JSLHR

Research Article

Short-Term Memory, Inhibition, and Attention in Developmental Stuttering: A Meta-Analysis

Levi C. Ofoe,[a] Julie D. Anderson,[a] and Katerina Ntourou[a]

Purpose: This study presents a meta-analytic review of differences in verbal short-term memory, inhibition, and attention between children who stutter (CWS) and children who do not stutter (CWNS).

Method: Electronic databases and reference sections of articles were searched for candidate studies that examined verbal short-term memory, inhibition, and attention using behavioral and/or parent report measures. Twenty-nine studies met the eligibility criteria, which included, among other things, children between the ages of 3 and 18 years and the availability of quantitative data for effect size calculations. Data were extracted, coded, and analyzed, with the magnitude of the difference between the 2 groups of children being estimated using Hedge's *g* (Hedges & Olkin, 1985).

Results: Based on the random-effects model (Hunter & Schmidt, 2004), findings revealed that CWS scored lower than CWNS on measures of nonword repetition (Hedges' $g = -0.62$), particularly at lengths of 2 and 3 syllables (Hedges' $g = -0.62$ and $-\ 0.50$, respectively), and forward span (Hedges' $g = -0.40$). Analyses further revealed that the parents of CWS rated their children as having weaker inhibition (Hedges' $g = -0.44$) and attentional focus/persistence (Hedges' $g = -0.36$) skills than the parents of CWNS, but there were no significant differences between CWS and CWNS in behavioral measures of inhibition and attention.

Conclusion: The present findings were taken to suggest that cognitive processes are important variables associated with developmental stuttering.

Executive function (EF; i.e., executive control or cognitive control) is a broadly defined term that refers to the higher mental processes that are involved in the conscious control of action and thoughts (Garon, Bryson, & Smith, 2008; Miller & Cohen, 2001; Miyake et al., 2000; Zelazo & Müller, 2010). These functions, among other things, allow us to choose and execute flexible, goal-directed responses to novel situations (Garon et al., 2008; Hughes & Graham, 2002; Zelazo, Müller, Frye, & Marcovitch, 2003). Although the precise nature of EF in young children has yet to be elucidated, some researchers have suggested that EF is composed of at least three components: (a) working memory, (b) inhibition (i.e., inhibitory control), and (c) cognitive flexibility (i.e., set shifting; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003).

The components of EF emerge in infancy and continue to develop well into the adolescent years (Huizinga, Dolan, & van der Molen, 2006; Wiebe, Espy, & Charak, 2008). During the preschool years, there is rapid growth in EF development, although not all components of EF develop at the same rate (Carlson, Mandell, & Williams, 2004; Diamond, Briand, Fossella, & Gehlbach, 2004; Espy & Bull, 2005; Müller, Zelazo, Hood, Leone, & Rohrer, 2004). For example, by 3 years of age, most children can successfully inhibit simple responses (Kochanska, 2002) and recall, on average, 1.58 items from memory (Garon et al., 2008), but they have more difficulty with cognitive flexibility (Zelazo & Reznick, 1991).

The components of EF emerge based on a developing attentional system, which manifests during early infancy (Garon et al., 2008; Reynolds & Romano, 2016). During infancy, the attentional system is a basic arousal system, which triggers a range of physiological conditions (e.g., decreased heart rate to indicate sustained attention), in response to internal and external stimuli (Reynolds & Romano, 2016). As the infant develops, this rudimentary

[a]Department of Speech and Hearing Sciences, Indiana University, Bloomington

Correspondence to Levi C. Ofoe: Lcofoe@indiana.edu

Katerina Ntourou is now at the Department of Communication Sciences and Disorders, University of Oklahoma Health Sciences Center.

Editor-in-Chief: Julie Liss
Editor: Bharath Chandrasekaran

Received September 29, 2017
Revision received February 7, 2018
Accepted March 26, 2018
https://doi.org/10.1044/2018_JSLHR-S-17-0372

Disclosure: The authors have declared that no competing interests existed at the time of publication.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

arousal system evolves into a network of attentional systems—alerting, orienting, and executive attention (Petersen & Posner, 2012). It is on this foundational network of attentional systems that the other components of EF then develop (Garon et al., 2008).

Given that the preschool years represent a period of rapid growth in EF and that developmental stuttering tends to have its onset during these years (Yairi & Ambrose, 2013), it may come as no surprise that some researchers have begun to examine the role of EF and attention in developmental stuttering (e.g., Anderson & Wagovich, 2017; Johnson, Conture, & Walden, 2012). Although research is ongoing, empirical findings to date have been equivocal and inconclusive, making it difficult to draw firm conclusions regarding the cognitive functioning of children who stutter (CWS). The purpose of this study, therefore, was to conduct a meta-analytical review of empirical studies that have examined EF and attention in CWS. To provide context for this study, we begin with an overview of the concept and measures of verbal short-term memory (VSTM), inhibition, cognitive flexibility, and attention, and then, we briefly review the literature on EF and attention in developmental stuttering.

Verbal Short-Term Memory

Working memory is a capacity-limited system that is responsible for the temporary storage (i.e., short-term memory) and manipulation of information (Baddeley, 1986; Diamond, 2013). As a resource-limited system, working memory involves monitoring incoming information relevant to a current task and updating, when appropriate, previously irrelevant information with more relevant information (Pelphrey & Reznick, 2002). There are four main components of working memory, on the basis of Baddeley's (1986, 2003) model: two sensory subsystems, the phonological loop and visuospatial sketch pad, which are dedicated to storing and manipulating verbal and visuospatial information, respectively; the episodic buffer, which temporarily stores multidimensional information and links working memory with long-term memory; and the central executive, which is an attentional-controlling system that coordinates the two sensory systems and episodic buffer (cf. Baddeley & Hitch, 1994).

Of interest to this study, in particular, is the phonological loop, which consists of a phonological store and articulatory rehearsal mechanism. The phonological store (i.e., VSTM) holds verbal information for a limited period (up to about 2 s) before it begins to decay (Baddeley, 2004). The length of time in which information can be stored, however, can be extended with vocal or subvocal rehearsal—that is, either overtly or covertly articulating the information being held in storage (Baddeley, Gathercole, & Papagno, 1998). The articulatory rehearsal mechanism is also involved in the process of recoding visual information (e.g., a pictured object) into a phonological form, so that it can access the phonological store (Gathercole, Pickering, Ambridge, & Wearing, 2004; Henry, 2012). The extent to which young children engage in articulatory rehearsal is not yet clear; although it has long been held that these skills typically do not emerge until around 7 years of age, recent evidence suggests that young children do employ rehearsal processes, albeit in a less mature manner (cf. Jarrold & Tam, 2011; Tam, Jarrold, Baddeley, & Sabatos-DeVito, 2010).

