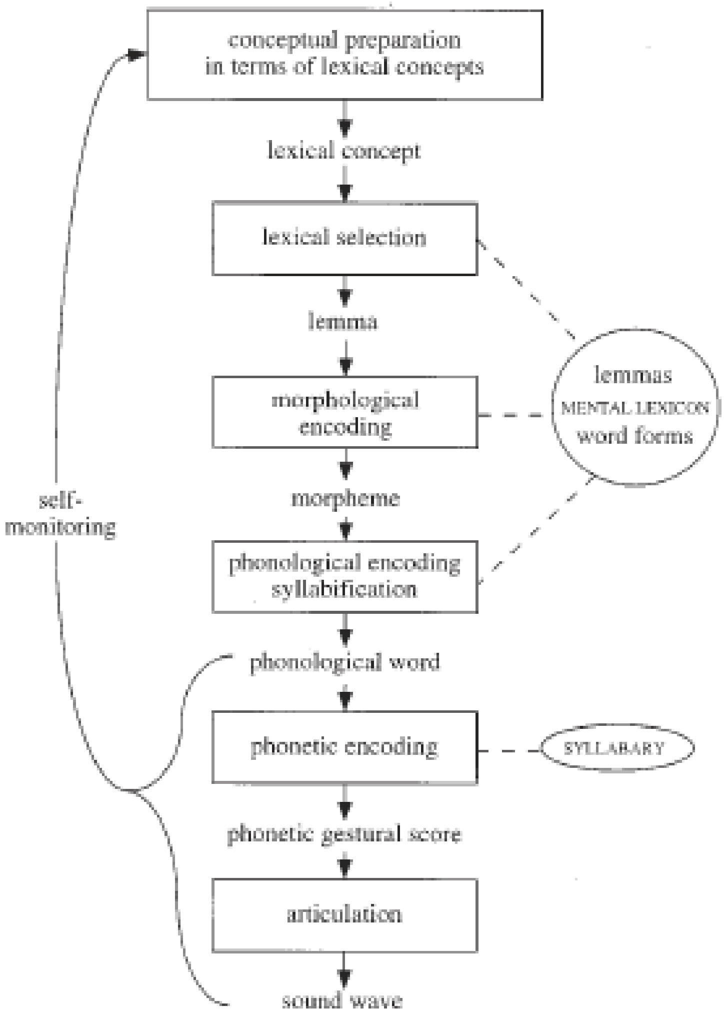

Figure 1. Outline of WEAVER++ stages of language formulation. (Levelt et al., 1999)

of an utterance. The phonological code obtained from the lexeme does not contain any metrical or defined syllabic properties. Such information is added at the level of phonological encoding. Syllable boundaries, as well as metrical and segmental information, are determined in the context of the utterance during the process of phonological encoding and are utilized in *phonetic encoding*. The two processes of phonological encoding and phonetic encoding occur nearly simultaneously but involve different tasks (Cholin et al., 2004; Cholin et al. 2006; Levelt et al., 1999). Once the phonemes that make up the initial syllable are retrieved during phonological encoding, *phonetic* encoding begins to incrementally retrieve the articulatory gestures for each phonologically specified syllable of the utterance in a sequential manner. These gestures are then utilized in the process of *articulation*. This final process is responsible for the execution of an articulatory plan for the intended utterance resulting in the output of overt speech. Many aspects of WEAVER++ have been experimentally supported through empirical investigations, although embedded processes such as phonological and phonetic encoding have been difficult to isolate and measure. Investigation of the more observable processes of phonological encoding is one way to gain additional information about the complex process of language formulation.

Although WEAVER++ is an influential language formulation model, it only partially represents the processes required to complete tasks of phonological awareness and phonological memory. WEAVER++ models the journey from a thought or concept through to speech output. However, most phonological processing tasks require more than just the "output" stage of language formulation. These tasks require an individual to hear stimuli, perform some sort of manipulation or identification, depending on the task, and then provide a spoken response. WEAVER++ only models language formulation, thus describing only half of the process that occurs during the completion of phonological processing tasks. A model that includes both speech perception and production would provide a framework to specifically examine phonological processing skills and is reviewed below.

2.1.1 An information processing model of speech perception and production

Ramus et al. (2010) present what they label a “general model” of speech perception and production, based on theories like WEAVER++. Ramus et al. have embedded WEAVER++ into their model (as indicated by the gray-shaded boxes in Figure 2) and inserted additional processes to provide a more comprehensive view of what occurs during completion of phonological processing tasks. Upon closer examination, it appears that two main routes that can be accessed when an individual completes a phonological awareness task: a *lexical route*, indicated by the large red circle, and a *phonological route*, indicated by the relatively smaller blue circle (see Figure 2). The lexical route is one that uses information contained in the lexicon to generate a response to speech input. This would be the case for most situations, with the exception being nonword repetition tasks (discussed below in section 2.2.2). Working from the bottom up, the lexical route begins when words are spoken by an outside source and an individual must make sense of the incoming acoustic information. This is accomplished by the retrieval of the *acoustic representation* and the subsequent decoding of the acoustic signal, via Arrow 2b, into a speech-specific phonological code (i.e., phonological word) at the level of *Input Sublexical*

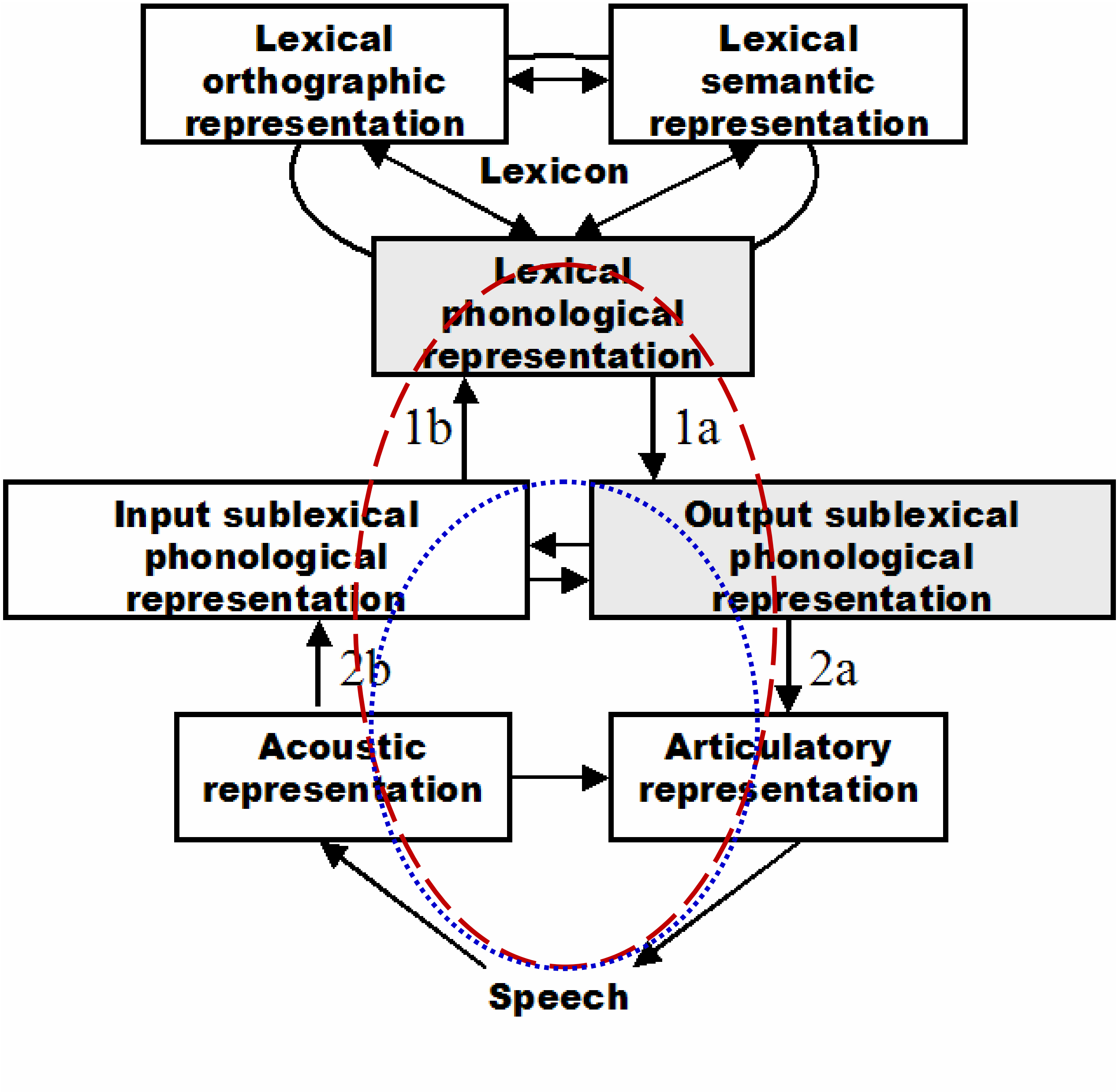

Figure 2.Information processing model of speech perception and production. Blue (small dashes) and red (long dashes) colored routes added by the current author for illustrative purposes. (Ramus et al., 2010)

Phonological Representation. The lexicon is then accessed, via Arrow 1b, in an attempt to match the auditorily presented phonological word to existing entries in the lexicon. Situated at the top of the figure, the lexicon contains orthographic, semantic, and phonological representations that provide information comparable to the lexemes found in WEAVER++ (Levelt, 1989; Levelt et al., 1999, Roelofs, 1997a). Once at the level of the lexicon, the meaning of the utterance can be determined and a response formulated. When an individual generates a response to the phonological input, the top of Figure 2 serves as the point of initiation and follows a series of steps similar to those found in WEAVER++ (Levelt, 1989; Levelt et al., 1999, Roelofs, 1997a). The phonological code is retrieved from the *lexical phonological representation* and travels down to the *Output Sublexical Phonological Representation* via Arrow 1a. Output Sublexical Phonological Representation acts as Levelt's phonological encoding, while Arrow 2a acts as Levelt's phonetic encoding. Arrow 2a delivers the phonetic code as the *articulatory representation* resulting in the output of speech. This is the route that would occur during most instances of speech. The phonological route (blue circle) provides an alternative to the typical lexical route and can be used in the performance of phonological processing tasks. The bi-directional arrows that share information between the Input and Output Sublexical Phonological Representation levels (i.e., the blue circle) would allow an individual to hear an auditorily presented item and repeat it back without a need to access the lexicon at all (Ramus et al., 2010).

Nonword stimuli are commonly used to test the phonological processing skills of phonological awareness and phonological memory. The lexicon does not possess any semantic, orthographic or phonological representations for nonwords, thus, the phonological route could be utilized for tasks involving nonwords, as with phonological awareness and phonological memory tasks. To access the phonological route, the speech input would be heard and the code would travel up Arrow 2b to the input phonological representation. Instead of continuing up Arrow 1b to the lexicon, the phonological code would be directly communicated from input to output sublexical phonological representation where the articulatory plan could be generated. The inclusion of two separate routes connected bi-directionally originated from case studies of conductive aphasia, where individuals with relatively intact language skills were able to repeat auditorily-presented real words, but not nonword utterances (Caramazza, Basili, Koller & Berndt, 1981). Ramus suggested that repetition of a nonword could bypass the lexicon all together and simply travel from the input phonological representation to the Output Sublexical Phonological Representation. However, this explanation does not account for the well-known influence of word-likeness on nonword repetition. Nonwords that are more "real word-like" are repeated faster and more accurately than less "word-like" nonwords (Hulme, Maughan, & Brown, 1991). There is also a tendency for nonwords to be lexicalized in error when the nonword is replaced with a real word that already exists in the lexicon (Ferraro & Sturgill, 1998). Additionally, many researchers argue for the existence of a process termed *redintegration*, in which access to lexical-semantic knowledge found in the lexicon are used to support language processes that might be weak or degraded (Baddeley, 1966; 1968; 2000; Baddeley & Hitch, 1974; Baddeley & Larsen, 2007; Hoffman, Jefferies, Ehsan, Jones, & Lambon, 2009; Hulme et al., 1997; Mueller, Seymour, Kieras, & Meyer, 2003; Roodenrys, Hulme, Alban, & Ellis, 1994). These factors argue against the idea of a purely phonological route, and suggest that perhaps the two routes may be combined.

A third possible route, in addition to the separate lexical and phonological routes, would include simultaneous lexical access while the phonological code of a nonword is communicated between input and output routes. Concurrent access to the lexicon, as well as communication between Input and Output Sublexical Phonological Representations, would account for the phenomena mentioned above.

Although the model was not designed to specifically account for what occurs during a phonological processing task, it can be used to hypothesize how the tasks could be completed within the model's framework. An example of a typical phonological awareness task demonstrates how the interaction between Input and Output Sublexical Phonological Representations can occur. Elision is a task that creates an artificial situation that does not occur in typical communication, but is used to measure phonological awareness skills. In this task, a phoneme of a given target word is removed, resulting in a new word (e.g., /fɑrm/ without saying /f/ = /ɑrm/). The task begins with the auditory delivery of the stimulus word and the phoneme to be removed. The task may then proceed in a number of different ways. The first scenario requires lexical access to complete the task. The phonological code of the stimulus word is heard and travels from the Input Phonological Representation level up to the lexical phonological representations in the lexicon via the lexical access route. The Input Sublexical Phonological code would then be matched to the lexical phonological representation in the lexicon and passed down to the level of Output Sublexical Phonological Representations (via Arrow 1a). There, the phonological code could be manipulated by the removal of a phoneme (e.g., /fɑrm/ "farm" minus /f/). The newly-formed phonological code (e.g., /ɑrm/) is then "double checked" with the input phonological representation via the bi-directional connection between input- and output-sublexical phonological representations. It is also possible that the lexicon is accessed again to confirm the newly-formed word via Arrow 1b after the phoneme has been removed. A second scenario that could theoretically describe the completion of the phonological awareness task of elision would entail use of the phonological route to complete the task. The stimulus word would be heard and maintained at the level of Input Phonological Representation and transferred directly to the Output Phonological Representation, thus by-passing the lexicon. There, the phonological code could be manipulated by the removal of a phoneme (e.g., /fɑrm/ minus /f/). The newly-formed phonological code (e.g., /ɑrm/) could then be turned into an articulatory representation and spoken aloud. In the final theoretical scenario to complete an elision task, access to a combination of these two routes could occur. The phonological code would be directly transmitted from Input to Output Phonological Representation for processing via the bi-directional pathway while the lexicon is concurrently accessed. The lexical access component would include activation of the original stimulus word (e.g., /fɑrm/), as well as an attempt to find a lexical match for the new target item (e.g., /ɑrm/). The various scenarios presented above are speculation at this point, as Ramus et al.'s model is not yet specified enough to provide an answer as to what may occur during these types of tasks. Considering the widely accepted influence of the lexicon it would be difficult to find sufficient evidence to support a purely phonological route. Yet, there may be certain situations where that may be the case (i.e., nonword repetition). The scenario that accounts for the strong influence of the lexicon, described above points toward the likelihood that individuals use a combination of both lexical and phonological routes the majority of the time.

The elision task described above illustrates how the phonological code of a given stimulus could be segmented and manipulated, via the removal of a given phoneme resulting in the creation of a new word. However, while considering what occurs during elision, it becomes clear that completion of the task would not be possible without the contribution of some mechanism that allows for the phonological code to be maintained long enough for the manipulation to occur (i.e., via phonological working memory).

2.1.2 Contribution of phonological working memory to language

Theoretical models of working memory account for a wide range of working memory systems, including visual working memory, episodic working memory, short-term memory, and long-term memory (Baddeley, 2000; Baddeley & Hitch, 1974; Baddeley & Larsen, 2007; Baddeley, Thomson & Buchanan, 1975; Baddeley & Wilson, 1993). Baddeley and Hitch (1974) proposed a prominent model of working memory that originally consisted of two components mediated by a single controlling entity. The most recent iteration of Baddeley's working memory model (2000) includes multiple components that work together to integrate and maintain information from both short-term and long-term memory stores (Figure 3). The model consists of a *central executive* that is the controlling body of the working memory system. The central executive mediates and integrates short-term storage information received from two main streams: the *visiospatial sketchpad* which is responsible for visual input, and a *phonological loop* which is responsible for auditory input. Additionally, an *episodic buffer* serves as a third short-term storage device that integrates "multi-dimensional code" obtained from the visiospatial sketchpad, the phonological loop, and long-term memory (i.e., visual, episodic, and language). This information is bound together to create an “episode” that can be volitionally recalled and is believed to aid in long-term learning (Baddeley, 2000). Auditory information is analyzed by the phonological loop and forwarded to a phonological buffer. The information in the phonological buffer is subject to rapid decay, as the system will only hold phonological information for a brief window of time. Phonological data in the buffer can be recycled and maintained for longer periods via silent or overt rehearsal (Baddeley, 1966; 1968; 2000; Baddeley & Hitch, 1974; Baddeley & Larsen, 2007). Additionally, the short-term maintenance of decaying phonological codes can also be refreshed via access to long-term memory stores, like the lexicon, which further bind information contained within the phonological buffer (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Hoffman et al., 2009; Martin & Gupta, 2004; Martin, Lesch, & Bartha, 1999; Patterson, Graham, & Hodges, 1994; Thorn, Gathercole, & Frankish, 2005). These processes highlight the

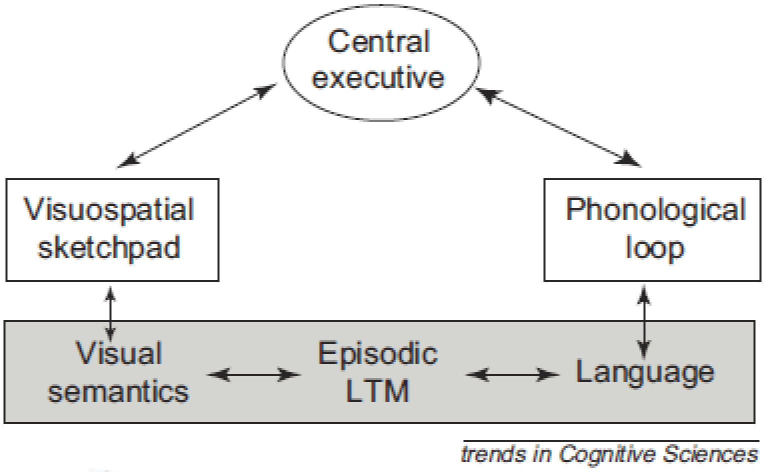

Figure 3. Baddeley’s model of working memory. This figure represents the most recent iteration of the model and includes additional features to account for influences of visual semantics, episodic LTM and linguistic influences (Baddeley, 2000).

importance of lexical access in working memory as well as in the perception and production of speech (Dell et al., 1997; Hoffman et al., 2009; Martin & Gupta, 2004; Martin et al., 1999; Patterson et al., 1994; Thorn et al., 2005). Both working memory and language formulation and production are influenced in similar ways by positional constraints, phonological similarity and long-term effects of linguistic knowledge (Acheson & MacDonald, 2009). Acheson and MacDonald suggest that working memory "might be viewed as the phonological encoding process itself" (p.56), providing further support that phonological processing skills are a valuable tool to investigate the obscured process of phonological encoding.

Baddeley's model is intended to cover a wide range of short-term memory phenomena but is not specific to any one aspect of short-term memory. Of particular interest to the current discussion is phonological memory, which is the ability to maintain phonological and auditory information for short-term retrieval and is so vital to performance of phonological processing tasks. In the present study, the discussion is focused specifically on phonological memory and its connections to the lexicon; a long-term memory store that can be used to help with the maintenance of phonological code in working memory. Gupta and MacWhinney (1997) suggests that phonological memory and vocabulary acquisition are closely connected and share some of the same underlying mechanisms.

2.2 PHONOLOGICAL PROCESSING

As mentioned above, phonological processing is an umbrella term that includes three skill sets: phonological awareness, phonological memory, and rapid automatic naming. The *Comprehensive Test of Phonological Processing: 5-6 year olds* (CTOPP; (Wagner, Torgesen, & Rashotte, 1999) is one standardized test that can be used to measure all three skill sets. Successful completion of phonological encoding requires the efficient retrieval of phonological segments, while phonological processing tasks measure an individual's ability to identify and manipulate these phonological segments. Although phonological encoding and phonological processing are distinct abilities, investigation of phonological processing can provide insight into the specificities of an individual's phonological encoding abilities. Thus, each of the specific skills comprising phonological processing will be discussed in more detail in the sections below.

2.2.1 Phonological awareness

Phonological awareness is an individual's ability to identify, isolate, and manipulate various-sized segments of speech (e.g., words, syllables, onsets/rimes, & individual phonemes). Phonological awareness begins to develop in very young children and continues to mature into adulthood. During the initial stages of development, a child's awareness is *implicit*: there is some level of understanding of sentences and words, but a child cannot isolate or identify these segments volitionally (Carroll, Snowling, Hulme, & Stevenson, 2003; Gombert, 1992). This vague awareness is inconsistently present until approximately the age of five, when phonological awareness is believed to stabilize enough to be reliably measured (Bryant, MacLean, Bradley, & Crossland, 1990; Lonigan, Burgess, & Anthony, 2000; Nittrouer et al., 1989; Snowling & Hulme, 1994; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner et al., 1997). As children mature, phonological awareness expands to include not only large phonemic units, such as sentences and words, but also an awareness of more fine-grained phonemic representations, such as syllables and individual phonemes. Phonological awareness in older school-age children and adults is *explicit:* they are able to volitionally identify, segment, and manipulate words down to the smallest constituent sound (Anthony & Lonigan, 2004; Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003; Fox & Routh, 1975; Liberman, Shankweiler, Fischer, & Carter, 1974; Nittrouer et al., 1989; Treiman, 1992; Treiman & Breaux, 1982, Treiman & Zukowski, 1991; 1996). Tasks that measure phonological awareness must be diverse enough to capture the full range of abilities and include measures of identification, blending, segmentation, and the ability to reverse or manipulate the position of specific phonemes.

2.2.1.1 Phonological awareness measurement

Various aspects of phonological awareness can be measured through a battery of tasks that are sensitive to the developmental changes that occur as a child matures to adulthood. This can be accomplished through task selection, as well as through hierarchical adjustments to the stimuli used in each task. There are three main accommodations that can be used to adjust the difficulty level for each task: (a) segment size, (b) number of syllables, and (c) degree of phonological complexity. The segment size to be manipulated or identified can make a task more or less difficult. The smaller the size of the segment (e.g., phonemes vs. words), the more developmentally difficult it is to identify and manipulate. The length of the stimuli in terms of the number of syllables used for each individual task can also be altered to account for developmental differences. Tasks containing more syllables are more difficult to complete as there are more phonemes to identify, sort, or blend (Sevald, Dell & Cole, 1995). The level of phonological complexity of the stimulus items will increase in difficulty with the presence of consonant clusters, as well as the inclusion of later developing phonemes (Moore, Tompkins, & Dollaghan, 2010; Storkel, 2001). Based on these parameters, the ability to identify and isolate an individual phoneme that is embedded in a consonant cluster is the most difficult because it is the most developmentally advanced. Many children consider consonant clusters to be a single unit, rather than individual phonemes (Snowling & Hulme, 1994, Storkel, 2001). For instance, children will identify /trit/ as having 3 phonemes: /tr-i-t/, rather than 4 phonemes: /t-r-i-t/. Segment size, stimuli length, and phonological complexity are all factors that are modified in the tasks of elision, word- and sound- blending, segmentation, word reversal, and phoneme deletion. These task modifications provide access to different facets of phonological awareness ability.

Accuracy and response time are two performance measures of phonological awareness tasks. The number of correct answers or productions determines an accuracy score, while the length of time required to complete a task is measured by verbal response time. Adults who stutter can demonstrate motoric instability during spoken word production, even during perceptually fluent speech (DeNil, 1995; McClean, Kroll, & Loftus, 1990; McClean, Levandowski, & Cord, 1994; Smith, Sadagopan, Walsh, & Weber-Fox, 2010; Zimmermann, 1980). Thus, even if only perceptually fluent spoken samples are used, any between-group differences in tasks requiring verbal responses may reflect motoric differences or differences due to linguistic planning stages of the task. Several researchers have reported that adults who stutter complete phonological awareness tasks more slowly than typically fluent adults (discussed in more detail in section 2.3.1). Although delays have been reported, it is unclear whether these reported delays are due to processing delays or delays due to differences in speech motor control. An alternative to a timed verbal task is to conduct a silent phonological awareness task immediately followed by a lexical decision task which provides a nonverbal response from which to determine how long it takes to complete the primary phonological awareness task.

Phonological awareness tasks can also be modified through use of lexical (i.e., real word) or non-lexical (i.e., nonword) stimuli to access different processing routes. Real word stimuli would access the lexical route, while the nonword tasks may be processed via the phonological route as outlined in Ramus et al.'s model. As mentioned in the section on theoretical models of language, access to the lexicon can influence task performance (i.e., redintegration). Tasks using words with an existing lemma (i.e., real words) have well-established activations that are accessed more quickly because they do not have to be newly constructed. The example of the elision task above illustrates that while the target phoneme is removed from the phonological code of the original word; the lexicon is searching for an appropriate target by comparing the partial phonemic code to possible matches. Often, a match can be found without the complete phonological code, before the task is fully completed, through a general understanding of language and phonotactic constraints (Gathercole, Frankish, Pickering & Peaker, 1999; Storkel, 2001; Storkel, Armbruster, & Hogan, 2006). Alternatively, non-lexical stimuli do not profit as much from the aid of the lexicon as do real-word stimuli. If a task is performed solely through the manipulation of the phonological code, as is presumed to be the case when nonwords are used, the target word would need to be newly assembled (Ramus et al., 2010). Construction of a novel phonological code takes longer to complete because it is generated on-line thereby increasing the length of time required to complete phonological awareness task that use nonword stimuli (Durgunoglu & Oney, 1999; Wagner et al., 1999). Although tasks using nonword stimuli take longer to complete, they can provide a closer approximation of phonological awareness skill level, separate from the influence of lexical access (Durgunoglu & Oney, 1999; Wagner et al., 1999). The resulting task creates an artificial situation, because lexical access is not typically restricted during speech, yet it isolates the processes that are used in phonological awareness tasks.

Phonological memory also contributes to performance ability in phonological awareness tasks discussed above, and a strong relationship exists between the two (Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe 2003; Dickinson & Snow, 1987; Wagner, Torgesen, & Rashotte 1994). Empirical evidence suggests that phonological processing skills interact more in younger children and separate into distinct processing skill-sets in older children and adults (Cornwall, 1992; Gathercole, Willis & Baddeley, 1991; Savage et al., 2005). Although phonological memory tasks have been shown to measure abilities that are distinct from phonological awareness, phonological memory remains a skill that is necessary for the completion of phonological awareness tasks (Lonigan, Wagner, Torgesen & Rashotte, 2007; Wagner et al., 1999). As the length and complexity of a stimulus item increases, so does the requirement that the phonological codes be maintained in phonological memory to allow for successful completion of the desired manipulation via a phonological route (Lonigan et al., 2007; Wagner et al., 1999). A full understanding of the range of phonological awareness skills, and the influence of lexicality on performance of phonological awareness tasks, can be gained through administration of a series of tasks that explore the segmental nature of language both with and without access to the lexicon. These tasks are discussed in detail next as well as in Table 1.

2.2.1.2 Elision

Elision, as mentioned above, requires the breaking apart of auditorily presented words to create a new word through the removal of specific phonological segments. The participants are presented with a target word (e.g., /mit/ “meet”) and instructed to remove one phoneme to create a different word (e.g., /mit/ without /t/ is /mi/). As mentioned above, phonological awareness tasks for children differ from adults primarily in the length and complexity of the stimuli. Thus, removal of larger segments, such as those found in compound words (e.g., Say /ɛrplen/ “airplane” without saying /ɛr/, with the correct response being /plen/), is developmentally easier than the removal of smaller segments, such as phonemes at the beginning of a word (e.g., Say /kʌp/ “cup” without saying /k/, with the correct answer being /ʌp/), or at the end of a word (e.g., /ʃut/ “shoot” without /t/ is /ʃu/). Most difficult is the removal of phonemes in the middle of a word (e.g., say /taɪgɚ/ “tiger” without saying /g/ with the correct answer being /taɪɚ/) because the embedded phoneme needs to be extracted while keeping the other phonemes in mind to create the new word. This task requires the maintenance and manipulation of the phonological code in phonological memory while the mental lexicon is searched for the new target word.

2.2.1.3 Blending

Blending requires the combination of individually presented words, syllables, and phonemes to be formed into a real word (e.g., /p-ɑ-p-k-ɔr-n/ “popcorn” blends together as /pɑpkɔrn/; / m-æn/ “man” blends together as / mæn/; / k-æ-t/ “cat” blends together as / kæt/). Again, difficulty for blending can be modified through the adjustment of the size of the segments to be blended. Small segments are more challenging to blend than syllable- or word-sized segments. For example, blending the word /pɑp- kɔrn/ is an easier task than blending individual phonemes, as in / p-ɑ-p-k-ɔr-n/. Stimuli length can be modified by increasing the number of phonemes to be blended, thus increasing the task difficulty (e.g., /mi/ “me” versus / græshŏpɚ/ “grasshopper”). The increased difficulty of the task can be attributed to having more phonemes to blend, but an additional contribution from phonological working memory is also required (Lonigan et al., 2007; Wagner et al., 1999). Phonological complexity is the final parameter that can be adjusted to account for developmental differences. The more consonant clusters contained in the blended target, the more difficult the task (e.g., / t-ɛ-l-ʌ-f-o-n/ = / tɛlʌfon/ “telephone” is easier than / s-p-r-ɪ-ŋ-b-ɔr-d/ = /sprɪŋbɔrd/ “springboard”).

2.2.1.4 Segmentation

Segmentation is a task that requires participants to listen to a word and repeat back the constituent phonemes individually (e.g., / mæt/ “mat” becomes / m-æ-t/). Task items that contain consonant clusters are more difficult, as it is developmentally more difficult to separate consonant clusters (e.g., /græshŏpɚ/ becomes /g-r-æ-s-h-ŏ-p-ɚ/). Segmentation of consonant clusters is one of the more difficult tasks for younger children (Sevald et al., 1995). The task of identifying and breaking apart the individual phonemes of a word into segments relies heavily on phonological memory. A word’s phonological code is heard and maintained in phonological memory, while each phoneme is spoken individually. Segmentation tasks can achieve various difficulty levels through modification of stimuli length and phonological complexity. The longer the stimulus item, the longer it must be maintained in memory while it is broken apart (e.g., /mæθʌmætɪks / “mathematics” becomes /m-æ-θ-ʌ-m-æ-t-ɪ-k-s/).

2.2.1.5 Phoneme reversal

School-aged children and adults are able to perform more complex phonological awareness tasks that require manipulation of phonemes in addition to combining or separating sounds, as is the case with elision, blending and segmentation. Participants completing a *phoneme reversal* task are presented with a pseudo-word (e.g., /nups/ “noops”) and asked to reverse the order of the phonemes to create a new real word (e.g., /nups/ is /spun/ “spoon” backwards). This task requires the auditory perception of a word and the maintenance of the phonological code in working memory while the phonemes to be reversed are identified and manipulated. Presumably, this can be accomplished solely through maintenance in phonological working memory, or in the more likely scenario, through the use of lexical access (i.e., redintegration) to help identify the new target word as is the case for phoneme blending and elision tasks (Hulme et al., 1997; Roodenrys et al., 1994).

