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Phonological memory in young children who stutter

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ABSTRACT

This study investigated phonological memory in 5- and 6-year old children who stutter. Participants were 11 children who stutter matched on general language abilities, maternal education level, and sex to 11 typically fluent children. Participants completed norm-referenced nonword repetition and digit span tasks, as well as measures of expressive and receptive vocabulary and articulation. The nonword repetition task included stimuli that ranged from 1 to 7 syllables, while the digit naming task contained number strings containing 2–10 digits. Standardized tests of vocabulary and articulation abilities were tested as well. Groups were comparable on measures expressive vocabulary, receptive vocabulary, and articulation. Despite the fact that the majority of participants scored within typical limits, young children who stutter still performed significantly less well than children who do not stutter on the nonword repetition task. No between-group differences were revealed in the digit naming task. Typically fluent children demonstrated strong correlations between phonological memory tasks and language measures, while children who stutter did not. These findings indicate that young children who stutter may have sub-clinical differences in nonword repetition.

1. Introduction

1.1. Phonological memory and phonological encoding

Several theories implicate motoric, temperamental, and linguistic differences that may contribute to the disruption of the forward flow of speech in stuttering (Bloodstein & Bernstein Ratner, 2008). In particular, theories involving psycholinguistic abilities suggest that a breakdown or delay may occur during the process of *phonological encoding*, or the retrieval and construction of the phonological segments of words. According to these theories, breakdowns or delays at the level of phonological encoding may then result in disfluent speech (Howell & Au-Yeung, 2002; Perkins, Kent, & Curlee, 1991; Postma & Kolk, 1993). Many researchers propose that the construction of phonological segments during phonological encoding requires the use of *phonological memory*, or the ability to maintain phonological and auditory information for short-term retrieval while the entirety of the phonological code is constructed (Acheson & MacDonald, 2009; Alt & Plante, 2006; Bajaj, 2007; Haberlandt, Thomas, Lawrence, & Krohn, 2005). Several authors have also suggested that phonological memory abilities are lower in young children who stutter than in young children who do not stutter (Anderson & Wagovich, 2010;

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Anderson, Wagovich, & Hall, 2006; Spencer & Weber-Fox, 2014), although the findings are inconsistent (Bakhtiar, Ali, & Sadegh, 2009; Smith, Goffman, Sasisekaran, & Weber-Fox, 2012). A better understanding of phonological memory abilities in young children who stutter will allow for determination of underlying cognitive mechanisms that may be affected in children who stutter.

1.2. Phonological memory

A prominent model of working memory by Baddeley (2000, 2003) proposes a four-component memory system that consists of a supervisory component (*central executive*) and three subservient systems (*visuospatial sketchpad*, *phonological loop*, and *episodic buffer*). The central executive mediates attention and directs resources to the subservient systems that operate as relatively passive stores of information. The visuospatial sketchpad stores visual and spatial information, while the phonological loop stores auditory and speech-based information. The phonological loop is comprised of two additional components: a *phonological store* and an *articulatory rehearsal mechanism*. The phonological store temporarily maintains auditory information for short-term retrieval, but is subject to rapid decay after approximately 2 seconds. The content in the phonological loop can be refreshed via silent or overt articulatory rehearsal to allow the phonological code to be recycled and maintained for longer periods of time (Baddeley, 2000; Baddeley & Larsen, 2007). The episodic buffer, a recently added component to the model, provides a link to long-term memory stores (e.g., the lexicon) and integrates the visual and auditory information from the other subservient systems regardless of the input mechanism (Baddeley, 2000). Some researchers argue that access to long-term stores may also help refresh the content in the phonological store by accessing the phonological code found in the lexicon (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Hoffman, Jefferies, Ehsan, Jones & Lambon Ralph, 2009; Martin & Gupta, 2004; Martin, Lesch, & Bartha, 1999; Patterson, Graham, & Hodges, 1994; Thorn, Gathercole, & Frankish, 2005). That is, access to the phonological code in pre-existing lexical entries may be used along with silent or overt articulatory rehearsal to help refresh and maintain the content held in the phonological store. This can occur even when attempting to remember nonword stimuli (Coady & Aslin, 2004). Phonological working memory requires input from several aspects of Baddeley's model, including access to long-term memory stores via the episodic buffer and attentional control via the central executive. Although differences in attentional control have been identified in children who stutter that could influence the processing of the central executive (Anderson, Pellowski, Conture, & Kelly, 2003; Anderson & Wagovich, 2010; Embrechts, Ebben, Franke, & van de Poel, 2000; Karrass et al., 2006), the focus of the current study explores whether inefficient or disrupted phonological memory may lead to difficulty in the maintenance of the phonological code for subsequent use in speech and language planning, thereby contributing to stuttering (e.g., Bajaj, 2007).

1.2.1. Measures of phonological memory

Nonword repetition tasks essentially measure the quality of the phonological representations held in working memory. That is, how well a person can maintain and access novel phonological code (i.e., nonwords) from the phonological store (Archibald & Gathercole, 2007; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1993). Typical tasks of nonword repetition require a participant to listen to and perceive the acoustic signal of the nonword and repeat it back exactly as it was heard. After hearing the nonword, a novel phonological and articulatory plan is assembled while articulatory rehearsal refreshes the signal continuously in the phonological store until the nonword stimuli can be repeated. During this process, the episodic buffer can also access phonological information from pre-existing lexical entries to help refresh decaying phonological code of the nonword during articulatory rehearsal. The more phonological characteristics a nonword shares with a real word (i.e., "word-like" nonwords) the more the lexicon can help support nonword repetition, particularly in young children (Coady & Aslin, 2004; Gathercole, 2006, 2007). Once the nonword is repeated by the participant, it is scored as correct or incorrect. A percentage of correct phonemes can also be calculated (e.g., Anderson et al., 2006; Anderson & Wagovitch, 2010; Hakim & Bernstein Ratner, 2004).

Digit span tasks are also frequently used in phonological memory research and can be used to measure the capacity of a person's phonological working memory (Jones & Macken, 2015). Capacity is a measure of how much phonological information can be held and accessed from the phonological store before the signal decays beyond retrieval (e.g., Conway, Cowan, Bunting, Therriault, & Minkoff, 2002). Digit span tasks use numbers or other "closed set" stimuli (i.e., stimuli with a limited number of items in a set, such as letters or numbers) that are presented in series of increasing lengths. The participant perceives the auditory signal of the stimuli, stores and rehearses the signal in the phonological loop, and then repeats back what was heard in the exact order it was given.

1.2.2. Factors that influence performance on phonological memory tasks

Phonological memory can be assessed in children as young as 2 when using a modified nonword repetition task (Hoff, Core, & Bridges, 2008; Torrington Eaton, Newman, Bernstein Ratner, & Rowe, 2015). Studies show that this skill continues to develop until approximately age 10 (Chiat, 2006; Gathercole, Service, Hitch, Adams, & Martin, 1999; Snowling & Hulme, 1994). Clear developmental differences exist in children's phonological memory abilities, with younger children possessing more limited skills than older school-age children. Although matching participants by chronological age is a fairly common practice, empirical evidence suggests that several additional factors influence performance on phonological memory tasks (Dollaghan, Biber, & Campbell, 1995). For example, a strong reciprocal relationship exists between general language and phonological memory abilities that is particularly pronounced in young children 4–6 years old (Gathercole, 2006, 2007).