As an example of Baddeley's (1986, 2003) working memory model, consider what happens when a child is asked to recall an auditorily presented target word, such as *cat*. Upon hearing the word, the child temporarily stores the sound sequence in the phonological store and its stored semantic representation (e.g., furry, pet, and four legs) is presumably activated in long-term memory via the episodic buffer, which is controlled by the central executive (Baddeley, 2000). Along with articulatory rehearsal, the activation of the long-term semantic representation is thought to keep the memory trace in the phonological store active, thereby preventing the trace from degrading and increasing the likelihood that the child will correctly recall the word (Campoy & Baddeley, 2008; Thorn, Gathercole, & Frankish, 2005). The child will then need to assemble the relevant phonemes and plan and execute the motor commands necessary to produce the word. Instead of presenting the target word auditorily, if the child was asked to recall where they last saw the cat, after being shown a series of animal pictures (e.g., sheep, dog, cow, pig, cat, horse), then these visual images would be stored in the visuospatial sketchpad, not the phonological store (Baddeley, 2012).

The phonological store has frequently been assessed using nonword repetition (Coady & Evans, 2008; Estes, Evans, & Else-Quest, 2007). In a typical nonword repetition task, children hear "funny, made-up" words, such as "trumpetine," that vary in length (usually one to five syllables) and, then, attempt to repeat it back to the examiner. Nonword repetition is primarily a measure of VSTM, but other processes, such as auditory-perceptual, phonological, and motor planning processes, are also involved (Gathercole, 2006).

Another popular method of assessing VSTM is the forward span task, which measures the extent to which a person can recall a list of presented digits, letters, or words in the order in which they were presented (Richardson, 2007). The maximum number of items correctly recalled in a forward span task is an index of VSTM capacity. These tasks differ from nonword repetition tasks in that, among other things, they rely more explicitly on long-term lexical knowledge and the stimulus items are presented and subsequently repeated in a series (e.g., dog, car, tree), not in isolation (e.g., trumpetine).

Another type of span task is the backward span task, which requires one to repeat the stimulus items in reverse order. Backward span tasks measure verbal working memory because, in addition to holding the stimuli in the phonological store, the information must be manipulated in some way (Engle, Tuholski, Laughlin, & Conway, 1999). The manipulation of information requires the involvement of additional cognitive processes or the central executive

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

in Baddeley's (1986, 2003) working memory model (Baddeley, 2012; Bull, Espy, & Wiebe, 2008; St Clair-Thompson & Gathercole, 2006).

Inhibition

Inhibition generally refers to the ability to resist, subdue, or withhold one's thoughts, behavior, and/or emotional response (Diamond, 2013; Miyake et al., 2000). Friedman and Miyake (2004) categorized inhibition into three types: (a) prepotent response inhibition, (b) resistance to distractor interference, and (c) resistance to proactive interference.

The first type of inhibition, prepotent response inhibition, can be simple or complex. Simple response inhibition involves the suppression of a dominant response (Garon et al., 2008). In a typical simple response inhibition task, the child must respond to a certain type of auditory or visual signal and refrain from responding to another type of signal. For example, in the stop-signal task, the child is presented with either a "go" or "stop" signal (Cragg & Nation, 2008; Lappin & Eriksen, 1966). The "stop" signal occurs much less frequently than the "go" signal, and the child must respond to the "go" signal but not the "stop" signal. The frequent response to the "go" signal is presumed to activate a dominant response pattern, which must be suppressed when the "stop" signal is presented. Complex response inhibition involves not only suppressing a dominant response but also executing a subdominant response. For example, in the day–night task, children say the word *day* when shown a picture of "night" and *night* when shown a picture of "day" (Gerstadt, Hong, & Diamond, 1994). In this task, only one feature is presented (i.e., a picture of "day" or "night"), and the conflict is between two response options (i.e., the prepotent response is to say "day" when shown a picture of "day," but the child must inhibit this tendency and say "night" instead; Martin-Rhee & Bialystok, 2008).

The second type of inhibition, resistance to distractor interference, refers to the ability to resist interference from irrelevant information in the external environment. An example of a resistance to distractor interference task is the Child Continuous Performance Test (Kerns & Rondeau, 1998). In this test, the child presses a button when an infrequent target picture appears on the computer screen but not when a frequent nontarget picture appears. It is this latter response that requires inhibition.

The third type of inhibition, resistance to proactive interference, is the ability to prevent prior irrelevant information from interfering with current performance on a task. An example of a resistance to proactive interference task is the Shape School task (Espy, 1997; Espy, Bull, Martin, & Stroup, 2006). In this task, the child must name the color of the shape character that appears on the computer screen when cued with a happy face and resist the tendency to name the color of the shape character when cued with a sad face (Wiebe et al., 2008).

In addition to behavioral/experimentally based tasks, inhibition can be measured using parent (or caretaker) report questionnaires. The Children's Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001) is one such measure that is designed to assess 15 dimensions of temperament in children between 3 and 7 years of age. Several CBQ temperament dimensions—namely, Attentional Focusing, Impulsivity, and Inhibitory Control—measure aspects of effortful control, which is similar to EF but focuses more on automatic emotional self-regulatory mechanisms (Blair & Peters Razza, 2007). A high score on the Inhibitory Control dimension of the CBQ, for example, reflects a greater capacity to plan and suppress inappropriate responses under instruction or in novel or uncertain situations.

Cognitive Flexibility

The third component of EF, cognitive flexibility, refers to the ability to shift between one stimulus–response association (i.e., "mental set") to another or adapt to varying circumstances (Diamond, 2013; Garon et al., 2008). Although it is not clear when cognitive flexibility emerges in childhood, it is thought to be among the later developing EF components because it builds on inhibition and working memory skills (Davidson, Amso, Anderson, & Diamond, 2006; Garon et al., 2008). Thus far, only two studies (Anderson, Wagovich, & Ofoe, 2015; Hollister, 2015) have examined the role of cognitive flexibility in developmental stuttering. In a meta-analysis, an effect size (ES) can be calculated on the basis of only two studies, but it is generally not considered to be very meaningful (Borenstein, Hedges, Higgins, & Rothstein, 2009; Coe, 2002). For this reason, cognitive flexibility is not considered further in this study.