2.2.1.6 Silent phoneme blending task

In addition to determining task accuracy, a combined *silent phoneme blending/lexical decision* task can help determine if adults who stutter perform phonological awareness tasks more slowly than adults who do not stutter without involving the speech motor system. This task uses both real word and nonword stimuli, so both the lexical and phonological routes would be accessed during completion of this task. Participants hear the individual phonemes and silently blend them together into either a real word or a nonword. Once the item is blended, a choice can be made regarding the blended item's lexical status. The decision would then be recorded through the pressing of a button on a stimulus response box that marks the accuracy and length of time taken to complete the task. Details of this procedure are discussed in more detail in section 3.5.3. Closely paired with the silent phoneme blending/lexical decision task is the tradition lexical decision task. The lexical decision task serves two purposes. The first goal of the task is to provide a measure of the participants' lexical abilities. Specifically, it is important to determine whether there are any between-group differences in lexical access that might account for potential differences revealed in the silent phoneme blending/lexical decision task. One way to confirm that the groups have typical lexical abilities is to determine the presence of the well-documented and expected lexical status effect (Durgunoglu & Oney, 1999; Wagner et al., 1999) and length effect (Meyer, Roelofs, & Levelt, 2003; Meyer, Belke, Hacker, and Mortensen, 2007; Santiago, MacKay, Palma, & Rho, 2000). Typical populations are able to discern real word stimuli more quickly than nonword stimuli (i.e., lexical status effect) and to respond to shorter stimuli faster than longer stimuli (length effect). The presence of these robust effects would indicate whether or not the two groups' lexical abilities are typical. The second purpose of the task is to provide a means for "subtracting out" the time required for a lexical decision from the silent phoneme blending/lexical decision task. When the participants' lexical decision time is statistically removed, a closer estimate of the time taken to blend the phonemes remains. Similar instructions are used for the lexical decision task as are used for the silent phoneme blending/lexical decision task. Participants listen to an aurally-delivered stimulus and make a decision regarding the item's lexical status by pressing a button to indicate their choice. The same stimulus response box is used to record the length of time and accuracy of an individual's decision as to whether the stimulus was a real word or nonword. Silent phoneme blending/lexical decision tasks allows for a duration measurement without the interference of the speech motor system.

2.2.1.7 Summary

The tasks reviewed above allow for use of both the lexical and phonological access routes. Phonological awareness task difficulty can be modified through manipulation of a number of parameters, including lexical status, stimulus length, and phonological complexity. These stimuli manipulations allow the same tasks to be used with both young children and adults without the risk of ceiling effects. The facilitative role lexical access plays in successful completion of elision, sound blending, and phoneme reversal tasks also highlights the importance of using both real-word and nonword stimuli to fully measure an individual's range of phonological awareness abilities. Finally, although phonological awareness and phonological memory are separate skills, phonological memory is an essential component in the completion of these tasks phonological awareness tasks. Without it, the phonological codes could not be maintained in short-term memory long enough for the manipulations required by phonological awareness tasks to be completed.

Table 1. Phonological awareness tasks. Descriptions and examples of phonological awareness tasks.

Task	Task Description	Examples
Elision (Lexical Route)	Create new words from existing words by removing a given segment (word or phoneme)	*/ɛrplen/ "airplane" without saying /ɛr/ = /plen/* */kʌp/ "cup" without saying /k/ = /ʌp/* */taɪgɚ/ "tiger" without saying /g/ = /taɪɚ/*
Elision (Non-lexical/ Phonological Route)	Create new non-word from existing real words by removing a given segment (word or phoneme)	*/karn/ "karn" without /k/ is /arn/ = nonword*
Blending (Lexical Route)	Formation of real words by synthesizing sounds together (words, syllables, phonemes)	*/k-æ-t/ "c-a-t" blends together as /kæt/*
Blending (Non-lexical/ Phonological Route)	Formation of nonwords by synthesizing sounds together (syllables, phonemes)	*/l-u-d-æ-t/ "loodat" blends together as /ludæt/*
Segmentation (Lexical Route)	Name the constituent phonemes that construct a given word	*/mæt/ "mat" = /m-æ-t/*
Segmentation (Non-lexical/ Phonological Route)	Name the constituent phonemes that construct a given nonword	*/slobo/ "slowboe"= /s-l-o-b-o/*
Phoneme Reversal (Lexical Route)	Reversal of a nonword into a real word	*/nups/ "noops" is /spun/ "spoon" backwards*
Phoneme Reversal (Non-lexical/ Phonological Route)	Reversal of a real word into a nonword	*/plæn/ "plan" becomes /nælp/ "nalp"*

2.2.2 Phonological memory

Baddeley’s theoretical model of memory, reviewed in detail above in section 2.1.2, describes phonological memory as the ability to maintain phonological code in memory for use in everyday speech. Typically, lexical and semantic representations of a word help with the recall and retention of that word in phonological memory (Dell et al., 1997; Hoffman et al., 2009; Martin & Gupta, 2004; Martin et al., 1999; Patterson et al., 1994). In fact, Gupta and MacWhinney’s (1997) model of phonological working memory suggests that vocabulary acquisition (i.e., new word learning) and phonological memory share many of the same underlying mechanisms. Gupta and MacWhinney suggest that phonological memory aides in the creation of the representations of new lexical items and that lexical access assists in the maintenance of phonological memory. These factors work in concert with phonological memory to improve performance; however, the assistance that lexical access provides may obscure analysis of an individual’s true phonological memory ability. Thus, nonwords are often used to measure phonological memory. A number of researchers argue that nonword repetition tasks are also influenced by a number of factors in addition to phonological memory (Coady & Evans, 2008; Edwards & Lahey, 1998; Gathercole, 2006). According to Coady and Evans (2008):

> Successful repetition of a nonword involves speech perception, phonological encoding (or segmenting the acoustic signal into speech units that can be stored in memory), phonological assembly (or formulating a motor plan that assembles the relevant speech units), and articulation. Further, it requires a robust representation of underlying speech units, and sufficient memory both to temporarily store and operate on the novel phonological string. A deficit in any of these component skills results in less accurate repetition. (Coady and Evans, 2008, p. 2)

It can be difficult to parse apart which process is truly being measured with all the factors that contribute to phonological memory and nonword repetition. Still, nonword repetition can provide some valuable information regarding phonological memory abilities and the phonological route when used in concert with another task such as digit span recall. Both nonword repetition and digit span tasks typically begin with shorter stimuli and increase in length as a way to tax memory capacity. Numbers typically have well-established phonological representations that suggest performance on a digit span recall task would be less susceptible to difficulties in creating or assembling a phonological plan **(**Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Damien, 2004**)**. Taken together, the two tasks can provide some insight into phonological memory abilities (Baddeley, Gathercole, & Papagno, 1998; Gathercole et al., 1999; Gathercole, Willis, Emslie, & Baddeley, 1992; Levelt et al., 1999; Roodenrys & Hinton, 2002; Thorn & Frankish, 2005; Thorn et al., 2005; Vitevitch & Luce, 2005).

2.2.2.1 Phonological memory measurement

Nonword Repetition and Memory for Digits are two tasks that are used in the CTOPP to measure phonological memory. The Nonword Repetition subtest requires an individual to repeat back aurally-presented stimulus items that adhere to the phonotactic rules of English but have no corresponding lexical or semantic representations (i.e., nonsense words). Memory for Digits requires an individual to hear a series of numbers of increasing lengths and repeat back the numbers in the exact order they were presented. Both of these tasks are thought to reflect phonological working memory ability (Baddeley et al., 1998; Brown & Hulme, 1996;

Gathercole, 1995; Houghton, Hartley, & Glasspool, 1996) and are highly correlated in typical populations (Baddeley & Wilson, 1993; Butterworth, Campbell & Howard, 1986; Gathercole, Briscoe, Thorn & Tiffany, 2008; Gupta, 2003).

The difficulty level of nonword stimuli, similar to phonological awareness stimuli, can be manipulated along three dimensions: (a) syllable length; (b) phonological complexity; and (c) phonotactic frequency or "word-likeness." Nonwords with more syllables are more difficult to repeat due to the increased memory load required, particularly since there are no lexical entries to help facilitate maintenance of the phonological code. Increased phonological complexity via the presence of consonant clusters and later-acquired phonemes also contribute to the difficulty of a nonword repetition task (Dollaghan & Campbell, 1998; 2003; Edwards & Lahey, 1998; Moore et al., 2010). Word-likeness, or how "word-like" a nonword seems, is another variable that can be manipulated. Many researchers argue that phonotactic frequency is a factor in determining the word-likeness of a nonword (Gathercole et al., 1999; Storkel, 2001; Storkel et al., 2006). Nonwords that contain high-frequency phonotactic syllables are considered more word-like and are easier to produce (e.g., "stirple;" "blonterstaping;" Gathercole, 1995). Nonwords with low phonotactic frequency are more difficult to produce and considered "less word-like" (e.g., "kipser;" "perplisteronk;" Gathercole, 1995). Less word-like nonwords, although more difficult to repeat and remember, appear to provide more insight into phonological memory because the system is not relying on phonotactic familiarity to aid in repetition of the nonword (Cholin et al, 2006; Gathercole & Baddeley, 1993; Hulme et al., 1991; Snowling & Hulme, 1994). Word-like nonword repetition tasks used to measure phonological memory can be interpreted as accessing some level of lexical or phonotactic information, whereas less word-like nonword stimuli can be interpreted to be slower and less accurate to produce because there is less facilitative lexical influence (Hulme et al., 1991).

A prominent test of nonword repetition for children, The Nonword Repetition Task (NRT), was created by Dollaghan and Campbell (1998) to be sensitive to language differences in children and has been used as a test of phonological memory as well. The nonword stimuli for the NRT is constructed with “Early-8” and “Middle-8” consonants (Shriberg & Kwiatkowski, 1994) in an effort to reduce the articulatory demands of the task due to the young age of the children it was meant to test. The stimuli range from 1- to 4- syllables in length and do not contain any consonant clusters. The NRT can be used to test nonword repetition ability in young children while avoiding floor effects, although the test may not be sensitive enough to determine subtle differences in older children and adults (Moore et al., 2010). In response to the concern that adolescents and adults may experience ceiling effects with the NRT, Dollaghan & Campbell (2003) designed the Late-8 Nonword Repetition Task (L8NRT). This task uses Shriberg & Kwiatkowski’s later developing “Late-8” consonants (e.g., /s, z, ʃ, ʒ, θ, ð, l, r/), ranges from 1-to 4- syllables, and contains no consonant clusters. The L8NRT is designed to test the nonword repetition abilities of older children and adults by increasing the articulatory demands of the stimuli, thereby taxing the speech system and avoiding potential ceiling effects.

Memory for Digits, a digit-span recall task, is another method used to test phonological memory that requires an individual to accurately repeat back digit strings of increasing length in the order that they were presented. The limited number of single digits (i.e., ordinal numbers 1-9) used to create a digit string also helps to reduce potential semantic activations that may interfere with recall. The digits are similar in syllable length, articulatory duration, phonological complexity and phonotactic frequency and are modified only by adjusting the length of the digit string.

2.2.3 Rapid automatic naming

The ability to rapidly retrieve coded phonetic information by converting orthographic symbols into a meaningful string of phonemes that represent entries in the mental lexicon is called *rapid automatic naming* (Anthony, Williams, MacDonald, & Francis, 2007; de Jong, & Vrielink, 2004; Manis, Seidenberg, & Doi 1999). Efficient rapid automatic naming is predicated on the notion that an individual can decode orthographic symbols or pictures and transform them into a string of phonological representations. Rapid transcription of orthographic symbols into phonological code enables a person to gain access to representations quickly and efficiently.

2.2.3.1 Rapid automatic naming measurement

Rapid automatic naming is measured via timed naming tasks requiring the participants to name the visual stimuli presented as quickly and accurately as possible. Children under the age of six are typically presented with non-orthographic stimuli, such as colors, pictures of objects, or large vs. small size discriminations, while older children and adults are presented with letters and digits (Anthony et al., 2007; Badian, 1993; Bowers, Sunseth, & Golden, 1999; de Jong & Vrielink, 2004; Manis et al., 1999; Meyer, Wood, Hart, & Felton, 1998; Savage & Frederickson, 2005; Savage et al., 2005; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). Well-known stimuli are traditionally used because rapid automatic naming tasks are intended to target the automatic process of translating the visual input into spoken words. Numbers and letters are often not yet habituated to the point of being automatic in young children, so picture stimuli are used instead. However, the pictures can activate additional semantic and phonological representations, as well as demonstrating increased phonological complexity and articulatory durations. As a result, completion times for rapid automatic naming tasks with picture stimuli typically take longer to produce in most populations (Coltheart et al., 2001; Wagner et al., 1999).

2.2.4 Core mechanisms

The majority of phonological processing tasks are influenced by certain core mechanisms or processes, including the quality of the phonological code, the ease with which a person can construct or assemble phonological codes, and the ability to sustain phonological code in memory long enough for the given task to be completed. If deficits or differences exist in any of these mechanisms, performance may be affected. Further discussion of how performance on phonological awareness tasks could be influenced occurs in the following sections.

2.2.4.1 Quality of the phonological representations

Phonological awareness tasks require the identification and manipulation of individual phonemes within words. Degraded phonological representations could make these tasks more difficult, particularly if the degraded phoneme was the one to be manipulated. Pre-existing lexical-semantic knowledge would allow for the code to be strengthened whether an individual phoneme was strengthened contextually within a pre-existing lexical entry or if access to the lexicon allowed for more frequent “refreshing” of the code during the phonological awareness task (i.e., redintegration). The quality of the phonological representations would also affect performance on nonword repetition tasks if the code for individual phonemes were degraded, the strength of the phonological representation would have to stand on its own. The benefit of semantic-lexical knowledge would not be present.

2.2.4.2 Construction of phonological representations

Impaired ability to construct phonological words can result in reduced performance on a variety of phonological awareness and phonological memory tasks. Phonological awareness tasks like phoneme blending can be challenging if the system has difficulty in the piecing together individual phonemes. Redintegration can help compensate for an impaired ability to construct phonological representations through use of existing lexical-semantic representations. If the phonological awareness task requires the manipulation of nonwords and redintegration is not able to bolster the weakened mechanism with pre-existing lexical-semantic knowledge to help recombine phonological code then any impairment in that mechanism could be reflected in poor phonological awareness performance. Repetition of nonword stimuli would require the generation and construction of a novel phoneme pattern and would require the online assembly of individual phonemes without use of pre-existing lexical information.

2.2.4.3. Maintenance of phonological representations

Completion of phonological awareness and nonword repetition tasks would also be affected if an individual had difficulty with the maintenance of phonological code in memory. Active code is necessary to allow for the manipulation required of phonological awareness tasks and for the repetition of nonwords. Typically, the phonological code of a word can be refreshed via access to the long-term memory store of the lexicon, thus reducing the demands on short-term memory. Phonological awareness tasks would evidence reduced performance if the system was unable to "refresh" or sustain the code to allow for task completion. Alternately, nonword repetition tasks and phonological awareness tasks that utilize nonword stimuli would not be able to benefit from long-term knowledge since there are no pre-existing nonword representations. These tasks would show a decrement in performance if *any* of these mechanisms were impaired or deficit.

2.2.5 Summary

The phonological processing skills of phonological awareness, phonological memory, and rapid automatic naming appear to be separate, albeit intertwined, skills that have been demonstrated by researchers to influence phonological processing abilities. Lexical access can influence performance on all three phonological processing tasks. Completion of phonological awareness tasks using real word stimuli are typically completed faster and with increased accuracy than tasks using nonword stimuli. Phonological memory tasks are completed more quickly and accurately when the stimuli are more "word-like" than when "less word-like" nonwords are used.

Timed rapid automatic naming tasks can also be influenced by lexical access. Tasks that require participants to quickly name colors and objects, which are words with lexical associations, are identified faster than digits and numbers, which possess fewer lexical associations. Factors such as phonological complexity, articulatory duration, and phonotactic frequency also influence speed of performance and accuracy of production for all three phonological processing tasks and should be considered when conducting any study of phonological processing.

2.3 PHONOLOGICAL PROCESSING IN INDIVIDUALS WHO STUTTER

Studies of phonological priming (Arnold, et al., 2006; Byrd et al., 2007) and behavioral tasks (Pelczarski & Yaruss, 2008; Weber-Fox, et al. 2008) report significant differences in the phonological awareness abilities of children who stutter as compared to typically fluent children. Pelczarski & Yaruss (2008) investigated a broad range of phonological processing skills in 5- and 6- year old children who do and do not stutter using the CTOPP. This version of the test was specifically designed to measure the developing phonological processing skills of preschool children. A variety of subtests measured performance on phonological awareness (e.g., Elision, Word Blending, Sound Blending, and Sound Matching), phonological memory (e.g., Nonword Repetition and Memory for Digits), and rapid automatic naming (e.g., Rapid Color Naming and Rapid Object Naming). Phonological awareness tasks that used nonword stimuli were not used in the Pelczarski and Yaruss study, since 5- and 6-year-old children are not yet developmentally able to complete tasks using nonword stimuli (Snowling & Hulme, 1994; Wagner et al. 1994). The results for each skill set will be discussed in the relevant section, thus only the findings of the phonological awareness tasks will be discussed here. Participants were well-matched on general language ability, sex, and socioeconomic status; all factors that influence performance on phonological processing skills. Significant differences between groups were found for phonological awareness and phonological memory tasks, but not for rapid automatic naming, further supporting the premise that aspects of phonological processing are different or delayed in children who stutter. Although statistically significant differences were present between groups, nearly all participants scored within normal limits indicating that the significant, yet subtle differences were present even when confounding factors were controlled. Some researchers (Hakim & Bernstein Ratner, 2004; Newman & Bernstein Ratner, 2007) term these differences as "sub-clinical" to indicate that differences are present and skills maybe somewhat depressed, but not considered disordered.

Phonological processing tasks, such as phonological awareness, can be completed through purely phonological methods, as suggested by the Ramus et al. model, or with some degree of lexical access (i.e., redintegration). Reliance on lexical access relieves some of the memory burden and allows the phonological awareness tasks to be completed with the help of pre-existing phonological codes. These skills are not stagnant; they grow and develop, leading to increased understanding and awareness of the precise facets of phonological code, specifically awareness of onset, rimes, and individual phonemes. Thus, performance abilities for children become more fine-tuned as they age, resulting in quantitatively different abilities as adults. Table 2 demonstrates that there is evidence to assert that there are subtle differences in the phonological awareness and phonological memory abilities of children who stutter as compared to normally fluent peers. A comprehensive study of the phonological processing skills of adults who stutter would allow for comparison to earlier studies that have measured these same abilities in children who stutter (Pelczarski & Yaruss, 2008) to determine if these differences persist into adulthood. Investigating phonological processing (i.e., phonological encoding) in people who stutter provides a more detailed picture of a process that is implicated in a number of psycholinguistic theories of stuttering.

Although no previous studies have explicitly designated phonological awareness and phonological memory as dependent variables with adults who stutter, these skills *have* been studied, albeit using different terminology. Thus, the following section reviews the existing literature within the framework of phonological processing, even if the original intention was not

Table 2. Phonological awareness in children. Research studies of stuttering and phonological awareness in children who stutter (CWS) and children who do not stutter (CNWS).

Authors	**Participants**	**Results**
Melnick, Conture, & Ohde (2003)	3-5 yr. old CWS/CWNS	No significant differences in response latencies. Children who do not stutter demonstrated greater variability than children who stutter from age 3 to age 5.
Byrd, Conture, & Ohde (2007)	3-5 yr. old CWS/CWNS	Significant difference at age 5. Children who stutter continued to respond to holistic primes faster than incremental primes (like adults and 5 year-old children who do not stutter)
Arnold et al. (2006)	3-5 yr. old CWS/CWNS	Replicated Byrd et al. 5 year-old children who stutter continued to respond to holistic primes faster than incremental.
Bajaj, Hodson, & Scholmmer-Aikins (2004)	5-8 yr. old CWS/CWNS	No significant differences in phonological awareness tasks, but tasks were too difficult for participants.
Pelczarski & Yaruss (2008)	5-8 yr. old CWS/CWNS	Children who stutter performed significantly below children who do not stutter, although still scored within normal limits.
Weber-Fox, Spruill, Spencer, & Smith (2008)	9-13 yr. old CWS/CWNS	Children who stutter were significantly less accurate on a visual rhyming task across all conditions, while reaction times between groups were similar.

explicitly to investigate phonological processing abilities. Use of the phonological processing paradigm allows for comparison and compilation of existing data through the use of common terminology. The results are then analyzed and synthesized to provide a comprehensive picture of phonological processing and stuttering. A number of studies using phonological awareness tasks also integrated phonological memory tasks into the research design as well. For the sake of clarity, only the results relevant to the specific section (i.e., phonological awareness or phonological memory) are discussed in an effort to more clearly outline and distinguish between the phonological awareness, phonological memory, and rapid automatic naming abilities of adults who stutter.

2.3.1 Phonological awareness and individuals who stutter

A number of studies provide empirical support for the existence of differences in the phonological awareness abilities of adults who stutter (Bosshardt & Fransen, 1996; Burger & Wijnen, 1999; Hennessey et al., 2008; Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2004; Wijnen & Boers, 1994) despite the fact that phonological awareness goals were not the stated aim. Many phonological awareness tasks were used even though they were not necessarily labeled as such. These studies are reviewed below and summarized in Table 3.

Wijnen and Boers (1994) conducted a priming study to investigate the facilitation effect of phonologically similar and different primes in nine adults who stutter and nine typically fluent adults. Participants learned to associate specific response words with visually presented cue words requiring a rapid spoken response. The cue word was paired with a semantically related target response word and tested in sets of five word pairs across two conditions: homogeneous and heterogeneous. In the homogeneous condition, the five target-word responses shared an initial syllable segment, where either the initial consonant (C-prime) or the consonant plus vowel (CV-prime), with the target word to be produced by the participants in response to the cue word. All the response words started with the same initial consonant or consonant + vowel, while the prime word was semantically related to the target word. The same word pairs were divided into a heterogeneous condition where dis-similar phonological onsets were used for the target words (i.e., the target words did not share initial segments, but semantic primes were still used). Wijnen and Boers reported that adults who stutter were significantly slower than nonstuttering adults in all conditions. The authors also reported a significant facilitation effect (i.e., faster naming times) for typically fluent adults when the target words shared segments in the homogeneous condition, with greater facilitation noted for larger segments (i.e., consonant + vowel, as compared to sharing only a consonant). Meanwhile, adults who stutter only demonstrated a significant facilitation effect when prime and target shared a larger segment (e.g., consonant plus vowel) but not in the consonant-only condition. Wijnen and Boers interpreted these findings to indicate "the encoding of non-initial parts of syllables, particularly the (stressed) vowel, is delayed" in people who stutter (p.1). Further, the authors argued that stuttering, particularly initial phoneme repetition and prolongation, "result[s] from attempts at executing a syllable prior to the incorporation of correct vowel information in the articulatory plan" (Wijnen & Boers, 1994, p. 1).

These findings can also be considered in the context of a phonological processing framework. Awareness of large phonological segments is an early-developing skill in typical populations and individual phoneme awareness is usually solidified in young school-age children. The authors reported that adults who stutter responded faster to only larger primes, rather than the more developmentally appropriate smaller segmental primes, whereas typically fluent adults were primed faster with smaller segments. Thus, it becomes clear that there is evidence supporting the existence of a difference in phonological awareness in adults who stutter. The one caveat to this study was that the primes were semantically, not phonologically, related to the target words. Target-word responses shared similar onsets, which the authors labeled as phonological priming. Typically, many phonological priming paradigms are constructed so that both the cue and target word share similar phonemes, leading to more direct measurement of the phonological priming effect without engaging semantic activation. Although phonological priming may have existed, as both groups demonstrated a facilitation effect, it is difficult to determine how much semantic and phonological priming contributed to the speed of response. The design of the study does not allow for specification of what aspects of phonological awareness may be different. Still, the fact that adults who stutter responded significantly slower than typically fluent adults across conditions suggests that there is some delay in phonological processing of adults who stutter.

Burger and Wijnen (1999) sought to replicate and expand the findings by Wijnen and Boers (1994) by utilizing a larger sample size and different stimuli to allow for manipulation of lexical stress factors. Again, word pairs were semantically related, reportedly to aid in learning of the pairs. In this study, as with Wijnen and Boers (1994), each target word appeared in both

Table 3. Phonological awareness in adults. Research studies of stuttering and phonological awareness in adults who stutter (AWS) and adults who do not stutter (AWNS).

Authors	**Participants**	**Results**
Wijnen & Boers (1994)	9 AWS & 9 AWNS	AWS were significantly slower than AWNS in all conditions. AWNS demonstrated a significant facilitation response with similar phonological primes (C & CV primes). AWS only demonstrated the facilitation effect with larger segment primes (CV prime).
Bosshardt & Fransen (1996)	14 AWS & 14 AWNS	No significant differences between groups for any of the conditions (identical, rhyme, or category judgment). No differences for rhyme judgments. The presence of multiple processes makes it hard to tease apart the contributing factors.
Burger & Wijnen (1999)	21 AWS & 17 AWNS	AWS responded significantly slower than AWNS, as before. The pattern where AWS only achieved facilitation with CV primes was not replicated (i.e., both groups responded faster to larger segment primes). However, new stimuli were used and stress patterns were modified.
Weber-Fox, Spencer, Spruill & Smith, 2004	11 AWS & 11 AWNS	AWS were significantly slower to judge in the rhyming but orthographically similar condition of rhyme judgment task. No other differences present (CWS were less accurate).
Sasisekaran, de Nil, Smyth & Johnson (2006)	11 AWS & 11 AWNS	AWS had significantly longer monitoring times for phonemes than AWNS in the silent naming task, but not in any other monitoring task. No difference in accuracy was reported.
Sasisekaran & de Nil (2006)	10 AWS & 12 AWNS	No between group differences were found for the perception tasks (orally presented targets), but a significant group difference was revealed for phoneme monitoring in silent naming with AWS taking longer to monitor for phonemes than AWNS.
Hennessey, Nang, & Beilby (2008)	18 AWS & 18 AWNS	No significant difference between groups for phonologically related primes or semantically related primes. However, AWS were significantly slower in lexical status RT (i.e., slower to repeat a nonword pair quickly than repeating a real word pair) than AWNS, but not in accuracy.

conditions (homogeneous and heterogeneous) and served as its own control. Speech-onset times for adults who stutter again responded significantly slower than typically fluent adults across conditions. Both groups, however, responded similarly to the homogeneous priming condition with all participants demonstrating greater facilitation with larger prime segments (CV-prime vs. C-prime). Although adults who stutter demonstrated significantly slower response times, they did not require larger segments to achieve facilitation as was evident in Wijnen and Boers (1994). It should be noted that Burger and Wijnen's study was not an exact replication of Wijnen and Boers's earlier study, as different stimuli were employed. The rationale for this change was to allow for variation in syllabic stress markers. In the original study, the target words all received stress on the initial syllable. The authors suggested that adults who stutter do not have difficulty in phonological encoding because the pattern of adults who stutter requiring larger segments to achieve facilitation was not evident. However, they did not provide a hypothesis of why the adults who stutter demonstrated significantly slower response times. This difference could have been due to difficulty with the articulatory initiation of the target word, influences of semantic priming, or phonological encoding. These two studies provide evidence that some difference does exist in phonological processing skills of adults who stutter as compared to normally fluent peers, but additional investigation is necessary to determine what specific aspects of phonological awareness may be affected.

Sasisekaran et al. (2006) explored the relationship of phonological encoding in the silent speech of adults who stutter as compared to typically fluent adults by judging the response time and accuracy of participants' monitoring abilities. Participants were screened for vocabulary and some phonological awareness abilities (i.e., a rhyme judgment task and identification of initial and final phonemes of an auditorily presented word). In addition to the screening and control measures, participants were administered a single word picture-naming task, auditory tonal monitoring task, and phoneme monitoring during silent naming task that required the participants to silently name a picture while scanning for the presence of a designated phoneme. The tonal monitoring task was included to help rule out any difficulty in auditory processing. Individuals who stutter demonstrated significantly longer monitoring times for phonemes than nonstuttering individuals in the silent naming task, but not in any other monitoring task. Adults who stutter were reported to be significantly slower in phoneme monitoring as compared to typically fluent adults, but no difference in accuracy was reported. The authors suggested that the longer response times demonstrated in phoneme monitoring were evidence of difficulties in phonological encoding. Additionally, although these were not dependent variables in the study, there were significant group differences in accuracy on two of the phonological awareness tasks: rhyme judgment accuracy and onset segmentation (identification of initial phoneme from aurally presented stimuli). Despite the significant differences on these two phonological awareness measures, the authors reported that all participants scored within normal limits on the measures, thus indicating a subtle, yet significant difference in phonological awareness abilities of adults who stutter.

Further evidence supporting the continued investigation of the phonological awareness skills of adults who stutter was provided by a similar, concurrently-run study using a different set of participants. Sasisekaran and De Nil (2006) used a phoneme monitoring task akin to the one used in Sasisekaran et al. (2006), but the complexity of the stimuli was modified to include noun phrases or compound words instead of a single bi-syllabic word. Additionally, the participants were required to listen to aurally presented stimuli and monitor for phonemes during a perception task. No between-group differences were found for the perception tasks, but a significant group difference was revealed for phoneme monitoring in silent naming. Adults who stutter took longer to monitor for phonemes than typically fluent peers. The authors interpreted these findings, in addition to the findings from their earlier study (Sasisekaran et al., 2006), as evidence that adults who stutter "were slower in the encoding of segmental, phonological units during silent naming" (p. 284). Sasisekaran and de Nil indicated there may be a delay in the phonological encoding of adults who stutter, rather than a difference, because both groups demonstrated equivalent accuracy scores. Although the stimuli were varied in complexity with compound words (e.g., "greenhouse") compared to short noun phrases (e.g., "a green house"), the stimuli may not have been complex enough to reveal a difference. Thus, the fact that there were no significant differences in accuracy between groups should be interpreted cautiously, as a ceiling effect may have been present due to the utilization of relatively simple phonological stimuli. More complex stimuli may tax the participants' phonological encoding systems more, which may transform delays found with simple stimuli into inaccuracies with more complex stimuli. Sasisekaran and colleagues cited a delay in phonological encoding as an explanation for their data; however, other researchers have suggested that this delay could also be indicative of processes other than phonological encoding, such as semantic, syntactic or word frequency processing (Newman & Bernstein Ratner, 2007). The significant differences in response times reported by Sasisekaran and de Nil provide evidence that adults who stutter possess a difference in at least one phonological awareness task. The concerns raised by Newman and Bernstein Ratner are valid, and could be easily addressed though investigation of a full range of phonological awareness tasks that use both lexical *and* non-word stimuli to mitigate confounding factors. Use of both real-word and non-word stimuli would allow for performance comparison to determine to some extent the influence of lexical factors on phonological awareness skills.

Weber-Fox et al. (2004) used forced-choice rhyme judgments (i.e., participant indicates whether a pair of words rhyme by selecting either a “yes” or “no” button) to investigate the speed and accuracy of rhyme judgments for word pairs that varied in terms of both orthographic and phonological congruency. The authors compared a group of 11 adults who stutter to a group of 11 adults who do not. Participants were required to judge rhyme similarity for word pairs in the following four conditions: (a) rhyming pairs with congruent orthography/phonology (e.g., *wood/hood*); (b) incongruent orthography/phonology (e.g., *could/hood*); (c) non-rhyming pairs with similar orthography/phonology (e.g., *blood/hood*); and (d) dissimilar orthography/phonology (e.g., *air/hood*). Participants were required to determine if the visually presented target words rhymed or not. Orthographic translation involves additional processes that require the conversion of symbols to phonological representations to be maintained in phonological memory while determining rhyme judgments. Adults who stutter demonstrated significantly slower response times than typically fluent adults for the non-rhyming, but orthographically similar, condition of the rhyme judgment task. The authors interpreted the longer reaction times to be indicative of differences that are only revealed when task demands were highest, suggesting that adults who stutter do not have a core phonological processing difficulty, but are susceptible to delays due to higher cognitive loads. The phonological processing framework would suggest that the differences are so subtle that they are only revealed when the phonological awareness tasks are most difficult. However, it would be difficult to determine whether increased cognitive load was a contributing factor or if the phonological encoding system was taxed due to the complexity of the phonological awareness task. Investigation of multiple phonological awareness tasks that are sensitive to subtle differences would be helpful in determining whether differences would be found on multiple phonological awareness tasks, or just ones with increased cognitive load. If differences were found on other phonological awareness tasks, that would be suggestive of an overall difference or delay in phonological awareness.