Attention

The core EF components rely on an existing foundation of attentional networks, which generally permit one to maintain interest in and focus on a specific task or idea while also managing distractions (Baddeley, 2002; Kane & Engle, 2003). Attention can be divided into three distinct but interrelated networks: alerting, orienting, and executive attention (Petersen & Posner, 2012; Posner & Petersen, 1990). As previously indicated, these attentional networks emerge from a rudimentary arousal system during the first year of life (Petersen & Posner, 2012; Reynolds & Romano, 2016). These networks continue to develop during childhood, with orienting attention reaching the adult level by midchildhood, alerting attention by late childhood, and executive attention by early adolescence (Rueda & Posner, 2013). Throughout development, these attentional networks are not only foundational for EF but are also associated with other skills, such as academic performance (Posner, Rothbart, Sheese, & Voelker, 2014).

An example of a task used to measure these three (alerting, orienting, and executive) attention networks is

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

the Attentional Network Task (ANT; Fan, McCanliss, Sommers, Raz, & Posner, 2002). In this task, the child begins each trial with one of four cue conditions: The cue, represented by an asterisk, can appear above a centrally fixated cross on the computer screen (spatial cue), both above and below the cross (double cue), at the exact location of the cross (central cue), or not at all (no cue). These cue conditions draw the participant's attention to the location of the stimuli that will subsequently appear on the screen. Following the cue condition, the child is presented with an array of stimuli, typically five cartoon fishes. The central fish is the target flanker, and the two fishes on either side of the central fish are the nontarget flankers. The child responds by pointing or pressing a button corresponding to left or right, depending on the direction of the central fish (e.g., if the central fish points to the right, the child presses the right button and vice versa). The five nontarget fishes face the same direction as the central fish on congruent trials and the opposite direction on incongruent trials. The central fish appears without the flankers on neutral trials. The accuracy and speed in which children respond to the central fish are recorded based on the cue condition (spatial, double, central, or no cue) and trial type (congruent, incongruent, or neutral).

Alerting attention refers to the ability to maintain a state of vigilance or readiness for processing information (Mezzacappa, 2004). Alerting attention is measured in the ANT by comparing children's accuracy and reaction time in the double cue condition to the no-cue condition (Pozuelos, Paz-Alonzo, Castillo, Fuentes, & Rueda, 2014; Rueda et al., 2004). Generally, alerting attention is boosted when a cue condition precedes the presentation of the stimulus. Therefore, it is expected that, in a state of alerting attention, children will be more accurate and faster in the double cueing condition compared to the no-cue condition (Mezzacappa, 2004; Mullane, Corkum, Klein, McLaughlin, & Lawrence, 2011; Rueda et al., 2004).

Orienting attention involves the process of scanning and selectively focusing on a specific stimulus from among a range of stimuli (Raz & Buhle, 2006). Upon orienting to a specific stimulus item, it is assumed that attentional resources are selectively allocated to facilitate further processing of that stimulus item. In the ANT, orienting attention is assessed by examining children's performance in the central cue condition versus the spatial cue condition. If children are orienting their attention, they will respond faster and more accurately to the spatial cue than the central cue (Rueda et al., 2004).

The third component of the attention network, executive attention, refers to the processes involved in controlling thoughts and behavior and resolving conflict among stimuli (Mezzacappa, 2004; Rueda et al., 2004). Executive attention is measured in the ANT by examining the difference in performance between the congruent and incongruent trials. Efficient performance (i.e., higher accuracy and faster response times) between the congruent and incongruent trials will indicate that the children are engaging in executive attention (Rueda et al., 2004).

Other types of attention, such as sustained, selective/focused, and shifting attention, are also described in the developmental literature (Garon et al., 2008). Both sustained and selective attention are analogous to the alerting and orienting attention networks, respectively. Shifting attention refers to the process of changing attentional focus from one task or stimulus item to another. Shifting attention and cognitive flexibility are similar in that they both require participants to create an initial mental set (i.e., stimulus–response association) or rule and then shift to a new mental set or rule that conflicts with the initial set (Garon et al., 2008). However, they differ in that the shift in mental set is based on some aspect of the stimuli in shifting attention (e.g., sorting the same set of cards first by color and then by shape) and the motor response in cognitive flexibility (e.g., pressing the left button for a red circle and the right button for a blue square and then doing the reverse—pressing the right button for a red circle and the left button for a blue square; Garon et al., 2008; cf. Ravizza & Carter, 2008; Rushworth, Passingham, & Nobre, 2005; Wager, Jonides, & Reading, 2004).

Attention can also be measured using parent report questionnaires. For example, one of the 15 dimensions of the CBQ is *Attentional Focusing*, which is defined by Rothbart et al. (2001) as the ability to respond to or focus on specific stimuli or tasks. Children who score high in Attentional Focusing tend to be better at maintaining their focus of attention when responding to specific stimuli/tasks than children who score low. Another commonly used parent report measure is the Behavioral Style Questionnaire (McDevitt & Carey, 1978). The Behavioral Style Questionnaire measures nine temperament dimensions, two of which are attention related: Attention Span/Persistence and Distractibility. As noted by Anderson, Pellowski, Conture, and Kelly (2003), Attention Span/Persistence refers to how long a child spends pursuing an activity (attention span) and his or her ability to continue an activity when presented with distractors (persistence), whereas distractibility refers to how well a child can keep extraneous stimuli from diverting his or her attention away from an ongoing behavior. Children who score high in Attention Span/Persistence tend to have lower attention spans and be less persistent, whereas children who score high in Distractibility are more apt to be easily diverted by environmental stimuli.

EF, Attention, and Developmental Stuttering

There has been growing interest in examining the role of cognitive processes in developmental stuttering. However, findings from the research that has been conducted, thus far, have been contradictory. In the case of VSTM, some studies have found that preschool and school-aged CWS may have weaker VSTM skills than children who do not stutter (CWNS; Anderson, Wagovich, & Hall, 2006; Anderson, Wagovich, & Hill, 2014; Hakim & Ratner, 2004), whereas other studies have found no differences

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

(e.g., Bakhtiar, Ali, & Sadegh, 2007; Smith, Goffman, Sasisekaran, & Weber-Fox, 2012).

Studies of inhibition and attention have suffered similar fates. For example, Anderson and Wagovich (2017) examined complex response inhibition in 41 CWS and 41 CWNS, aged 3 to 6 years, using the grass–snow (Carlson & Moses, 2001) and baa–meow tasks. These tasks are manual variants of the day–night task described above. Findings revealed that, when compared with the CWNS, the CWS were not only less accurate in the baa–meow task but also slower in both the baa–meow and grass–snow tasks. The authors suggested that the inhibition skills of CWS may be less effective and efficient than CWNS in the verbal domain. On the other hand, Eggers (2012) examined, among other things, exogenously generated response inhibition in 18 CWS and 18 CWNS between 7 and 11 years of age using the Stop-Signal task (Verbruggen & Logan, 2008). Participants pressed one button when they saw a square and another button when they saw a circle, except when they heard a tone. Findings revealed no significant difference between the CWS and CWNS in the speed or accuracy of response, suggesting that the two groups of children were comparable in externally triggered response inhibition.

Given the inconsistencies in findings across studies, it is not clear if CWS have difficulty with short-term memory, inhibition, and/or attention relative to CWNS and, if so, what the nature of these difficulties is. Theoretically, if CWS have difficulty with one or more of these cognitive processes, then it may provide some insight into their speech-language abilities, which have been shown in some studies to be less robust than CWNS (e.g., Ntourou, Conture, & Lipsey, 2011), as speech-language development also depends on these underlying cognitive processes (Anderson & Wagovich, 2014). Thus, the purpose of this study was to extract, synthesize, and summarize the existing quantitative data in a meta-analytic review to further elucidate the role of EF and attention in developmental stuttering.

Method

Inclusion Criteria

To be included in the meta-analysis, a study had to (a) include both CWS and CWNS; (b) include participants with no speech and language difficulties[1]; (c) be reported in English; (d) have monolingual participants between the ages of 3 and 18 years; (e) report group membership (CWS or CWNS) on the basis of formal and/or informal evaluation of fluency; (f) examine short-term/working memory, inhibition, and/or attention using behavioral and/or parent report measures; and (g) report quantitative results (e.g., sample sizes, means, standard deviations, and test statistics) that are amenable to ES calculation.

Data Sources and Study Selection

A known threat to the validity of the findings of a meta-analysis is publication bias, and it occurs when studies that have more favorable or positive results are more likely to be published than studies with less favorable or negative outcomes (Müller et al., 2013; Rothstein, Sutton, & Borenstein, 2005). Thus, to minimize such bias, a systematic four-stage approach was used to locate a representative sample of published and unpublished research studies using a diverse set of databases. During the first stage, substantive terms for the essential inclusion criteria and specific cognitive processes were identified. The search terms used as keywords in various permutations were as follows: *child**, *stutter**, *stammer**, *cognit**, *memory*, *inhibit**, attent*, and *executive function**. The asterisk following a root word instructs the search engine to search for derivations of the word (e.g., *cognit** will generate derivations, such as cognition or cognitive).

During the second stage, a comprehensive search of candidate studies was performed electronically using multiple databases and journals and manually from various conference abstracts/proceedings and reference lists. The searches were not restricted by publication date but were completed by December 2016. The following electronic databases were searched: ERIC, PsycINFO, PubMed, Cochrane, ProQuest Dissertations and Theses, and the American Speech-Language-Hearing Association's website for conference presentations and posters. The discipline-specific, peer-reviewed journals that were searched included the *American Journal of Speech-Language Pathology; International Journal of Language and Communication Disorders; International Journal of Speech-Language Pathology; Journal of Communication Disorders; Journal of Fluency Disorders; Journal of Speech, Language, and Hearing Research;* and *Language, Speech, and Hearing Services in Schools*. Manual searches were conducted from among the presentations and proceedings of the World Congresses of the International Fluency Association (2000 to 2015), World Congresses of the International Association of Logopedics and Phoniatrics (2000 to 2013), and the Oxford Dysfluency Conference (2014). Finally, studies that were cited in the reference lists of selected studies were manually searched for additional candidate studies. This comprehensive search yielded a total of 1,558 candidate studies, after removing duplicates from multiple sources.

During the third stage, the first author reviewed the abstracts of the 1,558 candidate studies to determine if the study was eligible to advance to the fourth stage. To be eligible, a study had to meet at least four of the seven inclusion criteria: examine at least one of three cognitive processes (short-term/working memory, inhibition, or attention) using behavioral and/or parent report measures,

[1]If a study included groups of CWS both with and without concomitant speech and language disorders, then the study was eligible for inclusion provided that it met the other inclusion criteria and an effect size could be calculated for the CWS group without concomitant speech and language disorders alone. Participants with other speech and language difficulties were otherwise excluded to ensure that any differences between CWS and CWNS could not be attributed to anything other than stuttering.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

reported in English, and include both CWS and CWNS between the ages of 3 and 18 years. From this review, a total of 35 studies were identified. Interrater reliability for the third stage was established by having the third author identify eligible studies for inclusion from the abstracts of a random sample of 311 studies (20% of the 1,558 candidate studies). The number of agreements and disagreements between the first and third author were tallied and interrater reliability (Cohen's kappa coefficient) was calculated at .95, which indicates almost perfect agreement.

During the final, fourth stage, the first author reviewed the full texts of the 35 eligible studies to determine if the study qualified to be coded for analysis. To qualify, the study had to meet the remaining three inclusion criteria: Participants did not have any speech or language difficulties (outside of stuttering for the CWS group), group membership was determined based on a formal and/or informal fluency evaluation, and the reported results were amenable to ES calculation. If a study qualified on the basis of the first two criteria but the reported data were insufficient for ES calculation, the first author attempted to contact the study's lead author to obtain the necessary information so that the study could be retained. A total of 30 studies were identified by the first author as meeting the remaining inclusion criteria. The initial 35 studies were also reviewed by the third author to establish interrater reliability. The third author identified a total of 28 studies for inclusion, yielding an interrater reliability index (Cohen's kappa coefficient) of .80, which indicates substantial agreement. The two studies for which the first and third author disagreed were discussed among all three authors, and the decision was made to include one study and exclude the other. Thus, a total of 29 studies emerged from the fourth stage to advance to the full coding stage.