Weber-Fox et al. (2008) conducted a study similar to Weber-Fox et al. (2004) described above using the same methodology with children who stutter. The children who stutter were less accurate in rhyming judgments across conditions, but were not significantly slower than the group of typically fluent children. Conversely, adults who stutter were equally as accurate in rhyming judgments but demonstrated a delay in reaction time. The authors presented these results as evidence of the maturation effect, suggesting children who stutter are still developing, although not at the same rate as their typically fluent peers, and thus perform differently than adults who stutter. Studies such as these highlight the importance of extending investigation to various age groups to help identify overall differences versus delays. As noted earlier, the research design was targeting phonological processing as one relatively ambiguous skill set and presumably unintentionally tapped into more than one phonological processing skill (i.e., both phonological awareness and rapid automatic naming). The results of the study do provide evidence of differences in phonological processing, but the design precludes any further distinction regarding what specific phonological processing skill may be different in these groups. Further investigation into the contributions of phonological awareness, phonological memory and rapid automatic naming in both children and adults who stutter will help determine in what way these skills develop as a child who stutters matures into adulthood. The evidence suggests that differences in the phonological awareness skills of children who stutter may "catch up" somewhat to their typically fluent peers.

Rhyme monitoring is a task that can be used to determine phonological awareness abilities. Bosshardt and Fransen (1996) used a rhyme-monitoring paradigm to investigate phonological and semantic processing of 14 adults who stutter and 14 adults who do not stutter. Participants were asked to silently read a number of sentences and monitor for a target word embedded in the sentence that was either phonologically related, where the target word rhymed with cue word, categorically related, where the target word belonged to same category (e.g., types of fruit), or was the same as the cue word. The phonologically related cues were presented visually, requiring the participants to convert orthographic symbols to phonological representations and hold in phonological memory in order to make the rhyming judgments (both a phonological awareness and phonological memory task). Bosshardt and Fransen reported that adults who stutter were significantly slower in the category judgment task but not in the rhyme monitoring task. Adults who stutter were also slower to make rhyme judgments, but not significantly so. Bosshardt and Fransen interpreted their findings as evidence that adults who stutter do not have deficits in phonological encoding. However, Bosshardt and Fransen's results can also be interpreted within a phonological processing framework. Visually presented tasks require an individual to encode orthographic information (rapid automatic naming) while maintaining a target word in memory (phonological memory) while making rhyme judgments (phonological awareness). The authors acknowledged that adults who stutter were slower to respond overall, but not significantly so. These results may be due to the overlapping of abilities required to complete the stated tasks. The phonological processing skills of phonological awareness, phonological memory, and rapid automatic naming do not all need to be operating optimally to be able to complete phonological processing tasks (Lonigan et al., 2000). Indeed, deficits in one aspect can be mediated by strength in another skill set. If an individual possesses a deficit in phonological awareness, for instance, but demonstrates strong phonological memory skills, the individual could still compensate to a certain degree. The presence of all three processing tasks makes it difficult to determine the contributing factor or factors using this research design; however, there are ways to tease apart the contributions of the various phonological processing skills, as will be discussed below. Thus, further investigation of the phonological awareness skills of adults who stutter using carefully controlled methodologies for studies is warranted.

Hennessey et al. (2008) conducted an auditory priming study that investigated a number of different processes in adults who stutter, including phonological facilitation, semantic inhibition, and nonword repetition reaction times (RT). Only the phonological and semantic priming are discussed in this section, while the nonword repetition RT task are discussed further in the phonological memory section. Participants were required to rapidly name a semantically related, a phonologically related, or an unrelated prime. No between-group differences were revealed for semantic or phonological prime trials. Hennessey et al. interpreted their findings as evidence that there is no deficit in linguistic encoding for adults who stutter; however, a number of factors may account for the lack of differences. The stimuli used in the phonological priming facilitation task consisted of one- and two- syllable words and contained no consonant clusters. The stimuli used may not have been long enough or complex enough to sufficiently tax the participants' system to reveal the subtle differences known to exist for adults who stutter

(Bernstein Ratner, 1997; Conture, 2001; Hall, Wagovich, & Bernstein Ratner, 2007; Pelczarski & Yaruss, 2008). Additionally, the authors acknowledged that their stimuli were used repeatedly, resulting in additional practice for participants. Repeated presentations may have masked delays that could have been revealed after only one presentation. Indeed, other studies have reported significant, "subclinical" differences in phonological priming when each stimulus item was only presented once (Hakim & Bernstein Ratner, 2004; Newman & Bernstein Ratner, 2007; Prins, Main, & Wampler, 1997). Thus, methodological concerns may account for the discrepant findings, and may not truly represent adults who stutter's phonological awareness abilities.

Caution must be used when exploring the speed of phonological awareness in people who stutter as in the studies described above. Tasks that require spoken response times may be longer for adults who stutter due to difficulties other than delays in phonological awareness and phonological memory (Smith et al., 2010). Delays in motor initiation, planning, speech avoidance, or anxiety could be responsible for response-time differences. Even if only perceptibly stutter-free responses are used, it would be difficult to guarantee a stutter-free response for every stimulus item. Without careful control, it would be difficult to separate out if a delay is due to the influence of possible motor issues or of a delay in phonological awareness. Although the stimuli used in prior studies may not have been complex enough to detect a difference, both accuracy and response times of phonological processing tasks should be measured. Exploration of these processes will provide a more robust understanding of the phonological processing and phonological encoding abilities of adults who stutter.

2.3.1.1 Summary of phonological awareness and individuals who stutter

Wijnen and Boers (1994), Weber-Fox et al. (2008), Burger and Wijnen (1999), Sasisekaran et al. (2006), and Sasisekaran and de Nil (2006) all presented evidence of significantly longer response times for adults who stutter across rhyme judgment and phoneme monitoring tasks indicating that there may be a delay in some aspects of phonological awareness processing. Weber-Fox and colleagues (2004; 2008) conducted investigations with both children and adults who stutter. The children who stutter were revealed to be significantly less accurate across conditions with no difference in response time, while the adults were reported to have demonstrated longer response times with no differences in accuracy. As with the other studies detailed above, longer processing times for adults who stutter may indicate a difference or difficulty in completing phonological awareness tasks. Thus, children who stutter were reported to have accuracy issues that appeared to resolve themselves in adults by apparently trading speed for accuracy. Bosshardt and Fransen (1996) and Hennessey et al. (2008) provided evidence against the possibility of differences in the phonological awareness skills of adults who stutter. Bosshardt and Fransen reported slower judgment times for adults who stutter, but statistical significance was not reached. Hennessey et al. did not report any differences in the response to phonologically related primes, but did report slower lexical status judgment was demonstrated by adults who stutter. As reviewed above, studies by both Hennessey et al. and Bosshardt and Fransen had methodological issues that may have masked significant findings. Despite the evidence suggesting adults who stutter have slower phonological awareness skills, most of the studies only looked at one or two aspects of phonological awareness and used rather simplistic stimuli. A more in-depth investigation of *all* of the different phonological awareness processing tasks with varying degrees of difficulty would provide a clearer picture of the phonological awareness abilities of adults who stutter.

2.3.2 Phonological memory and individuals who stutter

As mentioned above, phonological memory is a component of phonological processing that contributes to the completion of many language processes, including phonological awareness and novel word learning. Phonological memory is most often measured through two tasks that are found to be highly correlated in typical populations: nonword repetition and digit recall (Baddeley & Wilson, 1993; Butterworth et al., 1986; Gathercole et al., 2008; Gupta, 2003). Very few studies have explicitly investigated phonological memory in adults who stutter, but there have been a number of studies that have investigated nonword repetition (typically considered a measure of phonological memory) in children who stutter (Table 4). There is some evidence that digit recall and nonword repetition may not measure the same process in people who stutter. Pelczarski and Yaruss (2008) reported that there was a significant difference in the performance of children who stutter on the nonword repetition and digit naming tasks of the CTOPP; specifically, that performance was better on the digit recall task than on the nonword repetition task. Although these two tasks are highly correlated in non-stuttering populations, they were not correlated for children who stutter. Further investigation of the data revealed that the significant finding was due solely to scores on the nonword repetition task, while digit naming did not contribute to the variance in a statistically significant way. Pelczarski & Yaruss' findings suggest that phonological memory, specifically performance on nonword repetition tasks, is different in children who stutter as compared to normally fluent peers. This evidence suggests that nonword repetition appears to be “tapping into” some processing that memory for digits does not. Perhaps this is evidence of a difficulty not exclusively in phonological memory, but in the establishment or assembly of new phonological representations that may not be fully specified (Coady & Evans, 2008; Edwards & Lahey, 1998). Further investigation into the between-group differences in phonological memory and between nonword repetition and digit recall tasks is required. Some

Table 4. Phonological memory in children. Studies of phonological memory in children who stutter (CWS) and children who do not stutter (CWNS).

Authors	**Participants**	**Results**
Anderson et al. (2006)	3-5 year old CWS/CWNS	Significant differences in nonwords repetition only at 2- and 3- syllable levels
Pelczarski & Yaruss (2008)	5 &6 yr. old CWS/CWNS	Significant difference in nonword repetition, although within normal limits.
Hakim & Bernstein Ratner (2004)	4-8 yr. old CWS/CWNS	Significant difference in nonword repetition only at 3-syllable level.
Bakhtiar et al. (2009)	5-8 yr. old CWS/CWNS	No significant differences for 2- and 3- syllable nonwords, but lower scores reported for children who stutter.
Seery et al. (2006)	8 ½ - 12 ½ yr. old CWS/CWNS	Significant difference in nonword repetition only at 4-syllable level.

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additional studies (Anderson et al., 2006; Hakim & Bernstein Ratner, 2004; Seery et al., 2006) have also provided evidence suggesting that phonological memory, as measured by nonword repetition, is different in children who stutter as compared to their typically fluent peers. Studies that have investigated phonological awareness in *both* children and adults who stutter have reported significant differences in both populations (Weber-Fox et al., 2004; 2008). Thus, there is evidence to suggest that the differences found in nonword repetition may be present in adults who stutter as well.

Only a handful of studies have used nonword repetition tasks with adults who stutter (Sasisekaran, Smith, Sadagopan, & Weber-Fox, 2010; Smits-Bandstra & de Nil, 2009; Smits-Bandstra, de Nil & Saint Cyr, 2006), but the tasks were used to measure sequence-skill learning rather than phonological memory skills. The participants were required to repeatedly practice speaking nonwords aloud while accuracy and learning were measured. Repeated practice does not explicitly measure phonological memory ability, but rather measure how well novel speech sequences were learned. As such, the results of these studies are not directly related to the current discussion. A number of other studies have reported on the accuracy and speed of nonword repetition tasks performed by adults who stutter as compared to typically fluent adults (Bosshardt, 1993; Hennessey et al., 2008; Ludlow, Siren & Zikira, 1997; Smith et al., 2010). Table 5 summarizes these studies and they are described in more detail below.

Table 5. Phonological memory in adults. Studies of phonological memory in adults who stutter (AWS) and adults who do not stutter (AWNS).

Authors	**Participants**	**Results**
Bosshardt (1993)	19 AWS & 30 AWNS	Short-term memory and recall task. AWS were significantly less accurate in recognition and recall of CVC nonwords.
Ludlow, Siren, & Zikira (1997)	5 AWS & 5 AWNS	AWS demonstrated significantly more errors than AWNS after repeated practice of phonologically complex nonwords.
Hennessey, Nang, & Beilby (2008)	18 AWS & 18 AWNS	AWS were significantly slower than AWNS in the word/nonword choice reaction task.
Smith, Sadagopan, Walsh, & Weber-Fox (2010)	17 AWS & 17 AWNS	AWS showed no difference in accuracy of nonword repetition task. All participants were either at, or near, ceiling on the task. AWS repeated nonwords more slowly than AWNS.

Bosshardt (1993) used a nonword recall task that required participants to silently read visually presented nonwords and write down the nonwords that were presented. Adults who stutter were significantly less accurate in recognition and recall of CVC nonwords. In this case, the nonwords were used in a memory recall task, not a nonword repetition task. Although Bosshardt's study may address some aspects of phonological memory in adults who stutter, the main goal of the study was to measure immediate and delayed memory recall. Additionally, the visual presentation of the stimuli makes it difficult to separate to what extent visual memory contributed to performance on phonological memory tasks.

An investigation conducted by Ludlow et al. (1997) compared the ability of participants to produce phonologically complex nonwords (e.g., "abisthwoychleet") with repeated practice. The expectation was that accuracy and speed would improve with repeated practice, as was demonstrated by adults who do not stutter. Adults who stutter, however, did not demonstrate improved accuracy or speed with increased repetitions and the between group difference was significant. Thus, even with practice, the adults who stutter were still demonstrating phoneme errors when repeating the phonologically-complex nonwords in later trials. Ludlow et al. interpreted the results as reflective of reduced abilities in adults who stutter to learn new sequencing skills due to deficits in phonological encoding. Another interpretation exists when examined in a phonological processing context; there is the possibility that the lack of improvement with practice was the result of less well-formed phonological memory abilities, or relatedly, as unstable or under-specified phonological representations. More research to explore the nature of phonological memory abilities in adults who stutter would allow for increased understanding of the contributions of the various inter-related factors.

Hennessey et al. (2008) investigated nonword repetition in adults who stutter. Although the primary focus of their study was not an examination of phonological memory skills, the study can still inform our knowledge of phonological memory in this population. In addition to the phonological awareness tasks reviewed above, the authors investigated three RT tasks: choice RT, simple RT, and picture naming RT. Choice RT required the participants to learn to associate shapes with either a word or nonword pair. This task can also be considered a word-learning task as well. Once a shape was projected onto the screen, the participants were required to identify the pair and say the target word item (i.e., word and nonword) associated with the shape as quickly as possible. Simple RT was similar to choice RT except each item had only one shape and corresponding word or nonword. Picture naming RT required the participants to name a picture as quickly as possible. The authors reported that adults who stutter were significantly slower than typically fluent adults in the choice RT (i.e., when required to repeat the word and nonword pairs), but not the simple reaction time or picture naming task. Although adults who stutter were significantly slower in choice RT, Hennessey et al. deduced that there was no evidence to support a difference in phonological encoding because there was not a large difference between the nonword trials and the real word trials. The authors argued that nonwords would require online assembly of a novel speech plan that would not be necessary for real words as they would already have an existing speech plan. Thus, a timing difference should have been evident, with real words spoken faster than nonwords. This result was not present; however, closer investigation of the stimuli used in the study revealed that they were used multiple times across trials. That is, the picture/word or picture/nonword pairs were used in both choice RT and simple RT tasks resulting in repeated practice for the targets. Multiple repetitions of nonword targets would create a new speech plan that could account for the similar timings found for both word and nonword RT. Additionally, the choice RT task was the most challenging of the three tasks; the difference in performance on only that task may have been due to increased complexity of the task. Thus, as with studies discussed above, more stringent controls need to be utilized to obtain a more accurate understanding of the full extent of phonological memory skills of adults who stutter.

Smith et al. (2010) used nonword stimuli in a motor sequencing study, but also recorded behavioral data on the accuracy of nonword repetition using the NRT (Dollaghan & Campbell, 1998). As discussed above in section 2.2.2, NRT was designed and created to be a more sensitive measure for determining language disorders in children, but when administered to adults would often results in ceiling effects with participants performing at or near ceiling on the measure. Smith et al. reported that “both groups performed at or near-ceiling in the 1-, 2-, and 3-syllable nonword repetition. For the 4-syllable nonword repetition, median scores were 89% and 85% for normally fluent and stuttering adults" (Smith et al., 2010, p. 8). These data were used by the authors to suggest that there were no differences evident between adults who stutter and adults who do not stutter in nonword repetition ability. Interpreting Smith and colleagues' results with the knowledge that NRT is developmentally inappropriate to use with adult participants then provides more support for the argument that nonword repetition tasks that contain stimuli constructed out of earlier developing phonemes do not tax the adult system sufficiently to determine between-group differences. There is very little published about the phonological memory skills of adults who stutter, even though there is evidence that children who stutter demonstrate a difference in these abilities. Thus, further investigation into the phonological memory skills of adults who stutter is warranted.

2.3.3 Rapid automatic naming and individuals who stutter

Rapid automatic naming is the ability to quickly retrieve and name common visual symbols paired with phonetic representations. A number of studies have investigated reading rates of adults who stutter (Bloodstein, 1944; Bosshardt & Nandyal, 1988; Cullinan, 1963; Jasper and Murray, 1932; Max, Caruso, & Vandevenne, 1997; Moser, 1938; Roland, 1972), but those tasks are not considered rapid automatic naming tasks because the stimuli did not require automatic responses. Traditionally, rapid automatic naming stimuli include basic colors, letter or digits that can be retrieved quickly and by-pass any additional semantic activations. Pelczarski and Yaruss (2008) conducted a study that included an investigation of rapid automatic naming, along with phonological awareness and phonological memory in children who stutter, but did not reveal any differences in rapid automatic naming ability as compared to normally fluent peers. The results may be questionable due to the data pattern that revealed that some children who stutter performed very well on rapid automatic naming tasks, while an equal number performed on the lower end of normal. It is possible that these two response patterns may have cancelled out a significant finding in that sample of children. As a phonological processing skill that is so closely affiliated with phonological awareness and phonological memory, performance on rapid automatic naming matures with time as well. The equivocal results from Pelczarski & Yaruss suggest that further investigation may clarify whether there are differences in the rapid automatic naming abilities of adults who stutter. Thus, investigation of rapid automatic naming skills in adults who stutter is warranted to determine if this aspect of phonological processing changes with age or remains the same as when they are young in people who stutter.

2.4 PHONOLOGICAL PROCESSING AND STUTTERING SUMMARY

Evidence suggests that the phonological processing skills of children who stutter are different from their normally fluent peers (Anderson et al., 2006; Arnold et al., 2006; Byrd et al., 2007; Hakim & Bernstein Ratner, 2004; Pelczarski & Yaruss, 2008; Seery et al., 2006; Weber-Fox et al., 2008), but these findings cannot be generalized to the phonological processing abilities of adults who stutter because of the influence of maturation on these skills. As a child who stutters matures, the differences in phonological processing that were present may become exacerbated, reduced, or resolved altogether once adulthood is reached. A comprehensive study of the phonological processing skills of adults who stutter will allow for comparison to earlier studies that have measured these same abilities in children who stutter (Pelczarski & Yaruss, 2008) to determine if these subtle, subclinical differences will persist into adulthood. A thorough investigation would include lexical and non-lexical phonological awareness tasks (i.e., elision of words and phonemes, blending of word and phonemes, segmentation of words and phonemes, and phoneme reversal), phonological memory tasks (i.e., nonword repetition and digit span), and rapid automatic naming tasks (i.e., color, object, letter and digit naming). While Pelczarski and Yaruss (2008) reported significant differences in accuracy for children who stutter, studies of adults who stutter report only differences in the speed, but not the accuracy, of responses.

The studies reviewed above provide preliminary evidence that adults who stutter have different phonological processing skills; however, this evidence is gleaned from a small number of studies and some limitations exist. First, investigation of only one or two phonological processing tasks out of a wide range of abilities provides an incomplete picture of the phonological processing profile of an individual who stutters. Second, non-specification of which phonological processing skills were being measured coupled by the use of different nomenclature increases the difficulty of comparing and analyzing available evidence. Even though only a limited number of abilities were investigated, researchers tended to apply their results to phonological processing/phonological encoding as a whole. This is a very broad, and somewhat inaccurate, interpretation of the results. Third, nonword stimuli were not used in phonological awareness tasks in any study that would have allowed for a more accurate representation of phonological encoding free from the influence of lexical knowledge. Finally, the stimuli in the studies reviewed above may not have been complex enough to reveal the subtle linguistic differences in adults who stutter. Many studies have reported that linguistic differences in people who stutter tend to be subtle, where individuals who stutter scored within normal limits, yet still demonstrated a significant between-group difference (Bernstein Ratner, 1997; Conture, 2001; Hall et al., 2007; Pelczarski & Yaruss, 2008). The factors that influence performance on phonological processing skills can be controlled while utilizing a wide range of tasks that would be sufficiently difficult to stress the system in an attempt to reveal any subtle differences.

2.5 RESEARCH QUESTIONS

The focus of the current investigation was to utilize sensitive and well-controlled tasks to evaluate the full range of phonological processing abilities in adults who stutter. Evidence was presented that the phonological processing abilities of children who stutter are different from their typically fluent peers. Preliminary evidence also suggested that adults who stutter may have a delay or difference in phonological processing, although the evidence for adults who stutter came from investigations that did not closely control for variables known to influence phonological processing tasks. Thus, a well-controlled, comprehensive exploratory study of the phonological processing skills of adults who stutter was warranted.

The first aim of this study was to determine if the accuracy of phonological awareness abilities of adults who stutter were different from typically fluent adults. The phonological awareness tasks from the CTOPP, discussed in section 2.2.1, contain real-word stimuli and were similar to the ones administered in Pelczarski and Yaruss (2008) that revealed a significant difference in the phonological processing abilities of children who stutter. Use of a similar array of phonological processing tasks with adults who stutter allowed for direct comparison of the phonological processing skills of children and adults who stutter to determine if these abilities change as an individual matures. Previous studies have used tasks that have resulted in ceiling effects, yet if tasks and stimuli are sensitive enough to detect subtle linguistic differences it is hypothesized that adults who stutter will perform less accurately than non-stuttering participants.

The second aim of the study was to determine if adults who stutter possessed different phonological awareness skills when using non-lexical stimuli, as determined by accuracy performance on phonological awareness tasks with nonword stimuli. Lexical access has been shown to aid in the completion of phonological awareness tasks, thus making it difficult to determine whether performance is due to the help of the lexicon or is an accurate measure of an individual's phonological awareness ability. One way to address this concern was to utilize non-lexical stimuli in tasks to help isolate phonological awareness ability while reducing lexical influence. The Segmenting Nonwords and Blending Nonword subtests from the Alternate Phonological Awareness Composite Score of the CTOPP used non-lexical stimuli and could be used to address this concern. The differences in phonological awareness of children who stutter were reported to be significant, yet subtle, and it was believed that the differences in the more mature, adult system would require a more sensitive task to detect a difference. It was predicted that the nonword phonological awareness tasks would be more difficult for both groups; although adults who stutter would demonstrate more inaccurate responses than adults who do not stutter. Two sets of results were examined: within-group differences and between-group differences. Within-group differences between real word and nonword tasks were expected for both groups, with nonword tasks being more difficult than real word tasks. Between-group differences were also predicted, with the expectation that adults who stutter would perform less well on nonword phonological awareness tasks than typically fluent adults. A between-group difference on nonword phonological awareness tasks would indicate a difficulty retrieving phonological code at the level of phonological encoding instead of at the level of lexical access. If between-group differences were found for real word phonological awareness tasks, but not nonword phonological awareness tasks, the reverse would be true. It would be indicative of a difference involving the retrieval of the phonological code at the lexical level but not the level of phonological encoding.

The third aim of the study was to investigate whether adults who stutter perform phonological awareness tasks more slowly than their fluent peers. A number of studies have reported that adults who stutter display a delay, but not a difference, in the completion of phonological awareness tasks (Hennessey et al., 2008; Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2004; Wijnen & Boers, 1994). Some of these studies measured the time it took for participants to initiate a verbally spoken response (Hennessey et al., 2008; Wijnen & Boers, 1994). There is evidence that even the perceptually fluent speech of adults who stutter is different than the speech of typically fluent adults (Smith et al., 2010). Thus, it is difficult to know if the differences reported are due to a speech motor difficulty or a difference in phonological processing. An alternate way to access the processing speed of a phonological awareness task could be through the silent completion of the task (Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2008). In the present study, the participants performed a given phonological awareness task and used the result of that task to make a timed lexical decision as to whether or not the resulting item was a real word or a nonword. Although there was an added level of lexical access, due to the inclusion of a lexical decision component, the task could be completed without the possible influences of speech-motor differences which may be present even in perceptually fluent speech.

The fourth aim of the study was to determine whether adults who stutter perform less accurately on phonological memory tasks than people who do not stutter. Participants completed traditional tasks of phonological memory: digit naming and nonword repetition. These tasks are typically highly correlated and considered a good measure of phonological memory (Baddeley & Wilson, 1993; Butterworth et al., 1986; Gathercole et al., 2008; Gupta, 2003). Despite the strong correlation typically observed, the two subtests were not correlated in a study of children who stutter (Pelczarski & Yaruss, 2008). It was hypothesized in this study that adults who stutter will perform less accurately than adults who do not stutter on tests of nonword repetition, but not digit naming. If adults who stutter demonstrate no differences, contrary to the prediction, it would indicate that the phonological memory skills of adults who stutter have “caught up” to the performance of non-stuttering adults.

The fifth research aim also concerns phonological memory and nonword repetition. Not all nonword repetition tasks are sensitive enough to detect subtle linguistic differences. Specifically, it has been argued that the Nonword Repetition Task (Dollaghan & Campbell, 1998) may not be sensitive enough detect performance differences in older children and adults. Results of this test with adults and school-age children who stutter have often been cited as evidence that phonological encoding is not different in adults who stutter (Bakhtiar, Ali, & Sadegh, 2009;

Seery et al., 2006; Smith et al. 2010); however, there is evidence that ceiling effects are present with adults. The fifth research aim was to determine if adults who stutter performed differently within groups on the Late-8 Nonword Repetition Task (Dollaghan & Campbell, 2003) as compared to the Nonword Repetition Task. Between-group comparisons for each test were also conducted.

The sixth research aim was to determine if rapid automatic naming skills in adults who stutter were different from their typically fluent peers. Rapid automatic naming is closely associated with phonological awareness and phonological memory. Only one study has investigated rapid automatic naming in children who stutter and there are no studies that have investigated these skills in adults. The results of the study with children who stutter were equivocal (Pelczarski & Yaruss, 2008) but these abilities are known to develop with age, therefore, rapid automatic naming skills will be investigated as well.

Finally, it is important to note that performances on all tasks, even if significantly different from adults who do not stutter, are predicted to still be within normal limits or just slightly depressed (i.e., showing “sub-clinical” differences when compared to adults who do not stutter.; Newman & Bernstein Ratner, 2007; Hakim & Bernstein Ratner, 2004). If, contrary to the predicted results, adults who stutter were found to be no different from typically fluent adults in phonological processing, then one of three factors might be in play: (a) phonological encoding really may not actually be deficient in people who stutter (disproving the theoretical models of stuttering), (b) phonological processing skills may be interacting and supplementing each other to mask actual performance resulting in no between-group differences as evidenced by performance in the individual subtests and composite scores, or (c) phonological processing may not mirror phonological encoding as some researchers have suggested (Acheson & MacDonald, 2009).

In summary, the research questions are as follows:

1. Are adults who stutter less accurate in the completion of phonological awareness tasks as compared to adults who do not stutter indicating that phonological awareness differences persist into adulthood?
2. Does the lexical status of the stimuli (i.e., real word or nonword) influence the performance of adults who stutter on phonological awareness tasks indicating that lexical knowledge contributes equally for both groups?
3. Do adults who stutter take longer to complete phonological awareness tasks as compared to typically fluent adults, suggesting a speed-accuracy tradeoff?
4. Are adults who stutter less accurate in the completion of phonological memory tasks as compared to adults who do not stutter indicating that phonological memory differences persist into adulthood?
5. Will performance differences exist for adults who stutter on tests of nonword repetition that vary in phonological complexity, indicating that previous null findings (i.e., Nonword Repetition Task) have resulted due to the tasks not been sensitive enough to detect differences in phonological memory in adults who stutter?
6. Do adults who stutter take longer to complete rapid automatic naming tasks demonstrating a difference in rapid naming for adults that was not present for children?

The results of this line of research will help to clarify whether the phonological processing (i.e., phonological encoding) skills of adults who stutter are different from typically fluent adults. Findings from these research questions will also allow for comparison of the phonological processing skills of children who stutter (Pelczarski & Yaruss, 2008) to adults who stutter to determine if changes in these abilities occur across the lifespan. Finally, the research questions for the present study will help to support or disprove current psycholinguistic theories of stuttering that suggest that phonological encoding is delayed or disrupted in individuals who stutter.

3.0 METHOD

3.1 PARTICIPANTS

Participants were 19 monolingual, Standard American English speaking adults who stutter matched on age, sex, and education level to 19 adults who do not stutter. Participants ranged in age from 22 to 45 (mean age adults who stutter, $M = 32.68$; mean age adults who do not stutter, $M = 33.21$; $t(19) = .1627$, $p = 1.459$). The lower age limit was set at twenty-one years old to reflect the National Institutes of Health's definition of an "adult" being a person age 21 or older. The upper cut-off age for the study was 50 years old based on results reported by Fisk, McGee & Giambra (1988) that indicated young (i.e., aged 19-22) and middle-aged (i.e., aged 37-50) participants perform similarly on reaction-time studies and have reduced response variability as compared to an older group (i.e., aged 64-88) of participants. Each participant group consisted of 14 males and 5 females which reflected proportions similar to the sex ratio of 3 males to 1 female found in the general population (Bloodstein & Bernstein Ratner, 2008). A power analysis was performed with G*Power 3.0.10 to determine the appropriate number of participants necessary to reveal a medium effect size (.25) for this preliminary study. Alpha was set to .05 and power was .8 for a MANOVA with 2 groups and 1 response variable, recommended a total sample size of 34. The actual sample size of 38 was 13% larger than what was recommended by the power analysis. This study was approved by the Institutional Review Board (IRB) at the University of Pittsburgh. In accordance with IRB guidelines, all participants were read a "recruitment script" prior to their participation in the study. Participant recruitment occurred through the following four avenues: (a) fliers and advertisements posted around Pittsburgh, (b) referral by other speech-language pathologists, (c) word-of-mouth advertising for both stuttering and non-stuttering participants, and (d) the National Stuttering Association's membership. Aside from stuttering exhibited by the adults who stutter, all participants were free of known speech, language, hearing, or neurological difficulties based on participants' report.

3.2 INCLUSION AND MATCHING CRITERIA

3.2.1 Speech fluency

Participants were assigned to the group of adults who stutter if: (a) the participant received an overall score of at least 11 (mild) on the Stuttering Severity Instrument – 4th edition (*SSI-4*; Riley, 2009), (b) the participant identified him- or her-self as a person who stutters, and (c) the participant exhibited 3 or more stutter-like disfluencies (single-syllable word repetitions, part-word repetitions, sound prolongations, or blocks; e.g., Yairi & Ambrose, 1999) per 100 words of conversational speech. A range of mild to severe stuttering severities were included in the current study (very mild, N =4; mild, N =5; mild-moderate, N = 1; moderate, N = 1; moderate to severe, N = 5; severe, N = 3). Participants were placed in the group of adults who do not stutter if: (a) the participant received a total overall score of 10 (less than mild) or below on the *SSI-4*, (b) the participant did not identify him- or her-self as a person who stutters, and (c) the participant exhibited less than three disfluencies per 100 words of conversational speech (Yairi & Ambrose, 1999). Item (b) above indicates the participant's self-defined determination of their stuttering status, while item (c) indicates the speech-language pathologist's classification of the participant's overt stuttering characteristics.

3.2.2 Group matching criteria

Participants were matched by sex, age, and education level as these factors are known to influence language abilities. Equal numbers of male and female participants were balanced across groups. Participants were matched by age plus or minus 5 years to limit potential variability of language and/or cognitive ability that can occur in people of different age groups (Glisky, 2007). Education level of participants is often used as a measurement of SES and reading exposure. Participants' education level was obtained as one of the following categories: (a) some high school, N = 0; (b) graduated high school, N = 2; (c) some college, N = 6; (d) graduated college, N = 10; (e) advanced degree, N = 20. Table 6 summarizes the participants' demographic and background variables.