Data Management and Extraction

All relevant descriptive (inclusion/exclusion criteria, matching procedures, study design, cognitive process measured and specific tasks used, dependent measures, etc.) and quantitative (sample sizes, means, standard deviations, statistical tests used, etc.) data were extracted from each of the 29 studies that qualified for inclusion and manually coded into a Microsoft Excel 2013 spreadsheet. One critical aspect of this process was classifying each study by the cognitive process measured (VSTM, inhibition, and/or attention) for ES calculations. All three cognitive processes were subdivided by study design. VSTM was subdivided based on whether the studies used nonword repetition measures (e.g., the Children's Nonword Repetition Test; Gathercole & Baddeley, 1996) or forward digit, letter, or word span tasks,[2] as there are some important differences between these measures (see Archibald & Gathercole, 2007, for review). Nonword repetition was further subdivided by the length of the nonword stimuli into two, three, and four syllables.[3] An overall ES for nonword repetition (i.e., all syllable lengths combined) was also calculated.

Inhibition and attention were subdivided based on whether the study design included parent report questionnaires (e.g., the Inhibitory Control dimension of the CBQ [Rothbart et al., 2001] or behavioral tasks [e.g., the ANT; Fan et al., 2002]), as these measures may tap into slightly different underlying constructs that could conceivably affect the results. For example, parent report measures capture children's ability to succeed in pursuit of a goal on the basis of behavioral observations over an extended period in the natural environment, whereas behavioral measures capture the efficiency of children's cognitive abilities through tasks designed to obtain direct responses over a shorter period in a structured (i.e., laboratory) environment (Toplak, West, & Stanovich, 2013; see Discussion).

Parent report attention was further subdivided by the type of attention being measured, namely, attentional focus/persistence and distractibility. Behavioral attention was not subdivided by type because the sample size was small and many of the measures used in the studies sampled more than one type of attention (e.g., orienting and shifting). Neither parent report nor behavioral inhibition were further subdivided by type because the parent report measures of inhibition primarily assess one type of inhibition (simple prepotent response inhibition; see Discussion) and the sample size for behavioral inhibition was too small.

If more than one cognitive process was measured in a single study, then that study was included in each area of cognitive performance. For example, if a study included a Go/No-Go Inhibitory Control task and the Attentional Focusing scale of the CBQ, then an ES was calculated for the Go/No-Go task and included as a behavioral inhibition measure, and an ES was calculated from the CBQ scale and included as a parent report measure of attentional focus/persistence. Thus, in this case, two ESs were calculated—one for each cognitive process. The same was true if a study used more than one measure of the same cognitive process but was included in different subdivisions. For example, if the previous study included a sustained attention task instead of the Go/No-Go task, then two ESs were calculated—one for behavioral attention and one for parent report attentional focus/persistence. However, if a study used more than one measure to assess the same cognitive process in the same subdivision (e.g., two different VSTM tasks or one task with multiple measures, such as reaction time and accuracy), ESs were calculated for each measure separately and then averaged together to create a single ES. ESs were averaged within and/or across subdivisions to avoid violating the assumption of independent observations (Lipsey & Wilson, 2001).

[2]For consistency, this subdivision was limited to forward span tasks because only one study measured working memory using a backward span task.

[3]Nonword lengths of one syllable and five syllables were not included because only one and two studies, respectively, used measures that spanned those lengths.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Statistical Analysis

Computing ESs

Data were analyzed using the Comprehensive Meta-Analysis (Version 2.0; Borenstein, Hedges, Higgins, & Rothstein, 2005) software program. For each study, quantitative information (i.e., sample sizes, means, standard deviations, and/or test statistics [*p* values]) for each dependent measure was used to calculate the standardized mean difference ES, which was computed as the difference between the means of the CWS and CWNS groups divided by the pooled standard deviation across groups (Lipsey & Wilson, 2001). To account for bias associated with small samples, all ESs were adjusted using Hedges' formula (i.e., Hedges' *g*; Hedges & Olkin, 1985). Hedges' *g* is interpreted using Cohen's convention of small (0.20), medium (0.50), and large (0.80) effects (Cohen, 1988). An ES of 1.00 indicates 1 *SD* difference in performance between the two groups (Durlak, 2003). Further, a negative ES signifies that the CWNS group had a more desirable outcome than the CWS group, whereas a positive ES means that the CWS group had a more desirable outcome than the CWNS group. All ESs were calculated by the first author and subsequently validated by the third author.

Summary ESs were computed for each cognitive process subdivision using the random-effects model (Hunter & Schmidt, 2004). The random-effects model was selected based on the assumption that the qualified studies represented a random sample of ESs that have been observed and the true ESs differ between studies (Lipsey & Wilson, 2001). Additionally, under the random-effects model, the overall estimate ES for each subdivision is not solely influenced by sample size (Lipsey & Wilson, 2001).

Heterogeneity Testing

For each cognitive process subdivision, the consistency of ESs across studies was examined using heterogeneity tests on the basis of the Q statistic and I^2 index. Whereas the Q statistic reflects the total dispersion of studies around the summary mean (Borenstein et al., 2009), the I^2 index describes the magnitude of the differences between studies (Higgins, Thompson, Deeks, & Altman, 2003). In general, I^2 indices of 25% indicate low heterogeneity, 50% medium heterogeneity, and 75% high heterogeneity (i.e., the larger the value, the more inconsistency there is in ESs across studies; Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). However, according to Higgins et al. (2003), these categorizations should be deemed tentative, given that approximately one quarter of meta-analyses have I^2 values in excess of 50%. These authors, therefore, recommend that heterogeneity testing be considered in conjunction with close examination of the degree of clinical and/or methodological variability across studies.

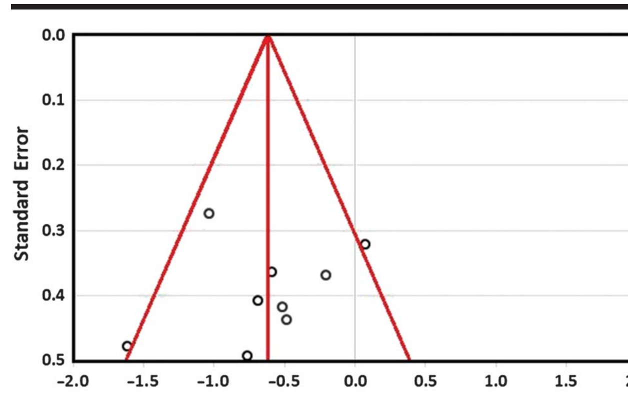
Publication Bias

The inclusion of unpublished studies reduces the potential for publication bias but does not eliminate it. Thus, the potential for publication bias was evaluated for each cognitive process under investigation by constructing funnel plots, in which the ES for each study is plotted against the standard error, and then visually inspecting them for evidence of asymmetry. If publication bias was detected, the "trim and fill" method was used to readjust the funnel plot and recalculate the ES (Duval & Tweedie, 2000). An example of a funnel plot for which no evidence of publication bias was found in the distribution of ESs—in this case, for overall nonword repetition—is shown in Figure 1. The distribution of studies in this figure is reasonably symmetrical to the left and right of the mean ES estimate, assuming the shape of an inverted funnel. Thus, no studies were added via the trim-and-fill method, and the ES was not recalculated. Figure 2 depicts the funnel plot for one of the cognitive processes, behavioral measures of attention, that exhibited asymmetry. In this figure, there were more studies to the left of the mean ES estimate than the right, resulting in a skewed inverted funnel. As a result, the trim-and-fill method added three hypothetical studies to the right of the mean ES estimate to realign the funnel plot and reestimate the ES.

Outliers

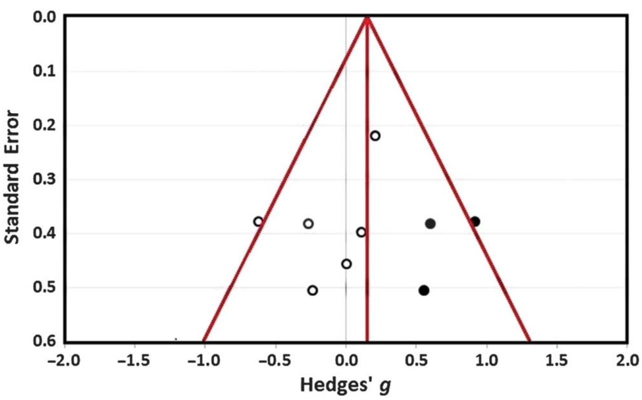
Extreme ESs (i.e., outliers) have the potential to disproportionately impact summary ESs in a meta-analysis. Thus, the ESs for each cognitive process subdivision were analyzed for extreme values based on visual inspection (Lipsey & Wilson, 2001). Using this approach, two outliers were identified for forward span. To reduce the impact of these outliers, two different approaches were used to calculate the ES for the forward span measures: trimming the distribution to exclude the two outlying studies and recoding the extreme ES values to the next highest ES (i.e., winsorizing; Lipsey & Wilson, 2001).

Figure 1. Funnel plot of the nine studies (open circles) included in overall nonword repetition. The triangle represents the region where 95% of the studies fall in the absence of publication bias. The vertical line represents the Hedges' *g* summary effect size of −0.62 found in the meta-analysis.



Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Figure 2. Funnel plot of the six studies (open circles) included in behavioral attention with three hypothetical studies (black circles) imputed using Duval and Tweedie's trim-and-fill method. The triangle represents the region where 95% of the studies fall in the absence of publication bias. The vertical line represents the adjusted Hedges' *g* summary effect size of 0.15 found in the meta-analysis.



Results

A descriptive summary of the 29 studies, which appeared between 2000 and 2016,[4] is found in Table 1. Twenty-five of the 29 (86%) studies were published in peer-reviewed journals or conference proceedings, two (7%) were conference posters or presentations, and two (7%) were doctoral dissertations. Four of the 29 (14%) studies excluded participants with speech, language, and/or cognitive difficulties on the basis of informal parent report measures, whereas 25 (86%) used norm-referenced, standardized tests. In most studies (n = 27; 93%), participants were classified into groups based on disfluency measures (e.g., percent stuttering-like disfluencies, and stuttering severity) obtained from speech samples. Group classification for the remaining studies (n = 2; 7%) was based on unspecified clinical disfluency evaluations. Participants in the two groups were matched or equated for age, gender, and/or socioeconomic status (SES) in most studies (n = 27; 93%). Sample sizes across studies ranged widely from 10 participants (five CWS, five CWNS) to 1,267 (138 CWS, 1,129 CWNS). Of the 29 studies, 14 (48%) included preschool children (age range = 3;0 [years;months] to 6;1) as participants, six (21%) included school-age children (range = 7;4 to 17;0), and nine (31%) included both preschool and school-age children (range = 3;0 to 11;0). Twenty-six of the 29 (90%) studies reported participants' gender. Of these 26 studies, gender was equally distributed across groups in 21 (81%) studies (mean gender ratio = 3.09:1 [boys:girls]), not equally distributed in four (15%) studies (mean gender ratio: CWS = 3.8:1, CWNS = 1.1:1), and not reported for the CWS group in one (4%) study (CWNS gender ratio = 1.2:1).

[4]One study that appeared during this time period was subsequently published in 2017.

Verbal Short-Term Memory

Nonword Repetition Measures

As revealed in Figure 3, nine studies examined VSTM in 127 CWS and 133 CWNS using nonword repetition tasks. The Hedges' *g* summary ES was significant ($p < .001$) at −0.62, with a 95% confidence interval (CI) of −0.94 to −0.30. This medium ES indicates that, as a group, CWS scored more than half a standard deviation below CWNS on measures of nonword repetition. Another way to interpret this ES, on the basis of the percent overlap between groups, is that the average participant in the CWNS group scored higher on VSTM measures than 73% of the CWS group. The Q statistic (Q = 12.86) was not statistically significant (p = .12), indicating no significant variability in ESs across studies. The I^2 index of 37.79% further indicates that the difference in the magnitude of ESs across studies was low. There was no evidence of publication bias on the basis of visual inspection of the funnel plot (Duval and Tweedie adjusted ES = −0.62, 95% CI = −0.94 to −0.30, number of imputed studies = 0).

Two-Syllable Nonword Length

Eight studies examined differences between 116 CWS and 122 CWNS at the two-syllable nonword length. The mean ES was medium at −0.62 (95% CI = −0.97 to −0.28) and statistically significant ($p < .001$). Heterogeneity testing revealed a nonsignificant Q statistic of 12.29 (p = .09) and a low–medium I^2 index of 43.03%. The adjusted ES from the Duval and Tweedie trim-and-fill procedure was −0.86 (95% CI = −1.23 to −0.49, number of imputed studies = 3).