Table 6. Demographics. Demographics of adults who stutter (AWS) and adults who do not stutter (AWS).

Pair Number	Fluency Status	Age	ARHQ	EVT	PPVT	Gender	Education level	Stuttering Severity
Pair 1	AWS	34	0.42	100	122	Male	College Degree	Mild
	AWNS	35	0.22	103	108			
Pair 2	AWS	29	0.47	128	119	Male	Graduate Degree	Mild
	AWNS	30	0.11	100	115			
Pair 3	AWS	37	0.42	96	96	Male	Graduate Degree	Moderate-Severe
	AWNS	38	0.27	108	105			
Pair 4	AWS	24	0.16	97	113	Male	Graduate Degree	Moderate-Severe
	AWNS	23	0.38	90	108			
Pair 5	AWS	35	0.2	112	102	Male	Graduate Degree	Mild
	AWNS	35	0.57	103	110			
Pair 6	AWS	28	0.22	113	122	Male	Graduate Degree	Mild
	AWNS	29	0.24	103	107			
Pair 7	AWS	33	0.22	102	119	Male	Graduate Degree	Very Mild
	AWNS	35	0.38	110	110			
Pair 8	AWS	32	0.37	90	90	Male	Graduate Degree	Severe
	AWNS	33	0.29	90	97			
Pair 9	AWS	42	0.3	93	96	Male	Graduate Degree	Moderate-Severe
	AWNS	44	0.23	120	112			
Pair 10	AWS	31	0.44	88	94	Male	Some College	Mild-Moderate
	AWNS	28	0.32	97	103			
Pair 11	AWS	32	0.33	91	97	Male	College Degree	Moderate-Severe
	AWNS	39	0.36	101	95			
Pair 12	AWS	45	0.28	110	110	Male	High School	Very Mild
	AWNS	43	0.31	89	92			
Pair 13	AWS	36	0.45	92	98	Male	Some College	Moderate
	AWNS	39	0.25	92	108			
Pair 14	AWS	30	0.28	81	85	Male	College Degree	Moderate-Severe
	AWNS	29	0.26	89	97			
Pair 15	AWS	29	0.22	94	92	Female	College Degree	Severe
	AWNS	29	0.24	93	100			
Pair 16	AWS	24	0.39	96	102	Female	Graduate Degree	Severe
	AWNS	22	0.16	104	107			
Pair 17	AWS	28	0.17	90	108	Female	Graduate Degree	Very Mild
	AWNS	26	0.16	99	107			
Pair 18	AWS	38	0.3	100	96	Female	Some College	Mild
	AWNS	38	0.42	90	100			
Pair 19	AWS	34	0.21	97	104	Female	College Degree	Very Mild
	AWNS	36	0.33	96	100			

3.3 BACKGROUND DATA

3.3.1 Reading history

Reading ability and phonological processing are intricately linked (Stahl & Murray, 1994; Treiman & Zukowski, 1991), so a measure of reading history was obtained. The Adult Reading History Questionnaire (ARHQ; Lefly & Pennington, 2000) is a self-report questionnaire with Likert-scale scoring that can be used to determine if participants have a history of difficulty with reading. A ratio score is obtained and “a score of .30 is considered to be indicative of a positive history of reading disability” (Lefly & Pennington, 2000, p 296).

3.3.2 Vocabulary

Many aspects of language development have been shown to influence phonological awareness skills in children (Cooper, Roth, Speece, & Schatschneider, 2002), although less is known about phonological processing skills in adults. Still, vocabulary ability is highly correlated with phonological processing in children (Walley, Metsala & Garlock, 2003) and was measured to ensure that vocabulary was not a factor that influenced the results. Two standardized tests of vocabulary were administered to measure: (a) receptive vocabulary ability (Peabody Picture Vocabulary Test – III [PPVT-III], Dunn & Dunn, 1997), and (b) expressive vocabulary (Expressive Vocabulary Test [EVT], Williams, 1997). The PPVT-III required the participant to listen to a target vocabulary word and point to one of four pictures that best depicts the given word. The EVT required the participant to listen to a target word while looking at a descriptive picture and provide a synonym for the given word. Group-wise comparisons of the data from these measures were completed to provide additional information on the participants' overall language abilities. Vocabulary and reading history can influence performance on phonological processing tasks, thus it was important for the groups to perform equally on these tasks to ensure that any difference found in phonological awareness abilities were not due to differences in the background measures.

3.4 INSTRUMENTATION

Digital audio recordings of the stimuli were used for the CTOPP tasks, the Nonword Repetition Task, the Late-8 Nonword Repetition Task, the silent phonological awareness/lexical decision task, and the traditional lexical decision tasks. The sound files were played via a Lenovo ThinkPad T510 laptop and presented to the participants via Sony Dynamic Stereo Headphones MDR-7506. The silent phoneme blending/lexical decision task, traditional lexical decision task, Nonword Repetition Task and Late-8 Nonword Repetition Task were programmed into E-Prime Professional v. 2.0, and run on the Lenovo ThinkPad laptop. Lexical decision choice was recorded on a Psychological Software Tools serial response box (model #200A). The participants' responses were recorded electronically by the serial response box and E-Prime software onto the laptop's hard drive, as well as manually by the examiner to ensure accurate data collection. Digital audio and video files of the entire session were recorded on a Samsung

AD69 Flash CAM digital video recorder. The sound and video files were used in reliability testing as described more fully in section 3.7.

3.5 DATA COLLECTION

3.5.1 Phonological awareness tasks with lexical stimuli

Four subtests that measure traditional phonological awareness skills were administered: Elision, Blending Words, Phoneme Reversal, and Segmenting Words (CTOPP, Wagner et al., 1999). These tasks were used to determine a Phonological Awareness Composite Score as instructed by the CTOPP manual. The Elision subtest required participants to listen, via headphones, to a digital recording of a word as well as instructions to remove one phoneme from the word to create a new target word (e.g., /mit/ “meet” without /t/ is /mi/). Stimuli difficulty increased through manipulation of the number of syllables, the location of the phoneme to be removed, and the presence of consonant clusters. Participants were provided with practice trials before the task was initiated. Participants spoke their responses aloud, and stuttered responses were included in the scoring totals because accuracy was being measured regardless of whether the answer was stuttered. Participants were scored on accuracy, not speed, until a ceiling was reached. A raw score was recorded and a standard score for the task was determined.

The Blending Words subtest required the participants to listen to a digital recording of individually-presented phonemes through headphones and were instructed to blend the sounds together to create a word (e.g., /k-æ-t/ “c-a-t” = / kæt/). Participants were asked to say their responses out loud to determine accuracy of the blending task. This task also progressed from developmentally simple to more difficult through adjustment of stimuli characteristics. The stimuli increased in terms of number of phonemes, ranging from two to ten phonemes, as well as number of syllables, ranging from one to four syllables. Accuracy was again the metric used and stuttered responses were also included in the scoring totals. Once a ceiling was reached, the raw score was translated into a standard score and combined with the standard score of the elision subtest to create a Phonological Awareness Composite Score of a participant’s abilities when using real-word stimuli.

Two additional subtests that were not included in either of the Composite Scores (i.e., Phoneme Reversal and Segmenting Words subtests) were also administered. The Phoneme Reversal subtest was the most developmentally difficult task to complete, and as such, had the potential to detect differences between the abilities of adults who stutter and typically fluent adults. Participants listened to a digital recording of a nonword via headphones and were given instructions to first repeat the nonword to ensure the item was heard correctly and then to “reverse the sounds to say the word backwards” (e.g. /kiʧ/ “keech” = / ʧik/ “cheek” backwards). Stimuli increased in difficulty through the number of phonemes that increased from two to seven, number of syllables that increased from one to two, and the presence or absence of consonant clusters. A spoken response was again required, and practice items were provided to allow participants to gain some experience with the task. Participants were scored on accuracy and a standard score was obtained by following the protocol outlined by the CTOPP’s authors.

Segmenting Words is another subtest that was administered to participants but was not included in a Composite Score for the CTOPP. This task required a real word to be spoken by the primary investigator and was to be repeated back by the participant to confirm that the item was heard correctly. Participants were then instructed to say the individual phonemes of the word aloud (e.g., “Say *pie*. Now say *pie* one sound at a time” = /p-i/). Just as with the other subtests, the stimuli increased in difficulty in terms of phonemes that increased from two to nine, syllable length that increased from one to three syllables, and the presence of consonant clusters. Practice items were completed before initiating the task. Participants’ responses were scored according to accuracy and converted into standard scores.

3.5.2 Phonological awareness tasks with nonword stimuli

Phonological awareness tasks that use nonword stimuli provide additional information on the phonological awareness abilities without the aid of lexical knowledge (Durgunoglu & Oney, 1999; Wagner et al., 1999). Thus, an Alternative Phonological Awareness Composite score was also obtained using nonword stimuli via the administration of the supplemental subtests: Blending Nonwords and Segmenting Nonwords. Stimuli for both subtests were digitally recorded and listened to by the participant via headphones. Blending Nonwords is similar to the Blending Words subtest described above in section 3.5.1, except that the phonemes are blended together to create a nonword. Several practice items were provided. Participants were asked to verbalize their responses to be transcribed by the examiner on-line. Any error in the response was marked as an incorrect answer regardless of the number of errors. Stuttered responses were counted as either correct or incorrect based on the answer, not on whether a stutter was present. A standard score was obtained by following the protocol outlined by the CTOPP’s authors.

The Segmenting Nonwords subtest of the CTOPP was also completed by the participants to provide additional data on non-lexical tasks. While listening to the stimuli through headphones, the participants heard a nonword and were asked to repeat the nonword out loud. The participants were then required to repeat the item back one sound at a time while the examiner transcribed the responses. As with the blending nonwords subtest, one phoneme error resulted in the item being marked incorrect and any stuttered responses were included in the scoring totals. The participants were provided with several practice items before the task was initiated.

3.5.3 Phonological awareness reaction times

3.5.3.1 Silent phonological awareness/lexical decision

There is evidence that adults who stutter take significantly longer to complete phonological awareness tasks than typically fluent adults (Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2004; Wijnen & Boers, 1994). Thus, a silent phoneme blending task was performed to allow access to the timing of phonological awareness abilities of people who stutter without requiring a spoken response (Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2004). The lexical decision component of the task was predicated on the successful blending of the item and the subsequent classification of the stimulus as a word or nonword. Stimuli were digitally recorded and programmed into E-Prime. Participants listened to the stimuli via headphones and were instructed to place the index finger of their dominant hand on “home base” of the response box (i.e., a button between the “word” and “nonword” buttons).

The same finger was used to select the response button for each trial, with the finger returning to a neutral position after each response. Initiating responses from the "home base" position ensured that the distance traveled to the response buttons on either side was the same, thus reducing the potential influence of distance on reaction times. Four practice opportunities were provided to allow participants a chance to become acclimated to the task. Participants were informed that they would first hear a brief tone followed by a string of phonemes spoken one at a time. Both groups were given instructions to blend those phonemes together silently to create either a real word or a nonword. Participants were then required to make a lexical decision by pressing the appropriate response-time button to indicate their choice. After the lexical decision was made, participants were asked to produce the newly blended item aloud to allow for an accuracy determination of the phoneme blending task by the examiner. This accuracy measure was recorded in addition to the lexical decision accuracy and response-time data collected by the E-Prime software. Responses were transcribed and scored by the clinician to determine a percent correct score. The E-Prime software was programmed to pause after recording the lexical decision response and not to proceed with the next item until the researcher pressed the space bar to re-initiate the program. This allowed the participant ample time to respond, and also allowed the researcher time to record the behavioral data. Both timing and accuracy data were collected on the lexical decision aspect of the task. Any stuttered response was indicated on the transcript and scored according to the accuracy of the response regardless of the stutter.

The stimuli used in the silent phoneme blending/lexical decision task contained 36 items balanced across two lists. Thirteen real words, 13 nonwords, and 10 filler words (i.e., five filler real words and five filler nonwords) populated the lists. The words range in length from two to ten phonemes, with three stimulus items at each length. The stimuli in each list were categorized into three separate blocks, each containing three sets of phoneme lengths (i.e., Block 1 = phoneme lengths 2, 3, & 4; Block 2 = phoneme lengths 5, 6, & 7; Block 3 = phoneme lengths 8, 9, & 10). The standard practice for tests of phonological processing is to gradually increase the length of the stimuli (Wagner et al., 1999), presenting shorter stimuli first and ending with longer, more challenging stimuli. Table 7 illustrates that this principle was followed in the presentation order for the current study; although the stimuli within each block was quasi-randomized to address presentation order concerns while still generally preserving the progression from shorter, simpler stimuli to longer, more complex stimuli.

The stimuli were created in consideration of multiple factors. First, the potential pool of words was restricted by word frequency (i.e., average word frequency: 43,399; range 25,500-65,500) according to the English Language Project (ELP; Balota et al., 2007), which rates word frequency according to the number of times a word occurs per every million words. Potential stimuli were excluded if they were compound words or contained grammatical morphemes (i.e., -s, -ed, -ly, -ing, un-, re-). Stimuli were then limited by mean accuracy in lexical decision tasks with an average accuracy score falling between 0.9 and 1.0 (ELP; Balota et al., 2007). Lists were also balanced for phonotactic probability between real word and nonword test items ($t = .387$; $p = 0.705$), between lists containing both real words and nonword test items ($t = .387$; $p = .705$), and between full lists of real word and nonword test and filler items ($t = .004$; $p = 0.99$). These

Table 7: Silent phoneme blending. Stimuli and presentation order for silent phoneme blending/lexical decision task.

Number of Phonemes	List 1 Stimuli	Number of Phonemes	List 2 Stimuli
2	/ ɚn/*	4	/bɔns/*
3	/dik/	2	/æg/
4	/kebl/*	3	/yit/*
2	/ig/	4	/ədlʊ/
4	/ʌsʊm/	3	/ʃɔt/
3	/luk/	2	/ais/
5	/vɪɡɪt/*	6	/stebʌs/*
6	/kɔmɛnt/	7	/sɛntræf/
7	/dɪmɪnɪʃ/	5	/fimel/
5	/fərgɛk/	6	/ɪnkrif/
7	/kɔngrɛs/	7	/ɪɡnoræns/
6	/momɛnz/	5	/dæmæʒ/
8	/ɪnfordeʃʌn/*	8	/ɪnstɪtuk/
9	/sʌkjerɪti/	9	/ikwɪdmɛnt/*
10	/kʌmjʊnɪket/	8	/ɛkʌnɔmɪk/
9	/ɑrgjəmənk/	10	/ilɛktrɑnɪd/
10	/ɪndəvɪdʒəwəg/	9	/dɔkjumɛnt/
8	/ʌdriʃiet/	10	/ɪkwɪvʌlɛnt/

* = filler words.

probability measures were determined through the Phonotactic Probability Calculator (PPC; Vitevitch & Luce, 2004). Nonword test stimuli were created from real words that matched the above-mentioned criteria and were converted into nonwords by changing the final phoneme only. Although the resulting nonwords were very “word-like” and thus easier to process than “less word-like” nonwords (Gathercole, 1995), the primary goal of the task was phoneme blending, and it was important for the participant to attend to the entire stimulus item. Typical populations have been observed to name real words faster than nonwords. Nonwords with a single phoneme changed in both the initial and medial positions were also included as foils. All stimuli were recorded onto a Dell Optiplex 760 desktop computer in a sound booth while using Adobe Audition 3.0 software and an Audio-Technica ATR20 microphone. Each individual phoneme of a stimulus item was recorded onto a single track and then cut, spliced, and saved into a separate sound file for each word. Phonemes were separated by 500 milliseconds of silence generated by the Adobe Audition 3.0 software, as this is the standard length of silence for tasks of this type (Wagner et al., 1999).

3.5.3.2 Traditional lexical decision

The instructions for the lexical decision task were similar to those for the silent phoneme blending/lexical decision task. Again, participants listened to the stimuli using headphones and were instructed that they would hear a short tone (75 milliseconds) followed by an aurally delivered stimulus item. In this task a word or nonword was presented instead of individual phonemes. A decision regarding an item’s lexical status was made by pressing the appropriate button on the stimulus response box, with no verbal response required. Once the button was pressed, the E-Prime software triggered the presentation of the next stimulus item after a 500 millisecond pause. In addition to the timing and accuracy data collected by the E-Prime program, the experimenter collected accuracy data by recording the individual's response on a score sheet during testing.

The purpose of this task was to; (a) ensure there were no significant between-group differences in lexical access, and (b) to provide data to "subtract out" the lexical decision component of the silent phoneme blending/lexical decision task. Thus, the stimuli for the traditional lexical decision task were created in the same manner as the silent phoneme blending/lexical decision task. Word frequency (i.e., average word frequency: 43,399; range 25,500-65,500; ELP; Balota et al., 2007) and phonotactic probability (PPC; Vitevitch & Luce, 2004) were controlled for experimental real words and nonwords as well as fillers for both lists. No differences in phonotactic probability were present between real words and nonwords ($t = 1.213$; $p = .420$), between lists of both real word and nonword experimental items ($t = 1.317$; $p = .204$), between full lists of experimental and filler items ($t = 1.169$; $p = .257$) or between-task (e.g., silent phoneme blending/lexical decision and lexical decision tasks) lists ($t = .498$; $p = .624$). Table 8 demonstrates that the presentation order for the items by phoneme length was identical to the preceding task. In addition to the experimental stimuli, both real word and nonword fillers were included as foils. Stimuli were digitally recorded and programed into E-Prime.

Table 8: Lexical Decision. Presentation order and stimuli for traditional lexical decision task.

Number of Phonemes	List 1 Stimuli	Number of Phonemes	List 2 Stimuli
2	/si/*	4	/mɪdl/*
3	/gʊt/*	2	/ot/
4	/ʊrɔs/*	3	/pɔt
2	/tʊ/	4	/siɔk
4	/pɛti/	3	/fɪt/
3	/dʌp/	2	/te/
5	/siɪns/*	6	/tɚfɛct/*
6	/ɛfɚvɛs/	7	/orɛndɪk/
5	/prife/	5	/ɪgnor/
7	/hɛtmɔks/	6	/stætʌf/
6	/frɪdʌt/	7	/præktɪs/*
7	/pɔpjulɚ/	5	/ilænd/
8	/tiʌhoktʌ/*	8	/kɔnfɚɛnt/
9	/ikwɪpmɛnt/	9	/ɛkspɛntɪv/*
10	/rɛdʒɪstreʃn/*	10	/stɪmjʊləɑŋ/
9	/dæpʊksɚɔg/	8	/kɔntrækt/
10	/zʊgmʊbgɛks/	9	/kʌmjunɪti/
8	/kʌmpjʊtɚ/	10	/tədɔksimɛg/

* = filler words

3.5.3.3 Pilot data

Typical populations demonstrate a word-length effect when performing a lexical decision task. Shorter words containing fewer phonemes are responded to faster than longer words containing more phonemes (Meyer, Roelofs, & Levelt, 2003; Meyer, Belke, Hacker, and Mortensen, 2007; Santiago, MacKay, Palma, & Rho, 2000). A similar effect exists when completing a lexical decision task with real word and nonword stimuli; the lexical items are responded to faster than non-lexical items in typical populations (Meyer & Schvaneveldt, 1971). One aim of the current lexical decision task was to demonstrate that these effects were present when using these stimuli to ensure that they would produce representative results. Tables 9 and 10 detail the results of a small pilot study (N = 6) that confirmed that both findings were present ($t > 2.583$; $p < .03$). A large effect size was present for both length and lexical status ($d > .70$). These data demonstrate that the stimuli for the silent phoneme blending/lexical decision task will produce the expected lexical-status effect and phoneme-length effect as expected in typical populations.

Table 9. Length effect. Mean (*M*), standard deviation (*SD*) and paired *t*-test (*t*), *p*-value (*p*), and *Cohen's d* (*d*) demonstrating evidence of a length effect.

	Average Response Time in Seconds for 2-4 Phonemes	Average Response Time in Seconds for 8-10 Phonemes	Test Statistics
Stimulus Length Effect	$M = 1152$ $SD = 271$	$M = 2134$ $SD = 639$	$t = 3.293$ $p = .030$ $d = -2.31$

Table 10. Lexical status effect. Mean (*M*), standard deviation (*SD*) and paired *t*-test (*t*), *p*-value (*p*), and *Cohen's d* (*d*) demonstrating evidence of a lexical status effect.

	Real Word Stimuli	Nonword Stimuli	Test Statistics
Lexical Status Effect	*M* = 1466 *SD* = 719	*M* = 1999 *SD* = 829	*t* = 2.583 *p* = .021 *d* = -.70

3.5.4 Phonological memory

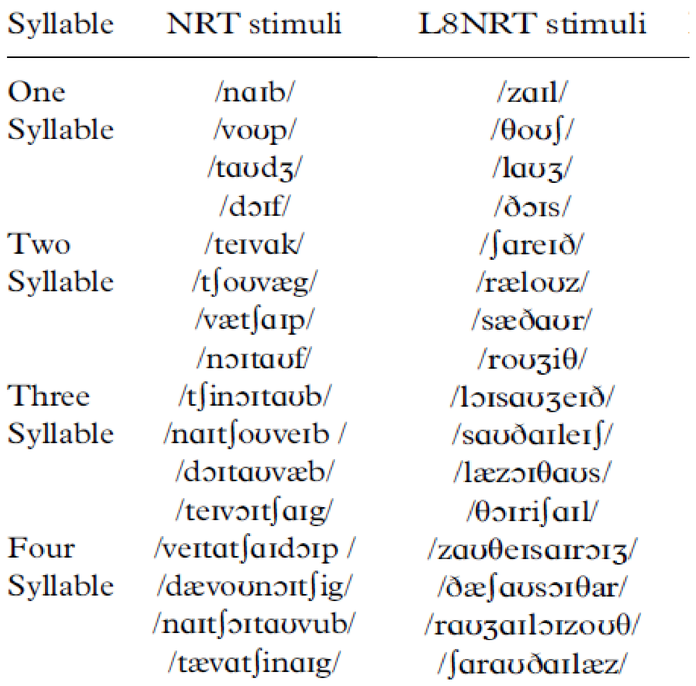
The Phonological Memory Composite Score represents the participant's performance on two traditional tasks of phonological memory from the CTOPP: Memory for Digits and Nonword Repetition. The Memory for Digits subtest required the participants to listen to a digital audio recording of digit strings via headphones and repeat the numbers back in the correct order. The digit recall began with two ordinal numbers from one through nine and increased in length up to eight ordinal numbers, and four practice opportunities were provided. The responses were recorded by the examiner on-line and included stuttered responses in the scoring total.

The Nonword Repetition subtest of the CTOPP required the participants to listen to a digital audio recording of phonotactically-legal nonwords and repeat them back aloud as accurately as possible. Stimuli increased in difficulty according to the number of syllables (e.g., ranging from one to seven syllables), number of phonemes (e.g., ranging from three to 15 phonemes), and the presence of consonant clusters. Three practice trials were presented before data collection began. The examiner transcribed the participants' responses, including any stuttered responses, to determine a standard score.

3.5.5 Nonword repetition

Two additional nonword repetition tasks were performed by the participants. The Nonword Repetition Task and Late-8 Nonword Repetition Task stimuli were digitally recorded and were presented to the participants via headphones. Each task consisted of 16 stimuli and ranged from

Table 11. Nonword repetition. Nonword Repetition Task and Late-8 Nonword Repetition Task stimuli.



Syllable	NRT stimuli	L8NRT stimuli
One Syllable	/naɪb/	/zaɪl/
	/voʊp/	/θoʊʃ/
	/taʊdʒ/	/laʊʒ/
	/dɔɪf/	/ðɔɪs/
Two Syllable	/teɪvak/	/ʃareɪð/
	/tʃoʊvæg/	/ræloʊz/
	/vætʃaɪp/	/sæðaʊr/
	/nɔɪtaʊf/	/roʊʒiθ/
Three Syllable	/tʃinɔɪtaʊb/	/lɔɪsaʊʒeɪð/
	/naɪtʃoʊveɪb /	/saʊðaɪleɪʃ/
	/dɔɪtaʊvæb/	/læzɔɪθaʊs/
	/teɪvɔɪtʃaɪg/	/θɔɪriʃaɪl/
Four Syllable	/veɪtatʃaɪdɔɪp /	/zaʊθeɪsaɪrɔɪʒ/
	/dævoʊnɔɪtʃig/	/ðæʃaʊsɔɪθar/
	/naɪtʃɔɪtaʊvub/	/raʊʒaɪlɔɪzoʊθ/
	/tævatʃinaɪg/	/ʃaraʊðaɪlæz/

one to four syllables (four stimuli at each syllable level, see Table 11). Participants were instructed to repeat the nonwords as clearly and accurately as possible to allow for the responses to be transcribed by the examiner. A percent-phoneme correct score was determined for both tasks.

3.5.6 Rapid automatic naming

A Rapid Automatic Naming Composite score was determined through the administration of four rapid automatic naming subtests: Rapid Object Naming, Rapid Color Naming, Rapid Letter Naming, and Rapid Digit Naming. All items from the four subtests (i.e., objects, colors, letters, and numbers) were expected to be familiar to adult participants. Before each subtest, participants were asked to name all of the items included in the rapid naming task to ensure participants' familiarity with the items. Administration of the four subtests occurred in the same manner and only differed in the stimuli that were depicted in the test booklet (e.g., objects, colors, letters, or digits). The participants viewed a sheet that depicted four rows of stimuli (36 stimuli per sheet) and were instructed to name them aloud as quickly as possible. The task was timed on a digital stopwatch and the examiner recorded the number of seconds it took to complete the task. The participants then repeated the task using the second sheet of stimuli, which depicted the same items as the first time, although in a different order, and a second time was obtained. The first and second times were added together to obtain a raw score that was converted into a standard score.

3.6 PROCEDURES

Participants were seated at a table with the examiner while performing all tasks, and all sessions were video- and audio- recorded to allow for reliability checks (please refer to section 3.7 below for more detail). Digital recordings of the task stimuli were used to provide consistency across participants. The stimuli were listened to via headphones and participants were asked to adjust the volume to a comfortable loudness level. The examiner also listened to the stimuli presentation via headphones to ensure that the stimuli were presented according to specifications. Testing occurred in a single session that lasted approximately one and a half hours, with short breaks taken as necessary. Speech fluency can change as the participants become more comfortable, so a fluency count was obtained at the beginning of the session during conversational speech between the participants and the researcher and also from a short reading sample. The Adult Reading History Questionnaire was also completed by the participants at the beginning of the session. Completion of the questionnaire required little effort by the participant and allowed some time for the participant to get situated before moving on to the completion of more difficult tasks. One of three presentation orders was administered by the examiner after the speech sample and reading history were obtained. Table 12 outlines the three quasi-randomized presentation orders.

Table 12. Counter-balanced task administration orders.

ORDER 1	ORDER 2	ORDER 3
Stuttering Severity Instrument-4	Stuttering Severity Instrument -4	Stuttering Severity Instrument-4
Adult Reading History Questionnaire	Adult Reading History Questionnaire	Adult Reading History Questionnaire
Peabody Picture Vocabulary Test-III	Comprehensive Test of Phonological Processing	Nonword Repetition Task
Expressive Vocabulary Test	Traditional Lexical Decision Task	Late-8 Nonword Repetition Task
Comprehensive Test of Phonological Processing	Silent Phoneme Blending / Lexical Decision Task	Peabody Picture Vocabulary Test-III
Traditional Lexical Decision Task	Late-8 Nonword Repetition Task	Expressive Vocabulary Test
Silent Phoneme Blending / Lexical Decision Task	Nonword Repetition Task	Comprehensive Test of Phonological Processing
Nonword Repetition Task	Expressive Vocabulary	Traditional Lexical Decision Task
Late-8 Nonword Repetition Task	Peabody Picture Vocabulary Test-III Test	Silent Phoneme Blending / Lexical Decision Task

3.7 MEASUREMENT RELIABILITY

3.7.1 Standardized test reliability and validity

Well-established, standardized phonological awareness subtests of Elision, Blending Words, Segmenting Words and Phoneme Reversal from the CTOPP were given to the participants. The CTOPP has been reported as a reliable and valid tool for measuring phonological processing. The reliability coefficients range from .77 to .90 for the individual subtests and from .83 to .95 for composite scores demonstrating a suitable degree of test reliability (Wagner et al., 1999). Per guidelines from Ebel (1972) and Pyrczak (1973), the CTOPP has also demonstrated adequate content validity of greater than .35 ($r = .41$ to .72) for all subtests and composite scores. The construct validity of the CTOPP yielded a confirmatory factor analysis of .99 (out of a possible 1.00) and yielded a *Chi Square* of 27.6, with 6 degrees of freedom, providing support for the test's construct validity (Wagner et al., 1999).

3.7.2 Inter- and intra-rater reliability

All data were collected by the examiner, a certified speech-language pathologist with eight years of experience administering standardized tests, to maintain consistency in instructions and procedures. Scoring was conducted on-line during the original experimental session, while the standard scores were calculated for a given participant after data collection was completed. Due to the overt nature of stuttering, it was not possible to completely blind the speech-language pathologist to the participant's group status (i.e., stuttering or non-stuttering). Thus, the data from the first six participants (i.e., three from each group; 15% of the data) were independently scored by a second certified speech-language pathologist to ensure that evaluator bias was not present. The second speech-language pathologist was experienced in the administration and scoring of the tests in the battery as well as in the analysis of disfluent speech. The original scores were compared to the independently scored data to determine percentages of agreement for the CTOPP (range = 90% to 100%; average = 95%), NRT (range = 94% to 100%; average = 97%), L8NRT (range = 92% to 97%; average = 94.5%), lexical decision (range = 99% to 100%; average = 99.5%), and silent phoneme blending/lexical decision task (range = 96% to 99%; average = 97.5%).

Intra-rater reliability was determined by randomly selecting six different participants (three from each group; 15% of the data) to be scored a second time by the examiner approximately two months after data collection was completed. The examiner was blinded to the original scores of the participants. The second round of scoring was compared to the original data to determine percentages of agreement for the CTOPP (range = 97% to 100%; average = 98.5%), NRT (range = 98% to 100%; average = 99%), L8NRT (range = 96% to 99%; average = 97.5%), lexical decision (range = 100%; average = 100%), and silent phoneme blending/lexical decision task (range = 99% to 100%; average = 99.5%).

3.8 ANALYSES

The current exploratory study sought to investigate whether adults who stutter would perform less well on phonological processing tasks as compared to typically fluent peers. As such, a series of paired, one-tailed *t*-tests were conducted to compare the groups' performance on the phonological awareness, phonological memory and rapid automatic naming tasks from the CTOPP. This exploratory study maintained individual *p*-values of .05 to maintain the paired samples and test the hypothesis that adults who stutter perform less well than adults who do not stutter. Because the individual alpha was set to .05, the results must be interpreted with caution and re-evaluated with future studies. General Linear Model analyses were conducted on the traditional lexical decision task and the silent phoneme blending task to determine the residual data for the silent phoneme blending task. Once the influence of the lexical decision times were removed from the overall silent phoneme blending times, only the residual data remained. The subtraction of the lexical decision reaction times then revealed silent phoneme blending reaction times that more closely represented the time required to complete the task. Finally, an ANOVA was conducted to compare the different length and lexical status conditions between groups. The outcomes from these analyses will be discussed next.

4.0 RESULTS

The aim of the current investigation was to determine if differences existed in the phonological awareness, phonological memory and rapid automatic naming abilities of adults who stutter as compared to adults who do not stutter. The following section provides the result of these analyses.

4.1 DESCRIPTIVE MEASURES

Table 13 displays the means and standard deviations for both groups on the descriptive measures. One-tailed, paired *t*-tests revealed no significant between-group differences ($t > .829$; $p > .05$) for age, reading history (ARHQ), expressive vocabulary (EVT), or receptive vocabulary (PPVT-III). Similar group performances indicated that the groups were relatively well matched on these factors. Effect sizes were at or near zero.