Three-Syllable Nonword Length

Eight studies examined differences between 116 CWS and 122 CWNS at the three-syllable nonword length. The mean ES was medium at −0.50 (95% CI = −0.77 to −0.23) and statistically significant ($p < .001$). Heterogeneity testing revealed a nonsignificant Q statistic of 7.72 (p = .36) and a low I^2 index of 9.30%. The adjusted ES from the Duval and Tweedie trim-and-fill procedure was −0.44 (95% CI = −0.74 to −0.15, number of imputed studies = 1).

Four-Syllable Nonword Length

Four studies examined differences between 43 CWS and 43 CWNS at the four-syllable nonword length. The low to medium average ES estimate (−0.30) was not statistically significant (p = .16), with a 95% CI of −0.71 to 0.12. Heterogeneity testing revealed a nonsignificant Q statistic of 2.64 (p = .45) and a low I^2 index of 0.00%. The adjusted ES from the Duval and Tweedie trim-and-fill procedure was −0.21 (95% CI = −0.59 to 0.17, number of imputed studies = 1).

In summary, CWS performed at least half a standard deviation below their normally fluent peers at the shorter two-syllable and three-syllable nonword lengths but were

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Table 1. Summary of the individual studies that compared cognitive processes in children who stutter (CWS) and children who do not stutter (CWNS).

Study	Cognitive construct	*N*, CWS (CWNS)	Age, CWS (CWNS)	Measures, *M*, *SD*, *p* values	Hedges' *g* (*SE*)
Anderson & Bates (2007)	Attention-PR	23 (28)	51.00 (48.80)	CBQ-SF attentional focusing (CWS: *M* = 4.76, *SD* = 1.11; CWNS: *M* = 5.19, *SD* = 0.78)	−0.45 (0.28)
	Inhibition-PR	23 (28)	51.00 (48.80)	CBQ-SF inhibitory control (CWS: *M* = 4.83, *SD* = 0.97; CWNS: *M* = 4.96, *SD* = 0.94)	−0.13 (0.28)
Anderson et al. (2003)	Attention-PR	31 (31)	48.03 (48.58)	BSQ distractibility (CWS: *M* = −0.30, *SD* = 0.83; CWNS: *M* = 0.26, *SD* = 0.78)	0.69 (0.26)
				BSQ attention span/persistence (CWS: *M* = 0.39, *SD* = 0.82; CWNS: *M* = 0.02, *SD* = 0.74)	−0.46 (0.25)
Anderson & Wagovich (2010)	Attention-PR	9 (14)	51.33 (52.93)	CBQ-SF attentional focus (CWS: *M* = 4.94, *SD* = 0.99; CWNS: *M* = 5.30, *SD* = 0.70)	−0.42 (0.42)
	Inhibition-PR	9 (14)	51.33 (52.93)	CBQ-SF inhibitory control (CWS: *M* = 5.00, *SD* = 0.84; CWNS: *M* = 5.06, *SD* = 0.78)	−0.07 (0.41)
Anderson & Wagovich (2017)	Inhibition-B	29 (29)	55.28 (56.00)	Grass–Snow task RT (CWS: *M* = 2012.69, *SD* = 403.84; CWNS: *M* = 1809.58, *SD* = 445.22)	−0.47 (0.26)
		41 (41)	52.30 (52.85)	Grass–Snow task accuracy (CWS: *M* = 13.00, *SD* = 3.63; CWNS: *M* = 13.29, *SD* = 3.26)	−0.08 (0.22)
		29 (29)	55.28 (56.00)	Baa–Meow task RT (CWS: *M* = 2138.19, *SD* = 579.81; CWNS: *M* = 1762.83, *SD* = 443.37)	−0.72 (0.27)
		41 (41)	52.30 (52.85)	Baa–Meow task accuracy (CWS: *M* = 12.07, *SD* = 4.52; CWNS: *M* = 13.88, *SD* = 3.16)	−0.46 (0.22)
Anderson et al. (2006)	Verbal STM-NWR	11 (11)	47.90 (48.30)	CNRep two-syllable errors (CWS: *M* = 10.82, *SD* = 7.15; CWNS: *M* = 7.09, *SD* = 6.64)	−0.52 (0.42)
				CNRep three-syllable errors (CWS: *M* = 19.73, *SD* = 14.01; CWNS: *M* = 11.45, *SD* = 9.56)	−0.66 (0.42)
				CNRep four-syllable errors (CWS: *M* = 29.45, *SD* = 18.31; CWNS: *M* = 19.82, *SD* = 14.96)	−0.55 (0.42)
Anderson et al. (2014)	Verbal STM-FS	41 (41)	51.40 (51.60)	PST similar proportion correct (CWS: *M* = 0.50, *SD* = 0.23; CWNS: *M* = 0.54, *SD* = 0.23)	−0.19 (0.22)
				PST dissimilar proportion correct (CWS: *M* = 0.53, *SD* = 0.23; CWNS: *M* = 0.63, *SD* = 0.26)	−0.38 (0.22)
				SCT homogeneous proportion correct (CWS: *M* = 0.64, *SD* = 0.31; CWNS: *M* = 0.67, *SD* = 0.26)	−0.10 (0.22)
				SCT heterogeneous proportion correct (CWS: *M* = 0.59, *SD* = 0.28; CWNS: *M* = 0.70, *SD* = 0.24)	−0.41 (0.22)
Bakhtiar et al. (2007)	Verbal STM-NWR	12 (12)	75.60 (76.80)	two-syllable errors (CWS: *M* = 5.33, *SD* = 1.80; CWNS: *M* = 3.75, *SD* = 1.90)	−0.82 (0.41)
				three-syllable errors (CWS: *M* = 7.10, *SD* = 4.00; CWNS: *M* = 5.10, *SD* = 2.90)	−0.55 (0.40)
	Verbal STM-FS	12 (12)	75.60 (76.80)	Digit span (CWS: *M* = 3.90, *SD* = 0.40; CWNS: *M* = 3.80, *SD* = 0.68)	0.17 (0.40)

(*table continues*)