Table 13. Descriptive measures. Means (*M*), standard deviation (*SD*), within-group, one-tailed *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for descriptive measures including age, reading history, and vocabulary.

	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Age	*M* = 33.4 *SD* = 5.74	*M* = 33.9 *SD* = 6.75	*t*(18) = -1.459 *p* = .163 *d* = -.09
Adult Reading History Questionnaire	*M* = .30 *SD* = .09	*M* = .30 *SD* = .08	*t*(18) = 1.012 *p* = .325 *d* = .19
Expressive Vocabulary Test	*M* = 94.2 *SD* = 7.19	*M* = 95.8 *SD* = 6.67	*t*(18) = .829 *p* = .418 *d* = -.11
Peabody Picture Vocabulary Test-III	*M* = 99.3 *SD* = 9.17	*M* = 102.2 *SD* = 6.20	*t*(18) = -.946 *p* = .357 *d* = -.10

4.2 PHONOLOGICAL AWARENESS WITH LEXICAL STIMULI

The CTOPP contains Phonological Awareness subtests that utilize both lexical (i.e., real word) stimuli and non-lexical (i.e., nonword) stimuli in the performance of similar tasks. Lexical and non-lexical stimuli are believed to assess different functions, and both were examined. Degrees of freedom for each task in the CTOPP varied due to the removal of outlier data as discussed in s section 3.8. The composite and subtest scores analyzed in the following section use real-word stimuli to which allows an individual to access stored lexical information that can influence performance on phonological awareness tasks.

4.2.1 Phonological awareness composite score

A series of five one-tailed paired t-tests are summarized in Table 14. No significant difference in performance on the Phonological Awareness Composite score was present for adults who stutter as compared to nonstuttering adults (*t* = -1.692; *p* = .119). Analysis of performance on the constituent subtests of Elision and Blending Words revealed that adults who stutter scored significantly lower than adults who do not stutter on the Elision subtest (*t* = -2.555; *p* = .02) yet performed similarly on the Blending Words subtest. The Phoneme Reversal and Segmenting Words subtests, which were not included in the computation of the Composite scores, did not reveal any significant differences (*t* > -1.692; *p* > .05) in group performance on these two subtests. As described above, the differences between groups were expected to be subtle, and these data may indicate that adults who stutter have difficulty with some phonological awareness tasks. This difference may not have been strong enough to reveal differences in both subtests, but still provides an indication that some differences are present.

Table 14. Phonological awareness - lexical. Means (*M*) standard deviation (*SD*), between-group *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for Phonological Awareness Composite Score (lexical) and subtests of the *Comprehensive Test of Phonological Processing*.

	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Phonological Awareness Composite	*M* = 96 *SD* = 12.5	*M* = 88 *SD* = 10.8	*t*(17) = -1.639 *p* = .119 *d* = -.42
Elision subtest	*M* = 101 *SD* = 8.7	*M* = 93 *SD* = 11.1	*t*(17) = -2.555 *p* = .020 *d* = -.64
Blending Words subtest	*M* = 10.1 *SD* = 2.7	*M* = 10.4 *SD* = 2.3	*t*(17) = -1.118 *p* = .279 *d* = -.12
Phoneme Reversal subtest §	*M* = 8.8 *SD* = 1.7	*M* = 9.8 *SD* = 2.0	*t*(15) = -2.052 *p* = .056 *d* = - .55
Segmenting Words subtest §	*M* = 8.9 *SD* = 2.7	*M* = 9.7 *SD* = 1.9	*t*(18) = -1.692 *p* = .108 *d* = -.35

§ Indicates subtests were not included in Composite Score

4.3 PHONOLOGICAL AWARENESS WITH NON-LEXICAL STIMULI

Phonological awareness tasks that use both lexical (i.e., real word) and non-lexical (i.e., nonwords) are included in the CTOPP, as discussed in section 4.2. The following section presents the between-group comparisons and correlational analyses of the Alternate Phonological Awareness tasks that utilize non-lexical stimuli.

4.3.1 Alternate phonological awareness composite scores

Table 15 presents the means and standard deviations for both the alternate and traditional Phonological Awareness Composite scores. One-tailed, paired *t*-tests revealed that both groups performed better on tasks with lexical, rather than non-lexical, stimuli demonstrating a large effect size (*d.>.73; t* > 2.558; *p* < .05).

Table 15. Phonological awareness composite scores. Mean (*M*) and standard deviation (*SD*), within-group *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for adults who stutter and adults who do not stutter on phonological awareness tasks.

	Phonological Awareness Composite Scores (Lexical)	Alternative Phonological Awareness Composite Scores (Non-lexical)	Test Statistics
Adults Who Stutter	$M = 96$ $SD = 12.5$	$M = 88$ $SD = 10.8$	$t(18) = 2.558$ $p = .019$ $d = .73$
Adults Who Do Not Stutter	$M = 101$ $SD = 8.7$	$M = 93$ $SD = 11.1$	$t(18) = 2.807$ $p = .011$ $d = .80$

Table 16 shows the average scores, standard deviations and between-group, one-tailed, paired *t*-tests for the non-lexical Alternative Composite and the related subtests. Adults who stutter performed significantly lower than typically fluent adults on the Alternate Phonological Awareness Composite score that used tasks with non-lexical stimuli (*t* > -2.164; *p* < .05). This difference was also present with the two constituent subtests: Blending Nonwords and Segmenting Nonwords (*t* > -2.168; *p* < .05). The results from the Elision task described in the previous section indicate that some differences in phonological awareness ability were present for adults who stutter when using lexical stimuli. These differences in performance on phonological awareness tasks became more pronounced when nonword stimuli were used. Taken together, these findings indicate that adults who stutter appear to perform better than nonstuttering adults on phonological awareness tasks *until* the real word stimuli are replaced with nonword stimuli. The use of nonword stimuli precludes access to lexical-semantic information that can bolster reduced phonological awareness abilities, thus masking any potential difference. Deficits in the phonological awareness of adults who stutter were fully revealed when nonword stimuli were used.

Table 16. Phonological awareness – nonlexical. Mean (*M*) and standard deviation (*SD*), between group *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for Alternative Phonological Awareness Composite score (non-lexical) and subtests of the *Comprehensive Test of Phonological Processing*.

	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Phonological Awareness Composite	*M* = 96.3 *SD* = 12.5	*M* = 100.7 *SD* = 8.7	*t*(17) = -1.639 *p* = .119 *d* = -.42
Alternate Phonological Awareness Composite	*M* = 88.0 *SD* = 10.8	*M* = 92.9 *SD* = 11.1	*t* (18) = -2.164 *p* = .022 *d* = -.42
Blending Nonwords subtest	*M* = 7.7 *SD* = 2.7	*M* = 9.2 *SD* = 2.5	*t* (18) = -2.168 *p* = .044 *d* = -.12
Segmenting Nonwords subtest	*M* = 7.7 *SD* = 2.0	*M* = 8.4 *SD* =1.8	*t* (17) = -2.232 *p* = .039 *d* = -.38

4.4 PHONOLOGICAL AWARENESS REACTION TIMES

A lexical decision task and a silent phoneme blending/lexical decision task were completed to determine how quickly adults who do and do not stutter were able to complete the task. The lexical decision task was used as a baseline to compare to the silent phoneme blending/lexical decision task, while the silent phoneme blending task was used to determine if adults who stutter complete phonological awareness tasks as quickly as typically fluent adults. The results of these analyses are discussed below.

4.4.1 Lexical decision accuracy

Table 17 outlines the number of stimuli that were correctly identified in the lexical decision task at each length and lexical status level. *Chi squared* analyses were conducted to determine whether the distribution of the number of correctly answered stimuli was equivalent for both groups across the length and lexical status conditions. No significant differences between groups were present for accuracy, as both groups performed the lexical decision task as expected for both real words ($\chi^2 = .131$; $p = .936$) and nonwords ($\chi^2 = .171$; $p = .917$). Table 18 provides the lexical decision reaction time means and standard deviations for each word length (i.e., short, medium, long) and lexical status (i.e., word, nonword) for adults who stutter and typically fluent adults. No statistically significant differences were present, indicating that the groups were comparable in terms of accuracy as well as reaction times ($t > .735$; $p > .05$).

Table 17. Lexical decision accuracy by length and lexical status. Accuracy and *Chi Squared* (χ^2) levels on traditional lexical decision task for adults who stutter and adults who do not stutter at short, medium, and long stimuli lengths.

	Adults Who Stutter	Adults Who Do Not Stutter	*Chi Squared* for Words and Nonwords
Word Short	221	225	
Word Medium	182	187	
Word Long	165	161	$\chi^2 = .131$ $p = .936$
Nonword Short	190	183	
Nonword Medium	203	199	
Nonword Long	184	188	$\chi^2 = .171$ $p = .917$
Total Number Correct	1145	1143	

Table 18. Lexical decision between groups. Mean (*M*) and standard deviation (*SD*), between group *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for lexical decision reaction times by group, lexical status and length.

	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Word Short	$M = 411.5$ $SD = 106.8$	$M = 400.1$ $SD = 122.6$	$t(18) = .783$ $p = .444$ $d = .05$
Word Medium	$M = 306.1$ $SD = 169.7$	$M = 290.3$ $SD = 130.7$	$t(18) = 1.199$ $p = .246$ $d = .23$
Word Long	$M = 302.5$ $SD = 170.0$	$M = 320.3$ $SD = 181.9$	$t(18) = 1.232$ $p = .234$ $d = -.28$
Nonword Short	$M = 461.9$ $SD = 174.5$	$M = 442.1$ $SD = 164.1$	$t(18) = .833$ $p = .416$ $d = .08$
Nonword Medium	$M = 472.4$ $SD = 209.5$	$M = 463.6$ $SD = 180.9$	$t(18) = .854$ $p = .404$ $d = -.08$
Nonword Long	$M = 441.1$ $SD = 278.4$	$M = 469.0$ $SD = 295.7$	$t(18) = .735$ $p = .472$ $d = -.03$

4.4.2 Lexical decision reaction times - lexical status

A series of four one-tailed, paired *t*-tests were conducted to determine if the expected within-group differences were present. Table 19 shows that significant within-group differences existed when comparing lexical and nonlexical stimuli were present ($t > 2.736$; $p < .05$), demonstrating that this effect was present for both adults who stutter and those who do not. Moderate effects sizes were found for the short and long conditions ($d > -.74$), while large effect sizes ($d > -1.08$) were present for medium and cumulative conditions.

Table 19. Lexical status effect. One-tailed, paired *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) within-group analyses of lexical status effect for adults who stutter and adults who do not stutter.

	Adults Who Stutter	Adults Who Do Not Stutter
Total Words vs. Nonwords	t (18) = 9.167 p = < .001 d = -1.33	t (18) = 14.464 p = < .001 d = -1.08
Word short - Nonword short	t (18) = 2.736 p = .013 d = -.57	t (18) = 3.311 p = .003 d = .57
Word medium - nonword medium	t (18) = 5.857 p = < .001 d = -1.54	t (18) = 8.609 p = < .001 d = -1.61
Word long – Nonword long	t (18) = 3.501 p = .002 d = .57	t (18) = 4.940 p = < .001 d = -.74

4.4.3 Lexical decision reaction times - length effect

Table 20 shows the results of one-tailed, paired *t*-tests that revealed significant within-group differences in length for both groups in the real word context ($t = 3.210$; $p = .004$), but not in the nonword context ($t = 1.586$; $p = .129$). Adults who stutter demonstrated a large effect size for the word condition ($d > .80$), but a near zero effect size was reported for nonwords ($d < .20$). Typically fluent adults demonstrated a small effect size for both word and nonword conditions ($d < .40$). No significant differences were present for either group when all short real words and nonwords were collapsed together and compared. These length effect results, combined with the lexical status effect results discussed in section 4.4.2, indicate that both adults who stutter and typically fluent adults demonstrated the word length effect and word status effect. No between-group differences were detected on the lexical decision task, suggesting that no deficits were present at the lexical level.

Table 20. Word length effect. One-tailed, paired *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) within-group analyses of word length effect for adults who stutter and adults who do not stutter.

Word Length and Lexical Status	Adults Who Stutter	Adults Who Do Not Stutter
Word Short - Word Long	$t(18) = 4.099$ $p = < .001$ $d = 1.06$	$t(18) = 3.210$ $p = .004$ $d = .40$
Nonword Short - Nonword Long	$t(18) = 1.070$ $p = .299$ $d = -.13$	$t(18) = 1.586$ $p = .129$ $d = -.20$
All Short Stimuli – All Long Stimuli	$t(18) = 1.958$ $p = .065$ $d = .26$	$t(18) = 1.032$ $p = .315$ $d = .006$

4.4.4 Silent phoneme blending/lexical decision task accuracy

Participants' silent phoneme blending/lexical decision reaction times were averaged according to participant, group, stimuli length, and lexical status and is outlined in Table 21. The data were inserted into a linear regression model to determine to what extent lexical decision contributes to the variance of silent phoneme blending. Lexical decision reaction-time data, outlined in Table 22, was entered into a generalized linear model which revealed a main effect for length and an interaction between lexical status and length. A linear regression analysis was subsequently conducted to determine to what extent the lexical decision reaction times contributed to the variance of the silent phoneme blending task. Silent phoneme blending data were entered into the statistical model as the dependent variable and lexical decision as the independent variable. Residual data were calculated as the values that remained after the variance attributed to lexical decision was removed, leaving only the silent blending data behind, as outlined in Table 23. The silent phoneme blending residuals were run through a generalized linear model, in the same way as the lexical decision data were, which continued to demonstrate a main effect for length. No main effects of group on interactions for blending were present, indicating that no difference was detected, but the performance of both groups was reduced as the stimuli length increased. Only stimuli that had a correct lexical decision response and a correct phoneme blending response were included in the analyses. Appendix A below displays the number of eligible stimuli and average reaction times for each participant. The degrees of freedom for each level of stimuli vary, and in some instances the average reaction times were

Table 21. Reaction times silent phoneme blending. Silent phoneme blending task reaction times for adults who stutter (AWS) and adults who do not stutter (AWNS).

	AWS Word Long	AWS Word Short	AWS Nonword Long	AWS Nonword Short	AWNS Word Long	AWNS Word Short	AWNS Nonword Long	AWNS Nonword Short
S1	-	748	-	2388	864	861.7	716	1009.5
S2	1706.3	1137.7	-	2045.5	407.3	386.8	1101.5	982.5
S3	45.0	701.3	1660	1243	339	713.3	-	1215
S4	627	632.3	2577	1766.5	-	863.5	-	1202.3
S5	1026	970.3	-	2065	1312	2260	-	3095
S6	1155.5	930.75	-	1454.7	1096	2392.5	-	1843
S7	914	1495.5	-	2048	558.3	369	3978	1107.7
S8	542.5	970.2	-	2608	174	1252.5	5274	1744.3
S9	1845	1116.5	-	2044.3	1340	1894.3	-	2528
S10	159	1436.8	-	1737.8	685.5	694	-	1095
S11	1418	1249.7	-	2161.7	1564	1598.5	2838	1664.7
S12	-	2125	-	1445.3	681	701.5	-	7147
S13	581.6	1392.7	-	893.3	-	705.6	-	949
S14	-	1182	-	2234	-	939.2	-	-
S15	488	995	954	1001.25	1432.5	816.5	-	1638.5
S16	813.5	972.3	-	1501.6	1908	713.7	1439.5	1654.5
S17	765.5	683.3	-	1554	791.3	663.3	1143	978.6
S18	662	651	-	821	1919	1923.5	-	2040.5
S19	1268.2	1622.6	-	1750	592.5	2202.2	7351	111

Table 22. Reaction times lexical decision. Lexical decision task reaction times for adults who stutter (AWS) and adults who do not stutter (AWNS).

	AWS Word Long	AWS Word Short	AWS Nonword Long	AWS Nonword Short	AWNS Word Long	AWNS Word Short	AWNS Nonword Long	AWNS Nonword Short
S1	510.7	523.8	493.8	355.2	423.3	476	409.5	320.3
S2	712.5	784	551	512	377	483.3	357.5	216.6
S3	458.5	386.2	336.5	341.8	267.1	214.8	330	239.4
S4	463.3	287.3	324.8	200.7	413.2	392.3	370.9	244.3
S5	376.2	579.3	460.3	199.6	705.2	749.2	605.1	666.5
S6	454.5	245.7	427.9	273.3	553.1	363.6	416.5	327.8
S7	688.8	830.7	446.8	468.5	431.2	269.5	276.5	230.6
S8	312.5	645.3	416.4	319.1	630.1	571.2	540.2	572.1
S9	398.2	299.4	421.4	243.3	546.7	690.2	533.8	535.3
S10	557.5	647	366.7	403.1	292.2	327.6	260.5	187.8
S11	421.1	616.7	344.1	228.4	409.8	310.6	292.3	212.5
S12	401.7	576.1	353.4	272	442.7	414.6	446.5	272.7
S13	432.5	322	382.3	294.5	408.8	334.2	304.9	334.6
S14	430.4	373.6	372.7	191.6	567.5	1009	389.4	497.8
S15	290.4	296.3	290	208.2	230.5	288.4	231.8	207.7
S16	368	353.7	439.2	332.3	289.1	263.7	243	267.2
S17	425.2	562.4	478.7	337	426	527.7	454.3	408.2
S18	317.5	256.5	254	454	640.3	682.1	620.1	497.5
S19	579.1	370.4	433	272	356.2	408.2	415.8	287.1

Table 23. Residual data. Residual silent phoneme blending reaction times adults who stutter (AWS) and adults who do not stutter (AWNS).

	AWS Word Long	AWS Word Short	AWS Nonword Long	AWS Nonword Short	AWNS Word Long	AWNS Word Short	AWNS Nonword Long	AWNS Nonword Short
S1	-	-674.4	-	982.9	-548.1	-555.9	-694.7	-392.1
S2	264.5	-311.4	-	624.3	-1000.0	-1031.5	-303.9	-408.4
S3	-1370.7	-707.0	256.8	-160.8	-1057.1	-677.4	-	-178.3
S4	-789.2	-765.8	1175.0	377.2	-	-545.4	-	-191.4
S5	-381.3	-457.9	-	675.8	-129.0	814.5	-	1657.9
S6	-259.8	-463.2	-	57.9	-329.4	958.5	-	440.7
S7	-525.4	41.6	-	631.2	-854.6	-1027.4	2581	-284.7
S8	-858.3	-464.6	-	1206.6	-1259.3	-174.8	3850	316.9
S9	435.4	-282.9	-	650.7	-84.8	454.8	-	1104.4
S10	-1266.9	1.7	-	327.7	-713.2	-708.3	-	-293.0
S11	6.1	-182.3	-	769.5	153.3	197.9	1439.3	274.2
S12	-	697.2	-	48.7	-733.1	-709.7	-	5750.3
S13	-831.5	-9.0	-	-505.6	-	-697.4	-	-454.0
S14	-	-225.0	-	845.6	-	-533.0	-	-
S15	-910.5	-404.1	-444.5	-388.8	40.1	-581.8	-	248.5
S16	-593.0	-432.7	-	98.8	509.6	-682.1	45.9	258.4
S17	-646.8	-743.1	-	150.7	-621.1	-759.6	-272.3	-432.0
S18	-739.3	-744.0	-	-594.3	484.6	484.8	-	620.8
S19	-159.9	215.9	-	353.4	-812.6	791.6	5939.6	-1287.2

taken from a single reaction-time response. Caution should be taken when interpreting these results, as the data sets for the nonword and long-length conditions have limited data points. The silent phoneme blending task was examined in two parts: first, the lexical decision reaction times for all correctly answered stimuli in lexical decision and second, the reaction times for *only* the stimuli in which the correct lexical decision was made *and* phoneme blending response was obtained as well. Table 24 displays average reaction times by group, lexical status, and length. *Chi Squared* analyses were again conducted to determine if both groups performed similarly in terms of accuracy. The distribution of correctly answered nonword stimuli were not evenly distributed ($\chi^2 = 6.419$; $p = .040$), while the word stimuli was not significantly different ($\chi^2 = .541$; $p = .763$). More errors were made on nonword stimuli resulting in an uneven distribution of data between the groups. As such, results should be interpreted with caution knowing that only a few data points contributed to the analysis, particularly at the nonword long level. Table 25 contains the means, standard deviations, *t*-tests and *Cohen's d* for both groups. No significant differences were present between groups across both lexical and length conditions ($t > .833$; $p > .05$).

Table 24. Accuracy and *Chi Squared* (χ^2) levels for silent phoneme blending/lexical decision task at short, medium, and long stimuli lengths.

Stimuli Length	Adults Who Stutter	Adults Who Do Not Stutter	*Chi Squared* for words and nonwords
Word Short	56	65	
Word Medium	51	67	
Word Long	34	36	$\chi^2 = .541$ $p = .763$
Nonword Short	48	38	
Nonword Medium	19	29	
Nonword Long	3	10	$\chi^2 = 6.419$ $p = .040$
Total Number Correct	211	245	

Table 25. Mean (M) and standard deviation (SD), one-tailed t-test (t), p-value (p) and *Cohen's d* (d) for silent phoneme blending/lexical decision reaction times by group, lexical status and length.

Stimuli Length	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Word Short	$M = 1105.9$ $SD = 385.6$	$M = 1155.3$ $SD = 666.0$	$t(18) = .869$ $p = .395$ $d = -.09$
Word Medium	$M = 1198.5$ $SD = 481.5$	$M = 1317.5$ $SD = 1205.8$	$t(16) = 1.075$ $p = .298$ $d = -.13$
Word Long	$M = 876.1$ $SD = 506.9$	$M = 979.0$ $SD = 546.7$	$t(13) = 1.030$ $p = .31$ $d = -.2$
Nonword Short	$M = 1724.4$ $SD = 505.1$	$M = 1778.1$ $SD = 1497.8$	$t(17) = .833$ $p = .416$ $d = -.05$
Nonword Medium	$M = 1883.2$ $SD = 723.0$	$M = 1507.2$ $SD = 864.9$	$t(9) = 1.668$ $p = .129$ $d = .5$
Nonword Long	$M = 1730.3$ $SD = 813.8$	$M = 2980.1$ $SD = 2384.1$	$t(9) = 1.230$ $p = .231$ $d = -.49$

4.4.5 Silent phoneme blending/lexical decision - lexical status

One-tailed, paired *t*-tests were conducted for (a) lexical status and (b) length for the silent phoneme blending/lexical decision task. Within-group analyses of lexical status are outlined in Table 26. Adults who stutter were able to correctly complete the silent phoneme blending task significantly faster for real words than for nonwords in the total list, short and medium lengths ($t > 3.552$; $p < .01$), but not the long length ($t = 2.328$; $p = .102$). Large effect sizes for all lexical status lengths ($d > 1.15$) were present for adults who stutter. Conversely, adults who do not stutter demonstrated a significant difference for the total list and the long length condition ($t > 3.288$; $p < .05$), but not the short and medium lengths ($t > 1.076$; $p > .05$). Large effect sizes were present for the word verses nonword comparison at the long length and the total combined word verses nonword ($d > -1.04$), while the short condition revealed a moderate effect for adults who do not stutter ($d >-.55$).

Table 26. Within-group analyses of lexical status effect for adults who stutter and adults who do not stutter in the silent phoneme blending/lexical decision task.

	Adults Who Stutter	Adults Who Do Not Stutter
Total Words vs. Nonwords	$t(18) = 6.788$ $p = < .001$ $d = -1.37$	$t(18) = 3.288$ $p = .004$ $d = -1.04$
Word short - Nonword short	$t(18) = 4.645$ $p = < .001$ $d = -1.42$	$t(18) = 1.982$ $p = .062$ $d = -.55$
Word medium - nonword medium	$t(12) = 3.552$ $p = .003$ $d = -1.15$	$t(13) = 1.076$ $p = .301$ $d = -.19$
Word long – Nonword long	$t(2) = 2.328$ $p = .102$ $d = -1.20$	$t(7) = 4.183$ $p = .024$ $d = -1.18$

4.4.6 Silent phoneme blending/lexical decision - length effects

One-tailed, paired *t*-test analyses were conducted for the silent phoneme blending/lexical decision task that was similar to analyses conducted for the traditional lexical decision task. Table 27 outlines within-group analyses of stimulus length analyses for adults who stutter and those who do not. A comparison of all short stimuli and all long stimuli for adults who stutter resulted in statistically significant differences ($t = 3.722$; $p = .004$). No other significant differences were reported for either adults who stutter or adults who do not stutter based on stimuli length ($t > 1.617$; $p > .05$).

Table 27. Within-group, one tailed, paired *t*-test and *Cohen's d* demonstrating word length effect and effect size for the silent phoneme blending/lexical decision task.

Word Length and Lexical Status	Adults Who Stutter	Adults Who Do Not Stutter
Word Short - Word Long	$t = 1.819$ $p = .088$ $d = .53$	$t = 1.729$ $p = .104$ $d = .30$
Nonword Short - Nonword Long	$t = 1.617$ $p = .126$ $d = -.01$	$t = 2.014$ $p = .062$ $d = -.039$
All Short Stimuli – All Long Stimuli	$t = 3.722$ $p = .04$ $d = .54$	$t = 1.622$ $p = .122$ $d = .02$

4.5 PHONOLOGICAL MEMORY

Phonological memory was measured in this investigation through the administration of the Phonological Memory Composite score, Memory for Digits and Nonword Repetition subtests of the CTOPP. Data were collected on two additional tests of nonword repetition abilities: the NRT and the Late-8 NRT. The results from these tasks are discussed below.

4.5.1 Phonological memory composite scores

One-tailed, paired *t*-tests revealed no significant between-group differences ($t = -1.034$; $p = .158$) for the Phonological Memory Composite. Table 28 outlines the means and standard deviations for the phonological memory tasks of the CTOPP. Although there was no difference in the Phonological Memory Composite scores, adults who stutter performed significantly lower than the adults who do not stutter on the Nonword Repetition subtest ($t = 3.157$; $p = .01$), while the Memory for Digits subtest displayed no between-group differences ($t = .734$; $p = .05$). Adults who stutter performed below nonstuttering adults on the Nonword Repetition subtest but not the Memory for Digits subtest. This finding indicates that adults who stutter demonstrated more difficulty assembling novel phonological sequences, as compared to retrieving existing phoneme sequences.

Table 28. Mean (*M*) and standard deviation (*SD*), one-tailed, between group *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for adults who stutter and adults who do not stutter on phonological memory tasks.

	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Phonological Memory Composite	$M = 97.9$ $SD = 7.4$	$M = 100.5$ $SD = 7.4$	$t(17) = -1.034$ $p = .158$ $d = -.36$
Memory for Digits subtest	$M = 11.3$ $SD = 2.0$	$M = 11.3$ $SD = 2.5$	$t(18) = 0.734$ $p = .472$ $d < 0.01$
Nonword Repetition subtest	$M = 7.7$ $SD =1.2$	$M = 8.5$ $SD = 1.2$	$t(17) = 3.157$ $p = .006$ $d = -.63$

4.5.2 Nonword repetition tasks

Table 29 shows that one-tailed, paired *t*-tests revealed that adults who stutter performed significantly lower than adults who do not stutter on the NRT Total Score, 2- syllable and 3-syllable levels ($t > -2.641$; $p < .05$) but not on the 1- or 4-syllable level of the Nonword Repetition Task ($t > 1.567$; $p > .05$). Adults who stutter also performed significantly lower than typically fluent adults on the Late-8 NRT Total Score, 2-syllable, 3-syllable, and 4-syllable levels ($t > -2.293$; $p < .05$). No significant differences were apparent for 1-syllable nonwords ($t =1.567$; $p =.135$). Large effect sizes were present for all of the significant differences.

Table 30 presents the effect sizes and within-group differences between the NRT and the Late-8 NRT for both groups at each length level. The expected within-group differences were present with the NRT scores being significantly more difficult than the Late-8 NRT scores for both adults who stutter and typically fluent adults ($t > 3.061$; $p < .05$). The analyses revealed that the Late-8 NRT was significantly more difficult than the NRT for both groups at all levels, with the only exception being the 1-syllable level for typically fluent adults ($t = 1.533$; $p >.135$). Small and moderate effect sizes were present at the one-syllable level ($d > .43$), while large effect sizes were present for the remaining analyses ($d > 1.04$). These results indicate that a large effect of articulatory complexity was present for both groups; nonwords constructed with earlier developing phonemes (NRT) were easier for the groups to correctly repeat than nonwords constructed using late-8 phonemes (L8NRT).

Table 29. Mean (*M*), standard deviation (*SD*), one-tailed *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for adults who stutter and adults who do not stutter on the Nonword Repetition Task and the Late-8 Nonword Repetition Task.

Syllable Lengths	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Nonword Repetition Task Total Score	*M* = 91.4 *SD* = 4.4	*M* = 94.1 *SD* = 3.1	*t*(17) = -2.766 *p* = .013 *d* = -.73
Nonword Repetition Task 1 syllable	*M* = 98.2 *SD* = 3.6	*M* = 96.5 *SD* = 4.2	*t*(17) = 1.567 *p* =.135 *d* = .45
Nonword Repetition Task 2 syllable	*M* = 96.1 *SD* = 3.6	*M* = 99.1 *SD* = 2.0	*t*(16) = -2.641 *p* = .017 *d* = -1.02
Nonword Repetition Task 3 syllable	*M* = 96.8 *SD* = 2.9	*M* = 98.8 *SD* = 2.5	*t*(17) = -2.808 *p* = .012 *d* = -.76
Nonword Repetition Task 4 syllable	*M* = 82.0 *SD* = 9.4	*M* = 85.5 *SD* = 9.9	*t*(18) = -1.717 *p* = .104 *d* = -.37
Late-8 Nonword Repetition Task Total Score	*M* = 82.5 *SD* = 5.5	*M* = 87.3 *SD* = 5.2	*t*(18) = -2.871 *p* =.010 *d* = -.92
Late-8 Nonword Repetition Task 1 syllable	*M* = 93.9 *SD* = 7.3	*M* = 94.3 *SD* = 6.2	*t*(18) = -.808 *p* =.430 *d* = -.06
Late-8 Nonword Repetition Task 2 syllable	*M* = 88.7 *SD* = 4.4	*M* = 91.6 *SD* = 4.1	*t*(18) = -2.432 *p* =.026 *d* = -.70
Late-8 Nonword Repetition Task 3 syllable	*M* = 86.5 *SD* = 8.2	*M* = 91.3 *SD* = 6.0	*t*(18) = -2.293 *p* =.035 *d* = -.69
Late-8 Nonword Repetition Task 4 syllable	*M* = 72.4 *SD* = 9.6	*M* = 79.2 *SD* = 8.6	*t*(18) = -2.386 *p* =.029 *d* = -.77

Table 30. Within-group performance *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) on the Nonword Repetition Task as compared to the Late-8 Nonword Repetition Task (total score and at each syllable level).

Syllable Length	Adults Who Stutter	Adults Who Do Not Stutter
Total	*t*(18) = 7.926 *p* = < .001 *d* = 1.84	*t*(17) = 5.637 *p* = < .001 *d* = 1.63
1 syllable	*t*(17) = 3.061 *p* = .006 *d* = .77	*t*(18) = 1.533 *p* = .142 *d* = .43
2 syllables	*t*(18) = 5.237 *p* = < .001 *d* = 1.89	*t*(16) = 8.086 *p* = < .001 *d* = 2.39
3 syllables	*t*(18) = 6.961 *p* = < .001 *d* = 1.72	*t*(17) t = 5.691 *p* = < .001 *d* = 1.68
4 syllables	*t*(18) = 3.821 *p* = .001 *d* = 1.04	*t*(18) = 3.272 *p* = .004 *d* = .70

4.6 RAPID AUTOMATIC NAMING

The rapid automatic naming measures in the current investigation include the four subtests from the CTOPP; the Rapid Color Naming, Rapid Object Naming, Rapid Digit Naming, and Rapid Letter Naming. The results for both groups of participants are discussed below.

4.6.1 Rapid automatic naming composite scores

One-tailed, paired t-tests, summarized in Table 31, revealed no significant between-group differences for the Rapid Automatic Naming Composite score or any of the rapid automatic naming subtests (i.e., Rapid Color Naming, Rapid Object Naming, Rapid Digit Naming, Rapid Letter Naming) ($t > -1.022$; $p > .05$). Adults who stutter scored significantly lower than typically fluent adults on the Alternate Rapid Automatic Naming Composite score only ($t = -2.187$; $p = .042$). The between-group difference reached significance according to the individual alpha set at .05; however, in the series of comparisons it cannot be considered particularly robust.

Table 31. Mean (*M*), standard deviation (*SD*), one-tailed *t*-test (*t*), *p*-value (*p*) and *Cohen's d* (*d*) for adults who stutter and adults who do not stutter on for rapid automatic naming composite scores and subtests of the *Comprehensive Test of Phonological Processing*.

	Adults Who Stutter	Adults Who Do Not Stutter	Test Statistics
Rapid Automatic Naming Composite	$M = 100.5$ $SD = 13.6$	$M = 107.1$ $SD = 18.3$	$t(16) = -1.537$ $p = .142$ $d = -.42$
Alternate Rapid Automatic Naming Composite	$M = 96.0$ $SD = 11.7$	$M = 107.6$ $SD = 20.3$	$t(17) = -2.187$ $p = .042$ $d = -.72$
Rapid Color Naming subtest	$M = 9.8$ $SD = 2.3$	$M = 10.8$ $SD = 2.9$	$t(17) = -1.497$ $p = .152$ $d = -.39$
Rapid Object Naming subtest	$M = 9.5$ $SD = 2.5$	$M = 11.2$ $SD = 3.9$	$t(16) = -1.917$ $p = .072$ $d = -.53$
Rapid Digit Naming subtest	$M = 10.7$ $SD = 3.0$	$M = 11.3$ $SD = 3.2$	$t(17) = -1.022$ $p = .320$ $d = -.20$
Rapid Letter Naming subtest	$M = 10.2$ $SD = 2.7$	$M = 11.1$ $SD = 3.0$	$t(16) = -1.217$ $p = .240$ $d = -.32$

4.7 RESULTS SUMMARY

The results discussed above revealed that adults who stutter performed below typically fluent adults on a number of phonological processing tasks. Compared to nonstuttering peers, adults who stutter demonstrated reduced phonological awareness ability that was initially masked when using real word stimuli, although one difference was still present (i.e., Elision subtest). When nonlexical stimuli were used, as in the Alternate Phonological Awareness Composite scores, adults who stutter were not able to rely on pre-existing lexical-semantic knowledge to bolster performance, thereby revealing a significant difference in phonological awareness abilities. Significant differences in phonological memory were evidenced for adults who stutter in nonword repetition tasks, but not in immediate digit naming, again suggesting that people who stutter over-rely on lexical access to complete phonological memory tasks. Performance is reduced when lexical access is not available to supplement the relatively reduced abilities. This same trend was also evident in the results for NRT and L8NRT. Adults who stutter performed less well than nonstuttering adults on the majority of the nonword repetition tasks. Performance on phonological awareness and phonological memory tasks was lower for people who stutter as compared to people who do not. Conversely, Rapid Automatic Naming subtests that used lexical stimuli (i.e., colors and objects) revealed significant differences for adults who stutter, while subtests that employed highly automatized digits and letters did not reveal any differences between groups.

No significant differences were revealed for phonological awareness subtests that used lexical stimuli (i.e., Segmenting Words, Phoneme Reversal, Blending Words). Performance on the phonological memory task of digit naming was not significantly different between groups and the automatic letter and digit naming tasks also did not reveal group differences. These findings all suggest that adults who stutter rely heavily on pre-existing lexical knowledge to perform phonological processing tasks, and decreased performance is revealed when that knowledge is not available (i.e., in nonword tasks).

5.0 DISCUSSION

This exploratory study compared the phonological processing skills of adults who stutter to typically fluent adults matched on age, sex, and education. Phonological awareness, phonological memory and rapid automatic naming abilities were evaluated in both groups through a series of tasks designed to evaluate a wide range of skills and difficulty levels. The results are discussed according to each phonological processing skill type. These processes and mechanisms responsible for these tasks are so closely intertwined that the performance on the different phonological processing skill sets are discussed within each section and also discussed in the larger theoretical context at the end of this discussion.

5.1 OVERALL PERFORMANCE

5.1.1 General performance

One general hypothesis of the study predicted that adults who stutter would perform within typical limits even if between-group differences were present. Pelczarski & Yaruss (2008) reported that although children who stutter were significantly different from their nonstuttering peers in phonological processing abilities, they still performed within typical limits. Thus, it was anticipated that any differences in phonological encoding ability exhibited adults who stutter would also be “sub-clinical” (Hakim & Bernstein Ratner, 2004; Newman & Bernstein Ratner, 2007) in nature. Individuals who stutter scored below typically fluent adults on a number of measures, but the majority of the scores for both groups fell within one standard deviation from the mean, supporting this hypothesis. This finding is not suggestive of "disordered" phonological processing, because the majority of scores for adults who stutter (84%) fell within typical limits. The small percentage of scores that fell more than one standard deviation below the mean (16%) was not indicative of poor performance on all tasks for a given participant. Rather, performance was below normal limits on one or two skill sets or tasks (e.g., phonological awareness, phonological memory, rapid automatic naming, *or* constituent subtest, but not all three) and within normal limits in the other skill areas. It is not uncommon for one or two phonological processing skills to be weaker than the others in a given individual. An individual exhibiting this type of performance profile would appear to have typical phonological processing skills overall, even though closer examination would reveal that some abilities are weaker than others. (Lonigan et al., 2000; Snowling & Hulme, 1994).

5.2 DESCRIPTIVE MEASURES

Descriptive data on the participants were collected to determine if differences were present in basic abilities or factors that are known to influence performance on phonological processing tasks (e.g., expressive and receptive vocabulary skills, reading history, age, sex, and education level). No significant differences were present between groups for any of these measures. Furthermore, a traditional lexical decision task found no between-group differences in the general lexical abilities of participants who do and do not stutter. The relative equality of the background measures for the groups suggests that differences found in the dependent variables are reflective of phonological processing ability and not the result of potentially influential or contaminating factors.

5.3 MECHANISMS OF PHONOLOGICAL PROCESSING

Completion of phonological processing tasks requires that certain core mechanisms operate in concert to produce a successful outcome (e.g., correctly completed phonological awareness tasks). The process of redintegration, as discussed in sections 2.2.1 and 2.2.3, accounts for how lexical-semantic knowledge can compensate for potentially deficient or delayed mechanisms. This top-down lexical knowledge can aid in the completion of phonological processing tasks by (a) bolstering degraded or unstable phonological representations, (b) supporting the construction of phonological codes, and/or (c) contributing to the maintenance of phonological representations in memory. Deficits in any of these mechanisms could present as disordered phonological awareness, phonological memory, or rapid automatic naming. In the following sections, the results from the current study are discussed in terms of deficiencies in the quality, construction or maintenance of the phonological representations. The implications of deficiencies in these mechanisms for adults who stutter are reviewed within each section and also in the summary discussion to provide an overview of the findings.

5.4 PHONOLOGICAL AWARENESS

5.4.1 Phonological awareness - real word stimuli

Adults who stutter were predicted to perform less well on phonological awareness tasks as compared to nonstuttering peers, for previous research reported that individuals who stutter take longer to complete phonological awareness tasks than individuals who do not stutter (Burger & Wijnen, 1999; Sasisekaran and de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2008; Wijnen & Boers, 1994). It was argued in section 2.2.1 that some previous studies' tasks and/or stimuli may have been too simple to reveal subtle differences present and that the delay reported may have represented a timing/accuracy tradeoff. Thus, an increase in complexity of the stimuli, coupled with greater task difficulty, was hypothesized to result in significant between-group differences. Contrary to prediction, however, phonological awareness tasks were performed equally well by individuals who do and do not stutter, even for the most challenging task, Phoneme Reversal. This outcome is consistent with other studies that reported no differences in the accuracy of performance between groups on phonological awareness tasks (Burger & Wijnen, 1999; Hennessey et al., 2008; Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006; Weber-Fox et al., 2004). The lack of difference found in phonological awareness abilities could be attributed to task difficulty; if the task was too challenging for both groups, any difference would be mitigated. Although possible, this explanation is not likely, for the majority of scores for both groups fell within the typical range. Looking at these data in isolation, it appears that phonological awareness abilities of individuals who stutter are not different from nonstuttering individuals when completing tasks that utilize real word stimuli. It is possible that the presence of subtle deficits could have been masked due to the facilitative effects of long-term lexical knowledge. This process of redintegration can help bolster a weaker mechanism by using information from the lexicon to strengthen it. As such, it is still difficult to know if there were truly no differences in the underlying mechanisms responsible for the completion phonological awareness tasks without looking at the entirety of the data collected in the current study. Examination of the phonological awareness skills of children who stutter discussed in the following section may inform this issue further.

Between-group differences were not found for adults who stutter in phonological awareness tasks with real word stimuli; however, empirical evidence indicates that phonological awareness abilities are different for *children* who stutter as compared to typically fluent peers (Pelczarski & Yaruss, 2008; Weber-Fox et al., 2008). Weber-Fox and colleagues (2008) reported that children who stutter were significantly less accurate in rhyme judgment and awareness (common phonological awareness tasks) as compared to children who do not stutter. The same tasks completed by adults who stutter did not show a difference in accuracy (Weber-Fox et al., 2004). Pelczarski and Yaruss (2008) also reported that children who stutter have significantly lower phonological awareness skills than typically fluent peers, while the current study with adults who stutter used similar phonological awareness tasks and found no between-group differences. Taken together, these studies suggest that phonological awareness abilities in children who stutter are less well developed than in nonstuttering children. One possible scenario to describe these findings is that the between-group difference present for children who stutter may completely resolve as the children mature, resulting in typical performance for adults who stutter. This could be due to a delayed or disrupted core mechanism “catching up” with typically fluent peers as they develop. The second alternative is that the phonological awareness skills remain “sub-clinically” different in adults who stutter, but due to increases in adult vocabulary knowledge, pre-existing lexical information may help to compensate for these subtle deficits, thus concealing any between-group differences in adults. It is unknown which of the core mechanisms might be responsible for phonological awareness differences present in children and possibly adults who stutter. Further investigation of the phonological awareness tasks using nonword stimuli from the current study may help to determine the nature of these differences.

5.4.2 Phonological awareness - nonword stimuli

Nonword phonological awareness tasks from the current study revealed results that differed from those reported for phonological awareness tasks that used real-word stimuli in this study. Both groups had a more difficult time completing the nonword phonological awareness tasks (i.e., the Alternate Phonological Awareness tasks), but participants who stutter performed significantly less well than typically fluent participants on this task. The nonword and real word tasks used similar tasks that differed primarily in the lexical status of the stimuli. Despite the similarities in the types of tasks used for both composite scores, there were marked differences in performance between groups. This evidence, combined with the results from the real word phonological awareness tasks, suggests that adults who stutter have reduced phonological awareness ability that is revealed once the lexicon cannot be depended on to supplement construction or retrieval.

Participants who stutter demonstrated significantly different between-group performance only on nonword phonological awareness tasks, indicating that lexical access plays an important role for adults who stutter. Typical performance on real word phonological awareness tasks, but not nonword tasks, suggests that individuals who stutter may rely heavily on pre-existing lexical-semantic knowledge to supplement decreased functioning in one of the core mechanisms that contribute to phonological awareness. The performance benefit evidenced when lexical knowledge was used during redintegration indicates that the quality of phonological representations are likely sufficient to contribute to completion of real word phonological awareness tasks. The facilitative influence of pre-existing semantic-lexical knowledge would have been cancelled out if the phonological representations were not stable and robust, resulting in poor performance on both real and nonword tasks. In the present study, only nonword tasks were deficient, indicating that the quality of phonological representations was likely not responsible for the differences displayed by adults who stutter. These findings indicate that the diminished process resides further “downstream” in language formulation planning, that is, a process closer to construction of phonological code before production. In prior studies (e.g., Arnold, et al., 2006; Byrd et al., 2007; Pelczarski & Yaruss, 2008; Weber-Fox et al., 2008), preschool children who stutter have only been administered real-word tasks because nonword tasks would have been beyond their developmental ability. Still, they scored below typically fluent peers on phonological awareness tasks. This could indicate that children who stutter initially have compromised or less well defined phonological representations that are strengthened or stabilized as they get older, perhaps through the development of larger vocabularies (Walley et al., 2003).

5.4.3 Phonological awareness timing

Previous studies reported that adults who stutter took significantly longer to complete a phonological awareness task but reported no difference in accuracy (Sasisekaran & de Nil, 2006; Sasisekaran et al., 2006). Weber-Fox and colleagues (2004) reported an increase in response time only on the more complicated tasks of the experiment. Weber-Fox argued that the longer reaction times were due to increased cognitive load. In the present study, it was hypothesized that those results were representative of a speed/accuracy tradeoff. It was predicted that when adults who stutter were presented with a more complex nonverbal phonological awareness task (e.g. silent phoneme blending/lexical decision task), an increase in processing time and a decrease in accuracy would result. That prediction was not supported in the present study, though it should be noted that the analyses lacked sufficient power. The task was intended to be challenging in an attempt to reveal potential differences, but the stimuli were too long and complex to be completed successfully by both groups. No between-groups differences were revealed for the effect of length or the effect of lexical status. Lack of usable data due to the difficulty of the task, particularly at the longer stimuli lengths, resulted in there not being enough power to reliably analyze the data. These findings are thus deemed to be inconclusive due to the difficulties inherent in the task. The inconclusive results prevent further speculation as to what core mechanisms that contribute to phonological awareness performance may be different in adults who stutter. Still, examination of the results for the phonological memory tasks for the current can provide further insight into the nature of phonological processing tasks in people who stutter.

5.5 PHONOLOGICAL MEMORY

5.5.1 Phonological memory tasks

The Memory for Digits and the Nonword Repetition subtests of the CTOPP were administered as measures of phonological memory in individuals who do and do not stutter. Participants who stutter performed significantly below nonstuttering participants on the Nonword Repetition task only. No between-group differences were present for the Phonological Memory Composite score or for the Memory for Digits subtest. A previous study by Pelczarski and Yaruss (2008) administered these same phonological memory tasks to preschool children who stutter with a similar outcome. Significant between-group differences were reported on the Phonological Memory Composite Score and the Nonword Repetition subtest, but no differences were present for the Memory for Digits subtest for preschool children who stutter. These results indicate that difficulties with nonword repetition exist for both children and adults who stutter and this between-group difficulty does not resolve with age.

As noted in section 2.2.2., nonword repetition is often used as a measure of phonological memory, although memory is not the only factor involved in nonword repetition. Like the other phonological processing tasks, successful completion of nonword repetition tasks requires the ability to not only hold phonological code in memory, but to construct a novel phonological plan, and to have robust phonological representations with which to build that plan. Weakness in any of these areas can be reflected in nonword repetition performance (Coady & Evans, 2008;

Edwards & Lahey, 1998; Gathercole, 2006). It appears that sufficient memory was present for individuals who stutter because performance on the Memory for Digits subtest was comparable for each of the groups. Memory capacity is tested in the Memory for Digits task by requiring the naming of longer and longer strings of digits, thereby requiring sufficient memory to complete the task. Memory capacity was not limited because people who stutter were able to perform typically on the digit span test but not on the nonword repetition task (Gathercole, 2006). Difficulty on only the nonword repetition task suggests that a factor other than phonological memory may be contributing to reduced performance on nonword repetition tasks for adults who stutter. These findings suggest that memory capacity (i.e., the ability to sustain phonological code in memory) is not an impaired mechanism for people who stutter. Results from the real word and nonword phonological awareness tasks discussed above imply that the stability of phonological representations is not impaired either. Thus, together these data suggest that the reduced performance on phonological processing tasks is likely due to a deficit or difference in the *online construction of novel phonological* codes. A discussion of nonword repetition tasks that are designed to vary in terms of articulatory complexity may provide additional information on the nature of phonological processing skills of people who stutter.

5.5.2 Nonword repetition and late-8 nonword repetition tasks

The NRT was designed to be a developmentally easy task with fewer articulatory demands as compared to the L8NRT. It was anticipated that all participants would show better performance on NRT than on the L8NRT. Indeed, both groups demonstrated this trend of reduced performance on the more demanding L8NRT as compared with the NRT. Between-group differences existed for the NRT at the 2- and 3- syllable levels as well as for the Total Score. The differences for the NRT at the 2- and 3-syllable level were strong enough to result in the Total Score being significantly different even when only half of the stimuli showed a difference (i.e., 2- and 3-syllable stimuli demonstrated a difference, while 1- and 4-syllable stimuli did not). The L8NRT was significantly more difficult for adults who stutter at the 2-, 3-, 4-syllable levels and the Total Score. Thus, between-group differences were present for the majority of syllable lengths, but not for all of them. It is not surprising that the groups performed equally well on the 1-syllable nonwords for NRT and L8NRT, as these stimuli were the least difficult. Longer stimuli are presumed to be more difficult due to the additional cognitive and memory demands placed on the task. Still, a difference was only present for the 4-syllable L8NRT and not the 4-syllable NRT. Closer examination of the data for the 4-syllable NRT reveals that 6 adults who stutter who outperformed their matched typically fluent partner. Adults who do not stutter performed better than adults who stutter in 11 of the 19 pairs. Two pairs were equally matched. It is unclear why the data were distributed this way for the NRT 4-syllable stimuli only, while the other syllable levels showed clear trends. A replication and expansion of the study would need to be conducted to determine if there was something in particular about those 4-syllable NRT stimuli or if this is a trend for other adults who stutter.

Novel phonological codes must be constructed online for nonword repetition since no pre-existing phonological representations are available for nonwords. This means that any difficulty in constructing new phonological codes would be revealed in reduced nonword repetition performance. Taken in sum, the robust between-group differences found on the nonword repetition tasks combined with data from the phonological awareness and phonological memory tasks provide further support for the argument that the ability to construct novel phonological representations is different in people who stutter as compared to nonstuttering individuals.

5.6 RAPID AUTOMATIC NAMING

Both groups of participants in this study performed equally well on the Rapid Automatic Naming Composite Score and subtests that contained letters and digits as compared to subtests that contained colors and objects. Adults who stutter performed less well than typically fluent adults only on rapid automatic naming tasks with the color and object stimuli. A number of factors, including articulatory differences and motoric sequencing, could account for people who stutter naming colors and objects more slowly than nonstuttering adults. One explanation may be that the articulatory difficulty is higher for naming colors (blue, black, red, green, brown, yellow) and objects (chair, star, boat, fish, pencil, key) due to the presence of later developing phonemes and consonant clusters (Moore et al., 2010; Shriberg & Kwiatkowski, 1994; Storkel, 2001). An alternate possibility is that the oral motor planning or sequencing required to rapidly name the stimuli aloud was more difficult for adults who stutter. Speech articulators in adults who stutter have less stable motor movements, even during perceptually fluent speech (de Nil, 1995; McClean et al., 1990; McClean et al., 1994; Smith et al., 2010; Zimmermann, 1980). Color and object names have longer articulatory durations that require more coordinated planning due to the increased number of phonemes. It has been argued in this discussion that people who stutter may have difficulty in the ability to construct phonological codes, particularly novel phonological codes. Colors and objects are well known lexical items to most people and would have well established phonological representations available in the lexicon, yet adults who stutter still demonstrated slower naming rates than nonstuttering adults. This discrepancy can be resolved if the additional time pressure required to "rapidly name" is considered. Added time pressure could be enough to tax the system while assembling the phonological code for these stimuli (Oomen & Postma, 2001). So even though lexical-semantic knowledge is available for these stimuli, the time pressure to "rapidly name" the colors and objects could potentially disrupt a vulnerable phonological assembly system, mitigating the effect of redintegration. Thus, the between-group difference revealed for rapid automatic naming can be accounted for, along with the other findings of this phonological processing study, by a reduced ability to assemble phonological code efficiently in adults who stutter.

5.7 THEORETICAL IMPLICATIONS

The prior sections have discussed the results of this study in light of the core mechanisms that may be deficient or different in people who stutter as compared to people who do not stutter (i.e., difficulty or differences in the quality, construction, and/or maintenance of the phonological code). The results can be discussed through a theoretical lens and interpreted in light of the psycholinguistic theories of stuttering and models of typical language formulation. Psycholinguistic theories of stuttering posit that a disruption or delay occurs during phonological encoding that can result in disfluent speech. The Output Sublexical Phonological Representation level in the Ramus et al. model was designed to be roughly equivalent to the Weaver++ model's phonological encoding. Please refer to Figure 4 to view the model again. Ramus et al.’s model incorporates the Weaver++ model as part of the larger model. As such, discussions of the theoretical models will include phonological encoding from Weaver++ and incorporate it into the Ramus model. The data from this study’s real word and nonword phonological awareness tasks can be accounted for using the Ramus model (Figure 4 presented again for convenience) particularly if we assume that a disruption occurs during Output Sublexical Phonological Representation /phonological encoding. In either situation (real word or nonword) the input will go up Arrow 2b to Input phonological representation level. From that point the input can follow Arrow 1b up to the lexicon *and* across the bidirectional pathway between input and output phonological representation. In all likelihood, the input is sent both up to the lexicon (to see if there is a phonological code for the item in question) and across to the output phonological representation (to see if the task can be completed there). If this is the case, then the input goes up to the lexicon, does not find established phonological code for the nonword, then circles down Arrow 1a to the output phonological representation. When there is phonological code from the lexicon available, it can bolster a delayed or disrupted process of the construction of the phonological code occurring at the level of the Output Sublexical Phonological Representation as the data suggests**.** With no input from the lexicon, the phonological representations must be constructed at the level of Output Sublexical Phonological Representation. If a delay or disruption occurs at that level, then these data provide support for the psycholinguistic theories

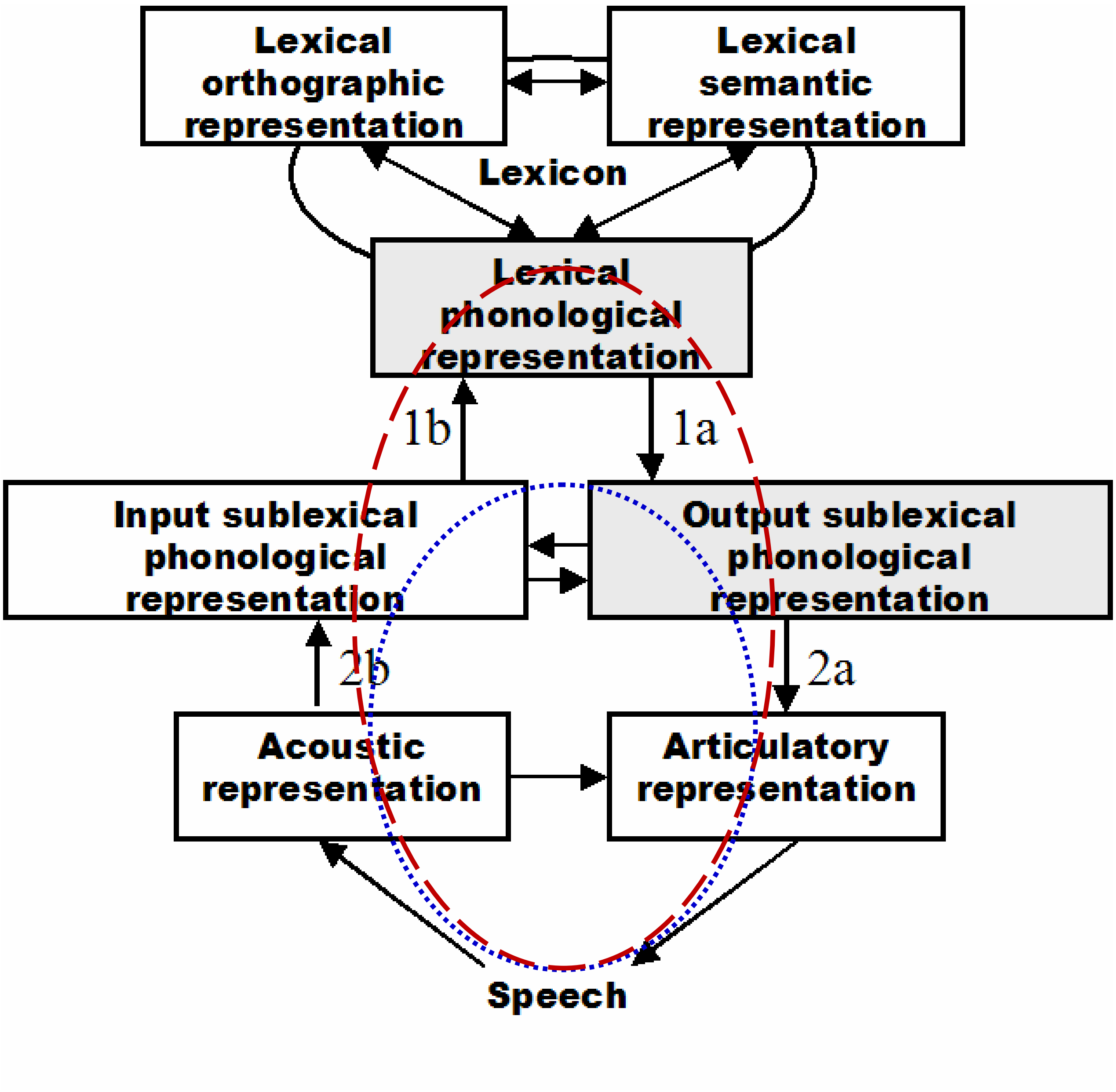


Figure 4. Information processing model of speech perception and production. Blue (short dashes) and red (long dashes) colored routes added by the current author for illustrative purposes. (Ramus et al., 2010)

of stuttering that implicate phonological encoding and hypothesize that a delay or breakdown does occur at the level of phonological encoding. The between-group differences reported for nonword repetition can also be interpreted within the framework of the Ramus et al. (2010) model. Three possible speech production routes (i.e., lexical, nonlexical, or combination) were outlined in the model. Ramus and colleagues would likely argue that nonword tasks would use the nonlexical route to complete a nonword repetition task. The nonlexical route crosses straight over from Input to Output Sublexical Phonological Representation would not be able to access pre-existing lexical knowledge (were any available). A deficit at the level of the Output Sublexical Phonological Representation, essentially the level where the phonological code is combined just prior to being sent to the articulators, would affect each route equally. The nonwords used in the repetition task would need to be constructed online, thus, if phonological encoding was disrupted, nonword repetition tasks would be difficult. This disruption would account for the reduced performance in nonword repetition tasks for people who stutter. Again, it is important to stress that these hypothesized disruptions are significant enough to result in a performance decrement, but not so severe as to cause clinically identifiable deficits.

5.8 LIMITATIONS OF THE STUDY

A limitation of the current study involved the silent phoneme blending/lexical decision task. As noted above, the task was designed to be difficult in order to reveal subtle differences that may have been present between adults who do and do not stutter, but the task turned out to be too challenging for both groups to perform with accuracy. Thus, it became impossible to determine conclusively if phonological awareness tasks take longer in people who stutter. In future studies, modifications to the original task could be made to slightly lessen the difficulty while still maintaining the complexity that is necessary in order to identify potential differences between people who do and do not stutter. An increase the amount of data collected will address the concern that there was not enough power (i.e., enough data) to answer the original question of whether people who stutter are delayed in the performance of phonological awareness tasks as compared to typically fluent adults. Stimuli containing fewer phonemes (i.e., shorter in length) would perhaps be more manageable for participants to complete, thus increasing the amount of usable data. Determining whether adults who stutter take longer to complete phonological awareness tasks could provide additional evidence of disordered phonological encoding.

A potential limitation of the study may be due to the fact that it was not possible to fully blind the experimenter to the participant's group. As described above, the inter-rater reliability ratings were obtained at the very beginning of data collection to determine if examiner bias was present in the scoring. Inter-rater reliability was sufficiently high to suggest that bias was not present. Although it is difficult to blind the examiner to a participant's group status, steps could be taken to ensure that the second rater (used to determine inter-rater reliability) was blinded to group status. Stuttering is typically an overt behavior and one that would be apparent to the experimenter. Very little stuttering was evident during the completion of the tasks, but was more evident during the speech sample and conversations with the participant in between tasks that would be seen if the whole experimental session was viewed to determine inter-rater reliability. Video recordings of tasks can be edited to include the task only and then be viewed by a third party to determine if any stutter-like behaviors were observed. If stuttering was evident, another task could be randomly selected until there were enough samples for the second clinician to use determine inter-rater reliability. This would allow for a quasi-randomized selection of samples to be evaluated while blinding the second rater to group status in an effort to reduce experimenter bias.

5.9 FUTURE DIRECTIONS

Despite these robust findings that support current psycholinguistic theories of stuttering, there were some limitations in the current study. A major assumption of this investigation was that phonological processing skills reflect phonological encoding abilities. The data are congruent with this assumption and provide additional evidence that a disruption in the construction of phonological codes occurs at the level of phonological encoding. Still, it cannot be assumed that phonological processing is reflective of phonological encoding. It does, however, suggest that the same underlying core mechanisms are different in people who stutter as compared to typically fluent adults. Further investigation of the nature of phonological processing skills as evidence of phonological encoding abilities is required.

This study demonstrated that the phonological processing skills of individuals who stutter are different from those who do not stutter. This difference is likely due to the ability to construct novel phonological code at the level of phonological encoding. If this is the case, then it would be reasonable to suggest that phonological processing/phonological encoding ability and stuttering severity level would be related. Individuals with more severe stuttering would then perform less well on phonological processing tasks in comparison to adults with milder stuttering. Future investigations could examine the phonological encoding abilities of individuals who stutter based on severity level to further examine the idea that phonological processing and phonological encoding are related.

Education level is known to have a positive affect phonological processing skills; the more education, the better phonological processing skills. This study was balanced for education through the matching of pairs, however preliminary analyses based on level of education revealed differences between education levels in some aspects of phonological processing (e.g., nonword repetition tasks, segmenting nonwords). Just over half of the sample had earned a graduate degree, and there was not enough power to be able to analyze each education level. It would be informative to explore whether educational differences would account for any of the variance revealed.

Investigation of the fast-mapping abilities in children and adults who stutter would also be helpful in determining if the differences uncovered in the current study were the result of difficulties establishing and/or storing new phonological codes. Fast-mapping is the ability to construct a lexical representation for a novel phonological item on the basis of a single exposure (Alt, Plante, & Creusere, 2004; Carey & Bartlett, 1978; Dollaghan, 1985; 1987). It is the process by which new words are initially learned and stored in the lexicon. Ludlow et al. (1997) reported that adults who stutter demonstrated greater difficulty sequencing nonwords than typically fluent adults even after repeated practice. The authors attributed the difference to a difficulty with motor sequencing, but it could also be explained as difficulty in the construction of a new phonological code. Learning more about how both children and adults who stutter learn new words and generate new phonological codes could help to clarify some of the questions raised by the results of the current study.

5.10 CONCLUSION

The current study accomplished the goal of conducting a broad-based exploratory study to investigate the phonological processing abilities of adults who stutter. The differences revealed in the present study between adults who do and do not stutter support current psycholinguistic theories. These theories account for stuttering in different ways, but primarily argue that phonological encoding is disrupted or delayed in people who stutter. An investigation into the core mechanisms that contribute to the completion of the various phonological processing tasks provided clear evidence that people who stutter have difficulty assembling phonological code, presumably at the level of phonological encoding. Although significant differences were present between individuals who do and do not stutter on phonological processing tasks, these differences appear to be “sub-clinical;” meaning that the phonological processing/phonological encoding abilities of people who stutter were significantly different from nonstuttering adults, but the majority of the scores still fell within normal limits. This may indicate that the difference in phonological processing/phonological encoding present between people who do and do not stutter may be just one of the contributing factors (e.g., various linguistic factors, speech-motor planning, temperament) that can lead to an unstable speech system in people who stutter.

APPENDIX A

DISTRIBUTION OF STIMULI FOR SILENT PHONEME BLENDING/LEXICAL DECISION TASK

Table 32. Number of stimulus items at each condition level in the silent phoneme blending/lexical decision task.

Pair	Stimuli	Adults Who Stutter - Short	Adults Who Stutter - Medium	Adults Who Stutter - Long	Adults Who Do Not Stutter - Short	Adults Who Do Not Stutter - Medium	Adults Who Do Not Stutter - Long
Pair 1	Number of Stimuli	1	0	0	3	4	4
	WORD	748	-	-	861.66	717	864
	Number of Stimuli	1	1	0	2	4	1
	Nonword	2388	1305	-	1009.5	1042.5	716
Pair 2	Number of Stimuli	3	2	4	4	3	3
	WORD	1137.6	1560	1706.2	386.7	751.6	407.3
	Number of Stimuli	2	3	0	4	2	2
	Nonword	2045.5	2404	-	982.5	909	1101.5
Pair 3	Number of Stimuli	3	4	1	3	4	1
	WORD	701.3	1054.7	45	713.3	375	339
	Number of Stimuli	1	0	1	1	2	0
	Nonword	1243	-	1660	1215	1117	-
Pair 4	Number of Stimuli	3	4	2	4	2	0
	WORD	632.3	1681.5	627	863.5	621.5	-
	Number of Stimuli	4	2	1	3	1	0
	Nonword	1766.5	1717	2577	1202.3	539	-
Pair 5	Number of Stimuli	4	4	1	1	2	1
	WORD	970.25	1586.2	1026	2260	2938	1312
	Number of Stimuli	3	0	0	2	1	0
	Nonword	2065	-	-	3095	3265	-
Pair 6	Number of Stimuli	4	3	4	4	6	4
	WORD	930.7	1023	1155.5	2392.5	993.1	1096
	Number of Stimuli	3	1	0	1	2	0
	Nonword	1454.6	1459	-	1843	1884	-
Pair 7	Number of Stimuli	2	1	2	3	6	3
	WORD	1495.5	1921	914	369	731.5	558.3
	Number of Stimuli	2	2	0	3	2	1
	Nonword	2048	2143.5	-	1107.67	625.5	3978
Pair 8	Number of Stimuli	4	4	2	4	4	2
	WORD	970.2	849.2	542.5	1252.5	1259.5	174
	Number of Stimuli	2	1	0	3	1	1
	Nonword	2608	1263	-	1744.3	1591	5274

Pair	Stimuli	Adults Who Stutter - Short	Adults Who Stutter - Medium	Adults Who Stutter - Long	Adults Who Do Not Stutter - Short	Adults Who Do Not Stutter - Medium	Adults Who Do Not Stutter - Long
Pair 9	Number of Stimuli	4	2	1	4	4	4
	WORD	1116.5	1617	1845	1894.2	3097.7	1340
	Number of Stimuli	3	0	0	1	2	0
	Nonword	2044.3	-	-	2528	2994.5	-
Pair 10	Number of Stimuli	4	3	1	4	4	2
	WORD	1436.7	1559.3	159	694	863.2	685.5
	Number of Stimuli	4	2	0	2	0	0
	Nonword	1737.7	3001	-	1095	-	-
Pair 11	Number of Stimuli	3	3	1	2	3	1
	WORD	1249.6	1583.6	1418	1598.5	1200	1564
	Number of Stimuli	3	1	0	3	0	1
	Nonword	2161.6	3159	-	1664.6	-	2838
Pair 12	Number of Stimuli	2	3	0	2	3	1
	WORD	2125	988.3	-	701.5	5274	681
	Number of Stimuli	3	1	0	1	0	0
	Nonword	1445.3	2701	-	7147	-	-
Pair 13	Number of Stimuli	4	5	3	3	1	0
	WORD	1392.7	465.2	581.6	705.6	402	-
	Number of Stimuli	3	0	0	2	1	0
	Nonword	893.3	-	-	949	1720	-
Pair 14	Number of Stimuli	1	0	0	4	2	0
	WORD	1182	-	-	939.2	954	-
	Number of Stimuli	1	0	0	0	0	0
	Nonword	2234	-	-	-	-	-
Pair 15	Number of Stimuli	3	2	1	4	3	2
	WORD	995	1041	488	816.5	1216	1432.5
	Number of Stimuli	4	1	1	2	3	0
	Nonword	1001.2	930	954	1638.5	2428.6	-
Pair 16	Number of Stimuli	3	1	2	4	3	1
	WORD	972.3	1338	813.5	713.7	498.6	1908
	Number of Stimuli	3	1	0	2	1	2
	Nonword	1501.6	1328	-	1654.5	1172	1439.5

Pair	Stimuli	Adults Who Stutter - Short	Adults Who Stutter - Medium	Adults Who Stutter - Long	Adults Who Do Not Stutter - Short	Adults Who Do Not Stutter - Medium	Adults Who Do Not Stutter - Long
Pair 17	Number of Stimuli	3	5	2	4	5	3
	WORD	683.3	1238.2	765.5	663.2	894.2	791.3
	Number of Stimuli	2	2	0	3	4	1
	Nonword	1554	1570	-	978.6	1135.5	1143
Pair 18	Number of Stimuli	2	1	3	4	2	1
	WORD	651	81	662	1923.5	1334.5	1919
	Number of Stimuli	1	0	0	2	0	0
	Nonword	821	-	-	2040.5	-	-
Pair 19	Number of Stimuli	3	4	4	4	6	3
	WORD	1622.6	787	1268.2	2202.2	910	592.6
	Number of Stimuli	3	1	0	1	2	1
	Nonword	1750	1501	-	111	677.5	7351

APPENDIX B

MOTORIC, LINGUISTIC, AND TEMPERAMENTAL FACTORS

Stuttering has long been considered a disorder of the oral speech musculature (Kleinow & Smith, 2000; Ludow et al., 1997; Smith & Goffman, 2004; Tasko, McClean, & Runyan, 2007; van Lieshout, Hulstijn, & Peters, 1996; Zimmerman, 1980). Researchers have historically argued that deficiencies in the motor system of people who stutter were the cause of stuttering, although the contribution of a motoric component in stuttering has evolved to suggest the motor system in people who stutter may become taxed or overwhelmed by internal demands that compete for shared resources (Bosshardt, 2002; Bosshardt et al., 2002; Kleinow & Smith, 2000; Packman et al., 2001; Smits-Bandstra & de Nil, 2009; van Lieshout et al., 2004). In the last 20 years, however, theorists have begun to investigate linguistic factors that affect stuttering and forward theories that argue stuttering results from deficits or dissynchronies in language production (Howell & Au-Yeung, 2002; Karniol, 1995; Perkins et al, 1991; Postma & Kolk, 1993; Wingate 1988). Recent research also suggests that an individual's temperament and emotional reactivity may influence stuttering (Anderson et al., 2003; Karrass et al., 2006; Schwenk, Conture, & Walden, 2007). This paper focuses solely on psycholinguistic factors that can affect stuttering, but is not meant to disregard the importance of studying all aspects affecting fluency disorders.

APPENDIX C

PSYCHOLINGUISTIC THEORIES OF STUTTERING

Psycholinguistic theories of stuttering suggest that the locus of stuttering may exist at the level of phonological encoding (Howell & Au-Yeung, 2002; Karniol, 1995; Perkins et al., 1991; Postma & Kolk, 1993; Wingate 1988). The current section provides an overview of the psycholinguist models of stuttering which all propose that some sort of delay or disruption occurs at the level of phonological encoding. Although each theory differs in terms of the details, they all suggest that phonological encoding plays a central role in the disorder. These theories are discussed in more detail below.

C.1 FAULT LINE THEORY

One of the first psycholinguistic theories of stuttering was forwarded by Wingate (1988) who suggested that stuttering occurred at the level of the syllable. He hypothesized that a disruption occurred along a “fault line” between the onset (i.e., initial consonant cluster of a syllable) and rime (i.e., vowel or nucleus plus the final consonant cluster or coda) of a word (Wingate, 1988).

Wingate argued that stuttering was not limited to difficulty at the level of motoric execution but rather the “phonological elaboration of the retrieved lemma” (p. 5) (i.e., phonological encoding). He further suggested that stuttering was the result of unstable or impoverished representations of non-initial phonemes, arguing that only the onset of the word possessed robust enough encoding to be maintained. The rime was believed to be less stable in individuals who stutter, thus creating difficulties at the “fault line” of a syllable. He also argued that there was also an asynchrony in timing of the linguistic components due to weakly encoded segments, resulting in a delay in the planning and construction of syllables. Wingate indicated that there may also be difficulty retrieving suprasegmental markers, such as lexical stress, that may impede proper planning and result in disfluency, in addition to delays or disruptions at the level of phonological encoding.

C.2 NEUROPSYCHOLINGUISTIC THEORY

Perkins et al. (1991) presented a psycholinguistic theory of stuttering based on the slots and fillers model of speech planning (Shattuck-Hufnagel, 1984). The slots and fillers model proposed that language was planned through the creation of linguistic scaffolding consisting of syllable frames (i.e., slots), which were then filled with the phonological code of a syllable (i.e., fillers). Perkins et al. argued that the filling of slots with phonological code was occasionally mistimed and usually coupled with a sense of real or perceived time pressure. The addition of time pressure would tax the speaker’s linguistic system and result in an asynchronous delivery of the syllable’s phonological code. This mistiming was believed to result in stuttering. Perkins et al.

further suggested that in addition to a delay in the retrieval of the phonological code (i.e., the filler); there may also be a delay in the retrieval of the syllable frames as well. A delay in retrieval of either the phonological code or the syllable frames would occur during the process of phonological encoding and would result in both stutter-like and non-stuttered disfluencies.

C.3 COVERT REPAIR HYPOTHESIS

The covert repair hypothesis proposed by Postma and Kolk (1993; Kolk & Postma, 1997) suggested that stuttering occurred when “prearticulatory repairing of segmental and subsegmental phonological encoding errors" (Postma & Kolk, 1993, p. 478) occurs. The authors used a broad definition of phonological encoding to include both phonetic encoding as well as semantic encoding. They argued that an internal speech monitor detects an error prior to articulation and attempts to correct it. Detected errors may be successfully repaired prior to articulation and result in fluent speech. Occasionally, the detected errors are unable to be repaired in a timely manner and result in stuttering. Postma and Kolk argued that the system retraces the phonological plan back to the syllable boundary marker preceding the error in an attempt to self-correct prior to articulation. How much of the speech and/or articulatory plan has been executed will dictate how much retracing of the phonetic code will occur. Regardless of whether a large or small segment requires repair, the authors argued that the retracing will always occur at a syllabic boundary. Postma & Kolk suggested the type of disfluency depends on where the error is detected during encoding. Errors in grammatical encoding are hypothesized to result in repetitions of larger syllabic segments, while phonological encoding errors are believed result in part-word repetitions. Thus, the covert-repair hypothesis is another example of a psycholinguistic theory that argues that errors at the level of phonological encoding may result in stuttering.

C.5 EXPLAN

Howell and Au-Yeung (2002) proposed the EXPLAN model of stuttering to account for stuttering in terms of phonological complexity. The authors outlined two concurrently occurring stages; the planning stage (e.g., PLAN) and the execution stage (e.g., EX), and suggested that stuttering would occur if the “interface of linguistic planning and motoric execution” (i.e., during phonological encoding) was mistimed (p. 82). Howell and Au-Yeung argued that dissynchrony can occur when a segment is "difficult and, therefore, time-consuming to generate" (p. 81). The authors defined difficult segments as phonologically complex segments containing consonant clusters, late-developing consonants, or possess increased word or segment length. Words belonging to an open class, such as content words, are classified by Howell and Au-Yeung to be more difficult to produce than closed-class words (i.e., function words). Thus, the increased phonological difficulty would result in slower retrieval of those segments during phonological encoding and a dissynchrony between the speech and motor systems would occur.

C.6 SUMMARY

The theories discussed above share some basic tenants, although they differ in the exact mechanism deemed to be responsible for stuttering. All of the theories suggested that either a difficulty or a delay occurs at the level of phonological encoding. These delays may be due to difficulty in retrieving the segmented plan, or due to a mistiming of segmental or suprasegmental components of the speech plan. Many of the theories included some mechanism for error detection, even if it was not fully specified (Howell & Au-Yeung, 2002; Kolk & Postma, 1997; Perkins et al., 1991; Postma & Kolk, 1993). Fundamentally, all theories assumed that the retrieval or assembly of the phonological code of words occurred in an incremental way; in that the code is able to be broken apart into smaller components (i.e., individual phonemes). They all also argued that a delay or disruption occurs at some point during the retrieval or assembly of these constituent phonological segments that results in stuttering. With so many theories implicating phonological encoding, further investigation into the intricacies of phonological encoding in people who stutter is certainly warranted.

APPENDIX D

INFLUENCES ON PHONOLOGICAL PROCESSING

The phonological processing skills of phonological awareness, phonological memory, and rapid automatic naming appear to be separate, albeit intertwined, skills that have been demonstrated by researchers to mutually influence the development of phonological processing abilities. There is a particularly strong interaction between phonological awareness and phonological memory skills (Dickinson et al., 2003; Dickenson & Snow, 1987; Snowling & Hulme 1987; Wagner et al., 1994). Each phonological processing skill is thought to influence the others in various ways, primarily by helping hone and refine skills enabling them to operate at a more automatic level. Empirical evidence suggests phonological processing skills interact more in younger children and separate into distinct processing in older children and adults (Cornwall, 1992; Gathercole et al., 1991; Savage et al., 2005).

In addition to the influence phonological processing skills have on one another, a number of other variables can affect an individual's phonological processing ability. Age, socio-economic status, general language skills, vocabulary, and speech sound production ability all influence an individual's performance on phonological processing tasks.

D.1 AGE

Phonological processing skills gradually develop over time beginning around age three (Anthony & Francis, 2005; Chaney, 1994; Metsala, 1999). Phonological awareness becomes increasingly refined as a child's awareness becomes sensitive to smaller phonological components of lexical items (Anthony & Lonigan, 2004; Anthony et al., 2003; Fox & Routh, 1975; Liberman et al., 1974; Nittrouer et al., 1989; Treiman, 1992; Treiman & Breaux, 1982, Treiman & Zukowski, 1996). Continued exposure to print material and reading facilitates children's increasing awareness of syllables, onset/rime, and individual phonemes. Previously, phonological awareness abilities were believed to stabilize around age five, but recent research indicates some early phonological awareness skills can be stable at even younger ages when memory load is controlled (Anthony et al., 2003; Anthony et al., 2007; Lonigan et al., 2007). A modified phonological awareness blending task has been implemented by a number of researchers to account for differences in phonological memory of young children (Anthony et al., 2003; Anthony et al., 2007; Lonigan et al., 2007). Pictures depicting a compound word to be blended (e.g., *cow* and *boy = cowboy*) provided along with auditory presentation of the stimuli allowed young preschool children to perform the phonological awareness blending task (at least for larger units like words and compound words). The developmental progression of phonological awareness evolves to include awareness of finer phonological distinctions as the child ages. This evolution occurs in a gradual fashion over a number of years.

Age also affects performance on phonological memory tasks. Adults are able to maintain longer, more complex strings of information in phonological memory than children (Baddeley, 2003; Gathercole, 2007). This occurs, in part, due to well-established connections to vocabulary knowledge. A number of researchers argue that increased lexical knowledge helps decrease reliance on phonological memory (Gathercole et al, 1999; Roodenrys & Hinton, 2002; Thorn and Frankish, 2005; Vitevitch & Luce, 2005). Thus, as older children and adults acquire additional vocabulary, phonological representations overlap and aid in the activation of the phonological form at the lexeme rather than relying solely on phonological memory. Phonological processing skills develop along a continuum as a child matures. Thus, it is important to control for age when investigation the phonological processing skills of children.

D.2 SOCIOECONOMIC STATUS

The household environment greatly influences a child's language and reading development (Bird et al., 1995; Bowey, 1995; Dickinson & Snow, 1987; Dollaghan & Campbell, 1998; Engel, Santos & Gathercole, 2008; Hauser, 1994; Hecht & Greenfield, 2002; Lonigan et al., 1998; McDowell, Lonigan, & Goldstein, 2007; Nittrouer, 1996; Nittrouer & Burton, 2005). As such, socio-economic status is a background factor often documented in current research. Measurements used to estimate socio-economic status include household income, maternal/parental education level, and parental occupation (Cooper et al., 2002; Dollaghan & Campbell, 1998; Engel et al., 2008). Low socio-economic status has been shown to negatively influence a child's general language skills (Chaney, 1994; Dickinson & Snow, 1987; Dollaghan et al., 1998), vocabulary acquisition (Bee et al., 1969; Bryant, MacLean & Bradley, 1990; Dickinson et al., 2003; Dickinson & Snow, 1987; Duncan & Brooks-Gunn, 1997; Farran, 1982;

Farran & Haskins, 1980; Hart & Risley, 1995; Heath, 1983; Hess & Shipman, 1965; Hoff-Ginsberg, 1991; McDowell et al., 2007; Schacter, 1979; Warren-Leubecker & Carter, 1988), phonological awareness abilities (Bowey, 1995; Burgess, 2002; Chaney, 1994; Lonigan et al., 1998; McDowell et al., 2007; Nittrouer, 1996; Nittrouer, & Burton, 2005), and phonological memory (Chaney, 1994; Dickinson & Snow, 1987; Engel et al., 2008; Lonigan et al., 1998; McDowell et al., 2007). Family environments with higher socio-economic status are reported to be more likely to employ teaching through maternal discourse, model early literacy behaviors, and provide early exposure to print and literacy (Brody & Flor, 1998; Fuligni, 1997; Hart & Risley, 1995; Hoff, 2003; Hoff & Tian, 2005; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Tomblin et al., 1997; Walker, Greenwood, Hart, & Carta, 1994). These elements positively influence phonological processing, reading, and other linguistic abilities. Socio-economic status exerts a powerful influence on many aspects of language and phonological processing that should be controlled for in studies involving any linguistic ability, particularly phonological processing.

D.3 GENERAL LANGUAGE

General language ability also influences phonological awareness and phonological memory, particularly in children (Dickinson et al., 2003; Frijters et al., 2000; Lonigan et al., 2000; Metsala, 1999; Olofsson & Neidersoe, 1999; Sénéchal & LeFevre, 2002; Silven, Niemi, & Voeten, 2002; Storch & Whitehurst, 2002). Chaney (1994) conducted a multiple regression analysis exploring phonological processing and general oral language skills. The study revealed that general oral language ability is strongly related to phonological processing skills, particularly phonological awareness abilities. Cooper et al. (2002) investigated the relationship of oral language skills and the development of phonological awareness in reading and non-reading children (kindergarten through 2nd grade). Oral language accounted for nearly 28% of the variance in phonological awareness for non-readers in kindergarten, 42% of the variance for non-readers in the first grade, and 41% for non-readers in the second grade. The influence of general language ability was not as high for children who already knew how to read. The authors interpret these findings as demonstrating the importance of general language ability in the development of phonological awareness. The studies discussed above highlight the importance of controlling for general language ability when investigating the phonological processing skills of children.

D.4 VOCABULARY

Phonological awareness ability in children is influenced by vocabulary knowledge (Carroll et al, 2003; Leseman & De Jong, 1998; Metsala, 1999; Silven et al., 2002). Metsala (1999) investigated the influence of vocabulary size on phonological processing in a sample of four- to six-year old children. She reported a significant correlation between phonological awareness segmentation tasks and receptive vocabulary size. A longitudinal study conducted by Leseman and de Jong (1998) reported vocabulary knowledge at age four predicted word decoding (a phonological awareness skill) at age seven. Early language development and phonological awareness was also investigated via another longitudinal study, this time by Silven et al. (2002). The authors reported that vocabulary knowledge at age two predicted onset-rime awareness at age four. Carroll et al. (2003) explored the relationship between a number of language measures and the development of phonological awareness in typically developing preschool children. Carroll et al. reported a strong correlation between receptive vocabulary skills and phonological awareness, particularly in what the authors termed “large-segment awareness” which is a combination of rime and syllable matching. It is also one of the first phonological awareness skills to develop. The authors interpreted this finding as support for the assertion that “early global sound sensitivity may be related to the growth of vocabulary knowledge” (Carroll et al 2003, p. 920).

Phonological memory is also influenced by vocabulary knowledge in young children (Baddeley & Wilson, 1993; Gathercole & Baddeley, 1989; Gathercole et al., 1992; Masoura & Gathercole, 2005.) A longitudinal study conducted by Gathercole and Baddeley (1989) investigated the relationship of phonological memory and vocabulary growth in typically developing children aged four and five. Phonological memory, as measured by a nonword repetition task completed by four year olds, was a strong predictor of vocabulary growth at five years old. This study provided evidence that phonological memory, as measured by nonword repetition, is implicated in new vocabulary acquisition. Nonword repetition requires the ability to form novel phonological representations in the same way new vocabulary words are formed. Any difficulties in nonword repetition could affect a child’s ability to acquire new words by delaying the establishment of stable representations or by development of incomplete or unstable representations. The literature provides evidence of a positive relationship/correlation between vocabulary knowledge and phonological processing ability. "There is substantial evidence linking the process of storing the unfamiliar phonological structure of a new word with verbal short-term memory" (p.762). The contribution of vocabulary knowledge to phonological memory in older children and adults responds differently than younger children (Masoura & Gathercole, 2005, Paulesu et al. 2009). As discussed briefly above, lexical knowledge appears to reach a critical level at approximately eight years of age. Lexical knowledge begins to be utilized, decreasing dependence on phonological memory for short-term memory recall and can also be used to bolster weaker systems.

D.5 SPEECH SOUND ABILITIES

The relationship of speech sound production abilities and phonological processing in children has also been investigated by a number of researchers. Webster and Plante (1992) conducted a study of phonological awareness abilities in children with speech sound production disorders compared to a matched control group. The group with speech sound disorders performed significantly less well than the typical group on three phonological awareness tasks. Bird et al. (1995) investigated the relationship between speech sound abilities, phonological awareness and general reading ability in a longitudinal study of children aged five to seven. Children from the phonologically impaired group performed significantly lower than controls on measures of phonological awareness and reading ability. Carroll et al. (2003) investigated the development of phonological awareness and related language abilities in typically developing preschool children. Articulation accuracy exerted a significant influence on phonological awareness. The authors reported children with large numbers of articulation errors performed less well on measures of phonological awareness. Not all studies report an interaction between articulation abilities and phonological awareness skills. Rvachew and Grawburg (2006) investigated articulatory abilities as a factor that affects phonological awareness skills in preschool children. The authors reported findings contrary to earlier studies and reported articulation accuracy was *not* a factor that affected phonological awareness abilities in children four to five years old. These results were similar to those presented by Larrivee and Catts (1999) who reported the severity of the articulation disorder could not account for phonological awareness skills; however, the phonological disorders group also included a large percentage of participants with concomitant language disorders as well. Larrivee and Catts split up the phonological disorders group into two further groups according to reading ability to explore the relationship between the language abilities of good and poor readers. A closer look at the data in both studies reveal not only significant differences between good and poor readers on phonological processing tasks, but also a significant difference in general language abilities that likely account for the paradoxical findings.

The discussion above provides evidence that many lexical factors appear to influence phonological processing. As such, experimental designs investigating phonological processing should account for the influence of age, socioeconomic status, general language ability, vocabulary, and speech sound production ability.

APPENDIX E

PHONOLOGICAL AWARENESS IN CHILDREN WHO STUTTER

There are only two studies that explicitly state phonological awareness as dependent measures in children who stutter; however, a number of studies do explore phonological awareness, phonological memory, and rapid automatic naming in children who stutter. These studies are reviewed below and interpreted within a phonological processing framework.

E.I IMPLICIT PHONOLOGICAL AWARENESS

Phonological priming studies are believed to measure *implicit phonological awareness,* that is, awareness of word onsets on a subconscious, non-volitional level. Traditionally, prime words with the same beginning phoneme (onset) as the target word are named faster when an onset is shared, resulting in a facilitative effect. The goal of phonological priming studies with children who stutter is often to determine whether children who stutter demonstrate similar facilitative effects, but the studies have reported mixed results.

Melnick et al. (2003) used a picture-naming phonological priming paradigm to examine the speed of phonological encoding in 36 preschool children who stutter and their typically fluent peers, aged three to five years. Phonological facilitation (i.e., faster response times in the presence of phonologically similar primes) was the primary dependent measure. Auditory primes were presented in three conditions: 1) no prime, 2) matching prime, and 3) incongruent (i.e., non-matching) prime. Melnick et al. hypothesized children who stutter would not benefit from phonological facilitation as much as children who do not stutter due to impairments in their ability to encode phonological information. All children individually demonstrated faster naming latencies when presented with an auditory prime with the same onset as the target word than when presented with an incongruent (i.e., non-matching) phonological prime. Results indicated no significant between-group differences in reaction times were present for any condition. The authors did report a great deal of variability in response times both between and within children who do not stutter. Conversely, children who stutter displayed relatively stable response times between ages three and five and did not demonstrate that same magnitude of change the non-stuttering children demonstrated. Melnick et al. argue this lack of variability in response time between the younger and older age children who stutter groups indicates the five-year olds might not be able to encode phonological information as rapidly. The authors also reported children who do not stutter demonstrated a significant negative correlation in picture-naming latencies when compared with scores on a measure of speech sound articulation (*Goldman-Fristoe Test of Articulation–2* [GFTA-2]; Goldman & Fristoe, 2000), whereas children who stutter did not. Children who do not stutter with shorter naming latencies demonstrated greater articulatory mastery, whereas those with longer naming latencies demonstrated less articulatory mastery. In contrast, children who stutter did not exhibit an association between speech sound articulation and naming latencies. Melnick et al. interpret the lack of negative correlation between articulation skills and response time to be indicative of less well developed/organized phonological encoding systems in children who stutter as compared to their typically developing peers. Other researchers (Anderson & Byrd, 2008; Hakim & Ratner, 2004) have suggested the findings could be indicative of a difficulty for children who stutter to hold phonological information in memory rather than a deficit in the specificity of their phonological representations. The lack of variability in children who stutter suggests there are some differences in how children who stutter respond to implicit phonological awareness tasks, although results were far from conclusive.

Byrd et al. (2007) explored the phonological encoding of three year-old and five year-old children who stutter and their age-matched, non-stuttering peers on their ability to respond to holistic (i.e., entire lexical item) and incremental (i.e., segment of a lexical item) phonological priming conditions. Participants were presented with incremental (e.g., “b” for book) or holistic (e.g., “ook” for book) auditory prime and were required to name pictures following the prime as quickly as possible. Speech reaction times revealed both groups of three year-olds responded to the holistic priming faster than incremental primes. The five year-old typically fluent children responded more quickly to the incremental priming conditions, much as adults do. Conversely, children who stutter continued to respond more quickly to holistic priming conditions and did not show developmental advancement. Byrd et al. suggests the retention of holistic processing for the children who stutter may be indicative of a delay in the incremental processing of phonological encoding. Alternatively, the differences between holistic and incrementally processing could be representative of a delayed or reduced awareness of the component parts of lexical items.

Byrd et al.'s (2007) results were replicated (although published before Byrd et al.) in a study by Arnold et al. (2006). Children were administered a holistic and segmental priming task, as in Byrd et al. Evoked-response potentials (ERPs) were also obtained while the task was performed. Children who stutter again responded faster in the holistic priming condition than in the segmental priming condition. Arnold et al. also reported differences in ERP signals between the two priming conditions, suggesting the two conditions demonstrate differences from both a behavioral and cognitive perspective. Replicated findings provide strong evidence for a different level of segmental awareness in young children who stutter. It is difficult to know if Byrd et al.'s findings are indicative of a delay that children who stutter eventually develop out of or a true difference in abilities compared to children who do not stutter. Further research with school-age children and adults would help to determine this distinction.

E.2 EXPLICIT PHONOLOGICAL AWARENESS

Explicit phonological awareness involves the volitional ability to parse apart phonological segments of language. Only three studies to date have specifically investigated explicit phonological awareness in children who stutter and are discussed in more detail below.

Bajaj et al. (2004) explored select aspects of phonological and grammatical awareness in children who stutter. Forty-six children in kindergarten through 2nd grade participated in the study (10 in kindergarten, 24 in first grade, 12 in second grade), half of whom stuttered and the other half did not. The children ranged in age from 5;10 to 8;10 and all were male. The participants completed three phonological awareness tasks and a grammar judgment task. The phonological awareness tasks included administration of *The Lindamood Auditory Conceptualization Test* (LAC; Lindamood & Lindamood, 1979) which requires phoneme identification and manipulation, as well as the Phoneme Reversal subtest of the *Comprehensive Test of Phonological Processing (*CTOPP, Wagner et al., 1999). Bajaj et al. reported no significant differences in the phonological awareness tasks, but children who stutter performed significantly lower on the grammatical judgment task. The authors reported children who stutter mean scores were lower than their typically fluent peers for all measures, but no other measure reached significance. A number of methodological concerns exist with Bajaj et al.'s study that should be taken into consideration. The children in each group ranged in age from 5:10 to 8:10 and many older, more experienced readers in each group than younger readers. Each group contained 10 kindergarteners, 24 first-graders, and 12 second-graders. Collapsing data across age groups without accounting for the effect of age on phonological awareness would mask any potential difference between groups. Also of concern in this study design is the use of phoneme reversal as one measure of phonological awareness. Phoneme reversal is a more developmentally advanced ability, requiring greater memory resources while the reversal task is conducted (Mann & Lieberman, 1984). In fact, according the CTOPP authors, the task is only recommended for children seven and older, suggesting it too difficult for over half the participants in Bajaj et al.'s study. Thus, regardless of group affiliation, the task may have been too difficult for many of the participants and resulted in a ceiling effect. In light of the above-stated methodological concerns, it is difficult to draw conclusions regarding the phonological awareness ability of children who stutter from the study.

In an attempt to account for the full spectrum of phonological awareness tasks, Pelczarski and Yaruss (2008) investigated a broad range of phonological processing skills in 5- and 6- year old children who stutter and children who do not stutter. The CTOPP (Wagner et al., 1999) was administered to all participants. The CTOPP is a standardized test developed to measure phonological awareness, phonological memory, and rapid automatic naming in children. The two versions differ in terms of task complexity, with more phonological awareness skills tested in the version for older children. A variety of subtest gauged performance on phonological awareness (e.g., Elision, Word- and Sound-Blending, Sound Matching), phonological memory (e.g., Nonword Repetition and Memory for Digits), and rapid automatic naming (e.g., Rapid Color Naming and Rapid Object Naming). Participants were well-matched on general language ability, sex, and SES. Significant differences between groups were found for phonological awareness, phonological memory, but not for rapid automatic naming (to be discussed in more detail below), further supporting the premise that aspects of phonological processing are different or delayed in children who stutter. Results indicate significant between-group differences in phonological awareness, despite all participants scoring within normal limits. Indeed, the differences were subtle, yet robust, indicating differences were present even when confounding factors were controlled.

Weber-Fox et al., (2008) investigated phonological awareness using a visual rhyming task in 10 children who stutter and 10 children who do not stutter. Participants ranged in age from 9;4 to 13;9 and were matched according to gender and age. The primary behavioral assignment was a rhyming judgment task utilizing four conditions: 1) rhyming pair of orthographic similarity (thrown, own), 2) rhyming pair with dissimilar orthography (cone, own), 3) non-rhyming pair with similar orthography (gown, own), and 4) non-rhyming pair with dissimilar orthography (cake, own). These same pairs were used in an earlier ERP study investigating the rhyming abilities of adults who stutter. Accuracy and reaction times were measured for the task and ERP data collected during the entirety of the task. Results reveal children who stutter were significantly less accurate across all conditions and both groups demonstrated particular difficulties with the non-rhyming, orthographically similar condition, as it was the most cognitively taxing of the four conditions. No between-group differences were reported for reaction times, only accuracy judgments. Although the authors suggest their rhyming task is simply a task of phonological awareness, closer examination of the task reveals the participation of two separate phonological processing skills – phonological awareness (rhyming judgment) and aspects of rapid automatic naming (rapid orthographic symbol decoding into a phonological representation). The design of the study makes it difficult to determine which skill may be contributing to any differences revealed. Growing evidence supports the premise that phonological awareness skills in children who stutter are different or delayed as compared to children who do not stutter.

APPENDIX F

PHONOLOGICAL MEMORY AND CHILDREN WHO STUTTER

Nonword repetition abilities reflect phonological knowledge and phonological working memory capacity (Baddeley et al., 1998). Phonological memory is another aspect of phonological processing studied in the literature, primarily through nonword repetition studies. No phonological template exists for nonwords, thereby requiring the use of phonological memory and online generation of the speech plan. A number of studies have explored the non-word repetition abilities of children who stutter across multiple age ranges.

Hakim and Bernstein Ratner (2004) studied nonword repetition ability in 8 children who stutter (mean 5-10; range 4;3-8;4) and 8 children who do not stutter (mean 5-9; range 4;1 – 8;4). The authors' stated rationale for using a nonword repetition task was based on previous research which suggested nonword repetition ability is a more accurate measure of overall language ability (Dollaghan & Campbell, 1998). Nonword repetition is also a task used to measure phonological memory in the context of phonological processing skills. All participants were administered the Children's Test of NonWord Repetition (CNRep; Gathercole et al., 1994). The CNRep is a standardized measure that requires participants to repeat 40 nonsense words after hearing them spoken aloud. The participants were administered ten nonwords from each syllable length condition (2-syllables, 3-syllables, 4-syllables, and 5-syllables). The stimuli are not real words, but are more “word-like” than other widely used tests of nonword repetition ability. The results reveal that children who stutter made more errors than their non-stuttering peers on both subtests of the CNRep, however, only the 3-syllable non-words reached significance.

Anderson et al. (2006) explored the non-word repetition abilities of young children who stutter between the ages of three and five. This study was similar to one conducted by Hakim and Bernstein Ratner (2004) that explored non-word repetition abilities of slightly older children who stutter (4-8 years old) and their non-stuttering peers. Participants were matched according to general language, sex, socioeconomic status and age (plus or minus four months). The CNRep was scored using procedures similar to those utilized by Hakim and Ratner (2004) to allow for direct comparison between the two studies. Children who stutter produced significantly fewer correct productions of 2- and 3- syllable nonwords than matched nonstuttering peers. Hakim and Bernstein Ratner’s results with slightly older children revealed significant differences for only the 3-syllable stimuli. Anderson et al. noted a ceiling effect was present in the Hakim and Bernstein Ratner study, but was not present in the current investigation with younger participants. Anderson et al. indicated a floor effect was present with the younger children as evidenced by difficulties from both groups with the five-syllable stimuli.

A further exploration of the nonword repetition abilities of children who stutter was conducted by Seery et al. (2006) using the CNRep as well. The participants consisted of an older group of children than had been previously studied and ranged in age from 8 ½ to 12 ½. Participants included 14 children who stuttered (11 boys, 3 girls) and 11 non-stuttering peers (9 boys, 2 girls). The CNRep was again the primary dependent measure, and unlike studies of younger children who stutter, the authors reported a significant difference between groups at the

5-syllable level only, with controls repeating more 5-syllable nonwords correctly. The authors report no significant differences in the types of errors produced. One limitation of this study goes back to the use of the CNRep as the primary measure. The CNRep counts an item as incorrect if at least one error is made, but does not explore the total number of errors produced, therefore it is difficult to know if any potential differences may have been masked due to the standard of scoring. Although the authors do not analyze these values specifically, the total number of errors made at each syllable level per group reveals that the group of children who stutter made approximately 17 errors across syllable levels whereas the children who do not stutter produced approximately 9 errors. A statistical analysis of the ratio the percent syllable/phoneme correct was not reported or analyzed, therefore it is impossible to say if they are significantly different. It can be stated that the number of phonemic errors were higher at each syllable level for the children who stuttered than the control group. The authors did compare the mean number of phoneme error types. This study was the first to examine nonword repetition in older school-age children who stutter. Although the authors do not report significant differences at all levels (only at the 5-syllable level), there are enough inconsistencies in the methodology to warrant further investigation. It is unknown if more differences would have been revealed with a different scoring structure/rubric or with a different nonword repetition test that did not have so many lexically embedded words.

Pelczarski and Yaruss (2008) also reported significant differences in nonword repetition and digit recall subtests of the CTOPP with 5- and 6- year old children who stutter. The CTOPP nonword repetition subtest consists of 18 items ranging from one to seven syllables. Children who stutter scored significantly lower than their matched, non-stuttering peers while still scoring within normal limits of the standardized subtest. The CTOPP nonword repetition subtest, like the CNRep, is scored only as correct/incorrect and does contain more “word-like” nonwords. Still, between group differences were present among the 5- and 6- year old participants. Perhaps differences were more obvious with the inclusion of harder (i.e., longer) stimuli that may tax the phonological memory of children who stutter.

Bakhtiar et al. (2009) conducted a nonword study with different results. Twelve children who stutter (8 boys, 4 girls) and 12 children who do not stutter (8 boys, 4 girls) between the ages of 5;1 and 7;10 were reported to possess typical language, articulation and short-term memory abilities. The participants repeated 2- and 3- syllable nonwords. Reaction times as well as percentage of phonemes correct were recorded. Participants were encouraged to say the nonwords as accurately and quickly as possible. Bakhtiar et al. reported more errors and slower response times for children who stutter, but these differences did not reach significance. This data conflicts with other studies exploring nonword repetition in children who stutter and may have been due in part to the length of stimuli used. Use of only 2- and 3- syllable nonwords in the older children may have resulted in a ceiling effect, not revealing potential differences resulting from differences in phonological memory or a larger cognitive processing load.

Weber-Fox et al. (2008) investigated a visual rhyming task in 10 children who stutter and 10 typically fluent peers. Participants ranged in age from 9;4 to 13;9 and were matched according to gender and chronological age. Children all possessed typical language skills. Additionally, all children were administered the Nonword Repetition Task (NRT; Dollaghan & Campbell, 1998) as an additional measure of language ability, but could also be considered a measure of phonological memory. No between-group differences were reported for the general language measures or the NRT. Although no significant differences were found between groups, closer examination of the data for NRT reveal that descriptively, children who stutter began to experience more difficulty with the task at the 3-syllable level. This is similar to findings from Hakim and Ratner (2004). Although the scores may not be significantly different, six out of ten children who stutter produced errors, while only two out of ten children who do not stutter produced errors. The authors do acknowledge that many participants performed at ceiling and suggest that longer and more phonologically complex nonwords might have revealed between-group differences.

Another non-significant finding was reported by Bajaj et al. 2004. Although phonological memory skills were not expressly investigated, Bajaj (2007) argues the lack of significant finding on phonological awareness tasks in his 2004 study can be translated as support for non-significant differences in phonological memory as well. Phonological awareness and phonological memory tasks are somewhat interdependent, particularly at younger ages, but as discussed above, the phonological awareness tasks used were too developmentally advanced for the majority of the children. Additionally, it is very difficult to parse apart the influence of phonological awareness and phonological memory when only phonological awareness was in fact measured. Still, additional research with more specific tasks and stimuli across different ages will provide further insight into the relationships of phonological processing and children who stutter.

Studies that have explored nonword repetition in children who stutter across a range of ages have all shown general trends of children who stutter performing less well than non-stuttering peers, but not all age ranges appear to perform/behave the same. Anderson and colleagues (2006) reported significant differences at the 2- and 3- syllable nonword level as compared to controls examined the youngest group of children who stutter (i.e., 3-5 year olds). Participants in Pelczarski and Yaruss' (2008) study of 5- and 6- year olds revealed significant differences in non-word repetition. Bakhtiar et al. (2009) conducted a non-word repetition task with 5- to 8-year old children and reported lower overall scores for children who stutter, but no significant differences. Hakim and Ratner (2004) studied children 4 to 8 years of age and reported generally lower scores with only a significant difference at the 3-syllable level. The oldest group of children, aged 8 ½ through 12 ½, was studied by Seery et al. (2006) who reported that although the children who stutter on average scored lower than nonstuttering peers, were only significantly different on stimuli at the 5-syllable level. In summary, all studies reported lower scores for children who stutter, which did not always result in statistically significant differences. Still some studies, particularly with younger children did demonstrate significant differences at some levels. The general trend appears to be that children who stutter have more difficulty with nonword repetition at younger ages and lessens as the children age. Nevertheless, the findings suggest any differences may be subtle; therefore, tasks must be sensitive enough to detect potential differences. Further study is needed taking into consideration the factors that may affect phonological memory/nonword repetition tasks. Phonological memory skills, along with phonological awareness skills, continue to develop and stabilize as children receive more exposure to and practice with reading and other phonological processing skills.

APPENDIX G

RAPID AUTOMATIC NAMING IN CHILDREN WHO STUTTER

Rapid automatic naming is considered and important skill for the acquisition and ease of learning to read. This early literacy skill is particularly important in determining visual-verbal associations and the learning of arbitrary associations between sound and print. Rapid automatic naming is included as a phonological processing skill due to its important contribution to literacy acquisition. Indeed, the specific value of measuring rapid automatic naming lies in the ability to quickly and efficiently retrieve phonological code from visually presented symbols. Few studies have investigated this skill in children who stutter, with contrary results reported. As discussed in the phonological awareness section, a study by Pelczarski and Yaruss (2008) explored the phonological processing skills of young children who stutter, including rapid automatic naming. Despite the timed nature of the task, children who stutter performed equally as well as children who do not stutter. The study's hypothesis was children who stutter would have difficulty with segmentation tasks (measuring phonological awareness) and phonological memory (which is a necessary skill whenever a lexical item needed to be retrieved and maintained in memory while it is manipulated). Considering the speeded nature of rapid automatic naming (naming objects or colors as quickly as possible) it was hypothesized that children who stutter would perform rapid naming more slowly than their non-stuttering counterparts; however, no difference for children who stutter was reported.

As discussed in the phonological awareness section above, Weber-Fox et al. (2008) used a visual rhyming paradigm with congruent and incongruent orthographic pairs. Children who stutter produced significantly more errors than children who do not stutter, demonstrating particular difficulty with the non-rhyming, orthographically similar condition. The interplay of both phonological awareness and rapid automatic naming in the study design makes it difficult to determine if children who stutter were less accurate due to rhyme identification or due to some aspect of rapid automatic naming. Additionally, Weber-Fox and colleagues suggest an alternative explanation where children who stutter reach a critical level of processing at which point a breakdown occurs. Further specified studies across age groups will help determine contributions of each skill set and possible interactions of processing limitations.

APPENDIX H

PHONOLOGICAL PROCESSING IN CHILDREN WHO STUTTER SUMMARY

It has been determined that reading acquisition is based on a number of skills including phonological awareness, phonological memory, and rapid naming. Evidence exists to support the premise that differences in phonological awareness, phonological memory, and rapid automatic naming exist in children who stutter. Children with reading difficulties or dyslexia may possess deficits in phonological awareness, phonological memory, rapid automatic naming, or a combination of these skills. Oftentimes, poor readers may have a deficit in a single skill area, but may be able to compensate for deficits in one area with strengths in another. (e.g., a child may have difficulty in phonological awareness, but have strong phonological memory skills or vice versa). As a result, children may have deficits that do not reveal themselves until specifically tested due to compensatory strategies the brain employs. This may account for why there is not currently any strong evidence that children who stutter have deficits in overall reading ability. Rather, it is likely that there may be a sub-group of children who stutter who have difficulty in reading ability due to deficits in multiple areas (phonological awareness, phonological memory, and rapid automatic naming) that affect their ability to acquire efficiently acquire literacy skills. Further specification of these subtle differences may allow for the creation of a phonological processing profile for individual children who stutter. It may be possible for children who stutter to display difficulties in just one aspect of phonological processing that are compensated for by other aspects of phonological processing. Once the system is taxed enough or tested specifically enough potential deficits be likely be revealed.

In many instances researchers explore a single aspect of phonological awareness, be it rhyme monitoring, segmentation, or nonword repetition and interpret their results in a sweeping/general statement asserting a statement about phonological processing in general, when only a small snapshot of phonological processing was in fact being measured and investigated. As discussed previously, aspects of phonological awareness can be measured using up to six different types of tasks depending on the age of study participants. Selective inclusion of isolated phonological processing tasks results in number of difficulties. First, investigation of only one or two phonological processing skills results in an incomplete picture of an individual who stutter's phonological processing profile. Second, non-specification of which phonological processing skills being measured coupled by the use of different nomenclature increases the difficulty of comparing and analyzing available evidence.

APPENDIX I

CORRELATIONAL ANALYSES OF PHONOLOGICAL PROCESSING

I.1 VOCABULARY

Vocabulary measures typically have strong correlations with measures of phonological awareness and phonological memory for children, although these relationships are not as strong in adults (Gathercole et al., 1992). Table 33 outlines the correlations between the expressive and receptive vocabulary measures and the phonological processing tasks for adults who stutter. Moderate correlations ($r > .476$; $p < .05$) were revealed between vocabulary scores and Phonological Memory, Late-8 NRT, and Rapid Automatic Naming. As seen in Table 34, the vocabulary scores for adults who do not stutter were weakly to moderately correlated ($r > .440$; $p < .05$) with the Alternate Phonological Awareness Composite score and the NRT.

Table 33. Vocabulary tests and phonological processing tasks correlation table for adults who stutter.

Phonological Processing Tasks	Expressive Vocabulary Test	Peabody Picture Vocabulary Test
Phonological Awareness Composite	*r* = .125 *p* = .316 N = 17	*r* = .354 *p* =.075 N = 18
Alternate Phonological Awareness Composite	*r* = .299 *p* = .122 N = 17	*r* = .265 *p* =.143 N = 18
Phonological Memory Composite	*r* = .589 *p* = .005 N = 18	*r* = .563 *p* = .006 N = 19
Nonword Repetition Task total	*r* = -.084 *p* = .370 N = 18	*r* = .192 *p* = .215 N = 19
Late-8 Nonword Repetition Task total	*r* = .476 *p* = .023 N = 18	*r* = .504 *p* = .014 N = 19
Rapid Automatic Naming Composite Score	*r* = -.499 *p* = .025 N = 16	*r* = -.559 *p* = .010 N = 17
Alternate Rapid Automatic Naming Composite Score	*r* = .201 *p* = .219 N = 17	*r* = -.034 *p* = .447 N = 18
Expressive Vocabulary Test		*r* = .664 *p* = .001 N = 18

Table 34. Vocabulary and phonological processing tasks correlation table for adults who do not stutter.

Phonological Processing Tasks	Expressive Vocabulary Test	Peabody Picture Vocabulary Test
Phonological Awareness Composite	*r* = .161 *p* = .268 N = 17	*r* = 316 *p* = .100 N = 18
Alternate Phonological Awareness Composite	*r* = .491 *p* = .019 N = 18	*r* = .393 *p* = .048 N = 19
Phonological Memory Composite	*r* = .313 *p* = .110 N = 17	*r* = -.006 *p* = .491 N = 18
Nonword Repetition Task total	*r* = .514 *p* = .017 N = 17	*r* = .440 *p* = .034 N = 18
Late-8 Nonword Repetition Task total	*r* = .112 *p* = .329 N = 18	*r* = .036 p = .441 N = 19
Rapid Automatic Naming Composite Score	*r* = -.136 *p* = .296 N = 18	*r* = .165 *p* = .250 N = 19
Alternate Rapid Automatic Naming Composite Score	*r* = -.019 *p* = .470 N = 18	*r* = .097 *p* = .347 N = 19
Expressive Vocabulary Test		*r* = .555 *p* =.008 N = 18

I.2 PHONOLOGICAL AWARENESS COMPOSITE SCORE

Table 35 displays within-group correlations for adults who stutter on all Phonological Awareness Composite Scores and subtests of the CTOPP. Adults who stutter demonstrated significant correlations between the Phonological Awareness Composite score and the Alternative Phonological Awareness Composite score, the Segmenting Nonwords, and the Segmenting Words subtests ($r > .475$; $p < .05$). The Elision subtest for adults who stutter was highly correlated with the Segmenting Nonwords and Segmenting Words subtests ($r > .543$; $p < .01$). The Blending Words subtest was moderately correlated with Phoneme Reversal and Segmenting Words ($r >.470$; $p < .05$) for adults who stutter. Segmenting Words was moderately correlated with Segmenting words and Phoneme Reversal subtests ($r > .546$; $p < .01$). Table 36 illustrates that the Phonological Awareness Composite scores for adults who do not stutter were highly correlated with two different subtests: Blending Nonwords and Phoneme Reversal ($r > .542$; $p < .05$). Non-stuttering adults demonstrated a moderate correlation between Elision and Phoneme Reversal ($r = .587$; $p = .007$). Both adults who stutter and those who do not demonstrated moderate correlations between the Blending Words subtest and the Blending Nonwords and Segmenting Nonwords subtest ($r > .439$; $p < .05$). Both adults who stutter and adults who do not stutter demonstrated the expected strong correlations between Phonological Awareness Composite score and the Elision and Blending Words subtests from which it is comprised ($r > .691$; $p < .05$).

Table 35. Correlations for adults who stutter for all phonological awareness tasks of the *Comprehensive Test of Phonological Processing*.

	Alternate PA Composite	Elision	Blending Words	Blending Nonwords	Segmenting Nonwords	Phoneme Reversal	Segmenting Words
PA Composite	*r* = .475 *p* = .023 N =18	*r* = .831 *p* = < .001* N =18	*r* = .727 *p* = < .001* N =18	*r* = .319 *p* = .098 N =18	*r* = .589 *p* = .005 N =18	*r* = .382 *p* = .072 N =18	*r* = .542 *p* = .010 N =18
Alternate PA Composite		*r* = .223 *p* = .187 N = 18	*r* = .557 *p* = .008 N = 18	*r* = .904 *p* = < .001* N = 18	*r* = .713 *p* =<.001* N = 18	*r* = .242 *p* = .183 N = 16	*r* = .559 *p* = .008 N = 18
Elision			*r* = .335 *p* = .068 N = 19	*r* = .160 *p* = .256 N = 19	*r* = .569 *p* = .006 N = 19	*r* = .378 *p* = .068 N = 17	*r* = .543 *p* = .008 N = 19
Blending Words				*r* = .563 *p* = .006 N = 19	*r* = .601 *p* = .003 N = 19	*r* = .559 *p* = .010 N = 17	*r* = .470 *p* = .021 N = 19
Blending Nonwords					*r* = .475 *p* = .020 N = 19	*r* = .223 *p* = .194 N = 17	*r* = .473 *p* = .020 N = 19
Segmenting Nonwords§						*r* = .546 *p* = .012 N = 17	*r* = .660 *p* = .001 N = 19
Phoneme Reversal§							*r* = .321 *p* = .104 N = 17

*expected significant correlations

§ Subtests not included in composite scores

Table 36. Correlations for adults who do not stutter for all phonological awareness (PA) tasks of the *Comprehensive Test of Phonological Processing*.

	Alternate PA Composite	Elision	Blending Words	Blending Nonwords	Segmenting Nonwords	Phoneme Reversal	Segmenting Words
PA Composite	*r* = .402 *p* = .049 N = 18	*r* = .691 *p* = <.001* N = 17	*r* = .725 *p* = <.001* N = 18	*r* = .450 *p* = .030 N = 18	*r* = .045 *p* = .432 N = 17	*r* = .588 *p* = .007 N = 17	*r* = -.141 *p* = .289 N = 18
Alternate PA Composite		*r* = .266 *p* = .143 N = 18	*r* = .642 *p* = .002 N = 19	*r* = .781 *p* = <.001* N = 19	*r* = .780 *p* = < .001* N = 18	*r* = .407 *p* = .047 N = 18	*r* = .327 *p* = .086 N = 19
Elision			*r* = .366 *p* = .068 N = 18	*r* = .152 *p* = .273 N = 18	*r* = .194 *p* = .227 N = 17	*r* = .587 *p* = .007 N = 17	*r* = -.148 *p* = .278 N = 18
Blending Words				*r* = .618 *p* = .002 N = 19	*r* = .439 *p* = .034 N = 18	*r* = .388 *p* = .056 N = 18	*r* = -.083 *p* = .386 N = 19
Blending Nonwords					*r* = .150 *p* = .277 N = 18	*r* = .319 *p* = .098 N =18	*r* = .200 *p* = .206 N = 19
Segmenting Nonwords§						*r* = .352 *p* = .083 N = 17	*r* = .440 *p* = .034 N = 18
Phoneme Reversal§							*r* = .042 *p* =.435 N = 18

*expected significant correlations

§ Subtests not included in composite scores

I.3 ALTERNATE PHONOLOGICAL AWARENESS COMPOSITE SCORES

Correlational analyses displayed in Table 35, found above, showed that adults who stutter demonstrated moderate correlations between the Alternate Phonological Awareness Composite score and the Blending Words and Segmenting Words subtests ($r > .557$; $p < .05$). Individuals who stutter demonstrated moderate correlations between the Blending Nonwords subtest and the Segmenting Nonwords and Segmenting Words subtests ($r > .473$; $p < .05$). Additionally, the Segmenting Nonwords subtest was significantly correlated with Phoneme Reversal and Segmenting Words in adults who stutter ($r > .440$; $p < .05$). Both groups demonstrated the expected strong correlations between the composite score and the subtests it was comprised of: Blending Nonwords and Segmenting Nonwords ($r > .713$; $p < .05$). Table 36 found above shows the Alternate Phonological Awareness Composite score was moderately correlated with the Blending Words and Phoneme Reversal subtest for nonstuttering adults ($r > .407$; $p < .05$). Typically fluent adults demonstrated a significant correlation between the Blending Nonwords subtest and the Blending Words subtest ($r > .618$; $p < .05$) but no significant correlations with the Segmenting Nonwords and Segmenting Words subtests ($r < .150$; $p > .05$). Adults who do not stutter demonstrated a moderate correlation between Segmenting Nonwords and Segmenting Words ($r =.440$; $p = .034$).

I.4 PHONOLOGICAL MEMORY COMPOSITE SCORES

Table 37 shows the correlational analyses of phonological memory tasks for adults who stutter. The expected correlations were demonstrated between the Phonological Memory Composite score and the component/constituent subtests of Memory for Digits and Nonword Repetition (*r* > .584; *p* < .05). The Phonological Memory Composite score was also strongly correlated with the Segmenting Nonwords subtest, one of the non-lexical phonological awareness tasks (*r* = .769; *p* < .001). Accordingly, Segmenting Nonwords was also highly correlated with the Phonological Memory subtests, Memory for Digits and Nonword Repetition (*r* > .574; *p* < .05). Segmenting Nonwords and Blending Nonwords, the two non-lexical phonological awareness subtests, were moderately correlated with one another (*r* = .475; *p* = .02). The Phonological Memory Composite score was not significantly correlated (*r* > -.156; *p* > .05) with either the NRT or the Late-8 NRT for adults who stutter.

Table 38 shows that adults who do not stutter demonstrated the expected correlation between the Phonological Memory Composite score and the Memory For Digits subtest was present (*r* = .896 *p* < .001), but not with Nonword Repetition, the other constituent subtest (*r* = .209; *p* = .203). A mildly significant correlation between the Phonological Memory Composite score and the NRT Total Score was present (*r* = .429; *p* = .04). There were no additional significant correlations between the phonological awareness subtests that use nonword stimuli (i.e., Blending Nonwords and Segmenting Nonwords) and the Phonological Memory Composite score or the Late-8 Nonword Repetition Task for adults who do not stutter ($r > .054$; $p > .05$).

Table 37. Correlations for phonological memory tasks for adults who stutter.

	Memory for Digits	Nonword Repetition	Blending Nonwords	Segmenting Nonwords	NRT total	L8NRT total
PM Composite	$r = .794$ $p = < .001$* N = 19	$r = .584$ $p = .005$* N = 18	$r = .395$ $p = .047$ N = 19	$r = .769$ $p = < .001$ N = 19	$r = .364$ $p = .063$ N = 19	$r = -.156$ $p = .262$ N = 19
Memory for Digits		$r = .157$ $p = .267$ N = 18	$r = .140$ $p = .283$ N = 19	$r = .623$ $p = .002$ N = 19	$r = .183$ $p = .226$ N = 19	$r = -.018$ $p = .471$ N = 19
Nonword Repetition			$r = .629$ $p = .003$ N = 18	$r = .574$ $p = .006$ N = 18	$r = .267$ $p = .142$ N = 18	$r = -.393$ $p = .053$ N = 18
Blending Nonwords				$r = .475$ $p = .020$ N = 19	$r = .199$ $p = .208$ N = 19	$r = -.011$ $p = .481$ N = 19
Segmenting Nonwords					$r = .447$ $p = .027$ N = 19	$r = -.245$ $p = .156$ N = 19
NRT total						$r = -.073$ $p = .382$ N = 19

* Expected significant difference

Phonological Memory (PM Comp), Nonword Repetition Task (NRT) and the Late-8 Nonword Repetition Task (L8NRT).

Table 38. Correlations for phonological memory tasks for adults who do not stutter.

	Memory for Digits	Nonword Repetition	Blending Nonwords	Segmenting Nonwords	NRT total	L8NRT total
PM Composite	*r* = .896 *p* = < .001* N = 18	*r* = .209 *p* = .203 N = 18	*r* = -.237 *p* = .172 N = 18	*r* = .238 *p* = .179 N = 17	*r* = .429 *p* = .04 N = 17	*r* = .365 *p* = .068 N = 18
Memory for Digits		*r* = .006 *p* = .491 N = 19	*r* = -.062 *p* = .401 N = 19	*r* = .352 *p* = .076 N = 18	*r* = .396 *p* = .052 N = 18	*r* = .269 *p* = .133 N = 19
Nonword Repetition			*r* = .222 *p* = .181 N = 19	*r* = .237 *p* = .172 N = 18	*r* = .465 *p* = .026 N = 18	*r* = .289 *p* = .115 N = 19
Blending Nonwords				*r* = .150 *p* = .277 N = 18	*r* = .248 *p* = .160 N = 18	*r* = .054 *p* = .414 N = 19
Segmenting Nonwords					*r* = .216 *p* = .203 N = 17	*r* = .179 *p* = .239 N = 18
NRT total						*r* = .269 *p* = .140 N = 18

* Expected significant difference
Phonological Memory (PM Comp), Nonword Repetition Task (NRT) and the Late-8 Nonword Repetition Task (L8NRT).

I.5 RAPID AUTOMATIC NAMING COMPOSITE SCORES

Correlational analyses of performance on Rapid Automatic Naming tasks by adults who stutter are outlined in Table 39. The expected correlations between the Rapid Automatic Naming Composite score and the constituent subtests of Rapid Digit Naming and Rapid Letter Naming were demonstrated ($r < .829$; $p < .05$). The Alternative Rapid Automatic Naming Composite score and constituent subtests Rapid Color Naming and Rapid Object Naming also demonstrated the expected relationship ($r < .935$; $p < .05$). Additionally, there were moderate correlations ($r > .492$; $p < .05$) between Rapid Digit Naming and Rapid Letter Naming, Rapid Color Naming and Rapid Digit Naming, and Rapid Color Naming and Rapid Object Naming.

Table 40 displays the correlational analyses of Rapid Automatic Naming tasks for individuals who do not stutter. Many more statistically significant correlations were revealed for typically fluent adults than for adults who stutter. The expected strong correlations ($r > .981$; $p < .05$) between the Rapid Automatic Naming Composite score and the associated subtests were present (i.e., Rapid Digit Naming and Rapid Letter Naming). Performance for typically fluent adults on the Rapid Automatic Naming Composite score was moderately correlated with the Alternate Rapid Automatic Naming Composite score, Rapid Object Naming and the Rapid Color Naming subtest ($r > .484$; $p < .05$). The Alternate Rapid Automatic Naming Composite score was strongly correlated ($r > .930$; $p < .05$) with the expected subtests (i.e., Rapid Color Naming and Rapid Object Naming), as well as moderately correlated to the Rapid Digit Naming and Rapid Letter Naming subtests ($r > .522$; $p < .05$). Adults who do not stutter also demonstrated strong correlations between the Rapid Automatic Naming subtests. Rapid Digit Naming was moderately correlated with Rapid Letter Naming and Rapid Object Naming ($r > .443$; $p < .05$). Rapid Letter Naming was moderately correlated with Rapid Color Naming and Rapid Object Naming ($r > .575$; $p < .05$). Finally, Rapid Color Naming was also strongly correlated with Rapid Object Naming ($r = .816$; $p = .001$).

Table 39. Correlations for rapid automatic naming tasks for adults who stutter.

	Alternate RAN Composite	Rapid Digit Naming	Rapid Letter Naming	Rapid Color Naming	Rapid Object Naming
RAN Composite	$r = .140$ $p = .303$ N = 16	$r = .869$ $p = <.001$* N =17	$r = .829$ $p =<.001$* N =17	$r = .112$ $p = .335$ N = 17	$r = .021$ $p = .467$ N = 17
Alternate RAN Composite		$r = .379$ $p = .067$ N = 17	$r = .101$ $p = .355$ N = 16	$r = .935$ $p = <.001$* N = 18	$r = .966$ $p =<.001$* N = 18
Rapid Digit Naming			$r = .661$ $p = .002$ N = 17	$r = .429$ $p = .038$ N = 18	$r = .289$ $p = .123$ N = 18
Rapid Letter Naming				$r = .376$ $p = .069$ N = 17	$r = .210$ $p = .209$ N = 17
Rapid Color Naming					$r = .833$ $p = <.001$ N = 19

* expected significant correlations

Table 40. Correlations for rapid automatic naming tasks for adults who do not stutter.

	Alternate RAN Composite	Rapid Digit Naming	Rapid Letter Naming	Rapid Color Naming	Rapid Object Naming
RAN Composite	*r* = .617 *p* = .002 N = 19	*r* = .982 *p* = <.001* N = 19	*r* = .981 *p* = <.001* N = 19	*r* = .484 *p* = .021 N = 18	*r* = .523 *p* = .011 N = 19
Alternate RAN Composite		*r* = .522 *p* = .011 N = 19	*r* = .693 *p* = .001 N = 19	*r* = .932 *p* = <.001* N =18	*r* = .930 *p* = <.001* N =19
Rapid Digit Naming			*r* = .927 *p* = <.001 N = 19	*r* = .374 *p* = .63 N = 18	*r* = .443 *p* = .029 N = 19
Rapid Letter Naming				*r* = .575 *p* = .006 N = 18	*r* = .588 *p* = .004 N = 19
Rapid Color Naming					*r* = .816 *p* = <.001 N = 18

* expected significant correlations

I.6 CORRELATION SUMMARY

Exploratory correlational analyses were conducted with the various composite scores and subtests of the CTOPP to determine if any strong relationships in phonological encoding abilities were present within groups. Both groups demonstrated the expected strong relationships and large effect sizes between composite scores and the constituent subtests. The remaining correlational analyses for phonological awareness, phonological memory, and rapid automatic naming tasks for both groups revealed some moderate relationships, but no large effects were revealed. A number of analyses were conducted in an attempt to determine if any significant patterns emerged with the many subtests that comprise the CTOPP. As expected, however, interpretation of the significance of the small and moderate correlations reported in the results section is complicated by the large number of analyses conducted. Had strong relationships been revealed in these exploratory analyses, then further exploration of those factors could have been targeted for future research. Since this was not the case, the correlations were not discussed further in this document.

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