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Table 1. *(Continued).*

Study	Cognitive construct	*N*, CWS (CWNS)	Age, CWS (CWNS)	Measures, *M*, *SD*, *p* values	Hedges' *g* (*SE*)
Chou (2014)	Attention-B	8 (8)	123.00 (121.00)	AADT deviant reaction time (CWS: *M* = 765.39, *SD* = 85.76; CWNS: *M* = 891.26, *SD* = 55.53)	1.65 (0.56)
				AADT standard reaction time (CWS: *M* = 724.08, *SD* = 105.10; CWNS: *M* = 847.30, *SD* = 85.76)	1.22 (0.52)
				AADT deviant hit rate (CWS: *M* = 70.81, *SD* = 29.03; CWNS: *M* = 88.15, *SD* = 13.13)	−0.73 (0.49)
				AADT standard hit rate (CWS: *M* = 75.21, *SD* = 20.26; CWNS: *M* = 92.12, *SD* = 9.39)	−1.01 (0.51)
	Attention-B	8 (8)	123.60 (121.20)	VST overall reaction time (CWS: *M* = 625.44, *SD* = 52.37; CWNS: *M* = 584.97, *SD* = 42.68)	−0.80 (0.49)
				VST overall hit rate (CWS: *M* = 94.53, *SD* = 4.05; CWNS: *M* = 96.8, *SD* = 1.45)	−0.71 (0.49)
	Inhibition-PR	8 (8)	123.60 (121.20)	TMCQ inhibitory control (CWS: *M* = 3.11, *SD* = 0.48; CWNS: *M* = 3.60, *SD* = 0.64)	−0.82 (0.49)
Clark et al. (2015)	Attention-PR	82 (120)	46.68 (49.23)	BSQ distractibility (CWS: *M* = −0.10, *SD* = 1.02; CWNS: *M* = 0.07, *SD* = 0.99)	0.16 (0.14)
Eggers (2012)	Inhibition-B	18 (18)	109.00 (109.00)	SST RT (CWS: *M* = 594.00, *SD* = 114.00; CWNS: *M* = 604.00, *SD* = 123.00)	0.08 (0.33)
				SST delay (CWS: *M* = 557.00, *SD* = 253.00; CWNS: *M* = 792.00, *SD* = 225.00)	0.96 (0.35)
				SST go trials RT (CWS: *M* = 905.00, *SD* = 217.00; CWNS: *M* = 1101.00, *SD* = 229.00)	0.86 (0.34)
				SST stop trials RT (CWS: *M* = 1152.00, *SD* = 298.00; CWNS: *M* = 1396.00, *SD* = 266.00)	0.85 (0.34)
				SST go trials accuracy (CWS: *M* = 94.00, *SD* = 4.55; CWNS: *M* = 89.00, *SD* = 11.23)	0.57 (0.33)
				SST go trials missed (CWS: *M* = 3.66, *SD* = 3.75; CWNS: *M* = 7.5, *SD* = 5.34)	0.81 (0.34)
	Inhibition-B			SAT misses (CWS: *M* = 8.47, *SD* = 3.65; CWNS: *M* = 5.04, *SD* = 3.39)	−0.95 (0.35)
				SAT false alarms (CWS: *M* = 7.68, *SD* = 4.12; CWNS: *M* = 4.85, *SD* = 3.18)	−0.75 (0.34)
				SAT premature responses (CWS: *M* = 0.16, *SD* = 0.32; CWNS: *M* = 0.16, *SD* = 0.25)	0.00 (0.24)
				SAT omissions (CWS: *M* = 0.07, *SD* = 0.29; CWNS: *M* = 0.07, *SD* = 0.16)	0.00 (0.33)
				SAT overall RT (CWS: *M* = 906.00, *SD* = 227.00; CWNS: *M* = 1069.00, *SD* = 202.00)	0.74 (0.34)
				SAT overall *SD* RT (CWS: *M* = 329.00, *SD* = 153.00; CWNS: *M* = 411.00, *SD* = 177.00)	0.49 (0.33)
Eggers et al. (2010)	Attention-PR	58 (58)	61.32 (61.32)	CBQ attention focusing (CWS: *M* = 4.84, *SD* = 0.88; CWNS: *M* = 4.92, *SD* = 0.84)	−0.09 (0.19)
	Inhibition-PR	58 (58)	61.32 (61.32)	CBQ inhibitory control (CWS: *M* = 4.01, *SD* = 0.97; CWNS: *M* = 4.47, *SD* = 0.82)	−0.51 (0.19)
Eggers et al. (2012)	Attention-B	41 (41)	81.00 (81.00)	ANT RT (CWS: *M* = 921.00, *SD* = 160.00; CWNS: *M* = 945.00, *SD* = 154.00)	0.15 (0.22)
				ANT accuracy (CWS: *M* = 91.80, *SD* = 7.90; CWNS: *M* = 89.20, *SD* = 11.70)	0.26 (0.22)

(*table continues*)

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Table 1. *(Continued).*

Study	Cognitive construct	*N*, CWS (CWNS)	Age, CWS (CWNS)	Measures, *M*, *SD*, *p* values	Hedges' *g* (*SE*)
Eggers et al. (2013)	Inhibition-B	30 (30)	89.00 (89.00)	Go/no-go misses (CWS: *M* = 0.56, *SD* = 1.81; CWNS: *M* = 0.69, *SD* = 1.92)	0.07 (0.26)
				Go/no-go false alarms (CWS: *M* = 8.47, *SD* = 6.79; CWNS: *M* = 4.72, *SD* = 4.61)	−0.64 (0.26)
				Go/no-go premature responses (CWS: *M* = 2.80, *SD* = 4.55; CWNS: *M* = 0.27, *SD* = 1.06)	−0.76 (0.26)
				Go/no-go RT (CWS: *M* = 509.00, *SD* = 132.00; CWNS: *M* = 534.00, *SD* = 104.00)	0.21 (0.26)
Embrechts et al. (2000)	Attention-PR	38 (38)	60.00 (60.00)	CBQ attention focusing (CWS: *M* = 4.22, *SD* = 0.82; CWNS: *M* = 4.55, *SD* = 0.54)	−0.47 (0.23)
	Inhibition-PR	38 (38)	60.00 (60.00)	CBQ inhibitory control (CWS: *M* = 4.15, *SD* = 0.79; CWNS: *M* = 4.66, *SD* = 0.94)	−0.58 (0.23)
Hakim & Ratner (2004)	Verbal STM-NWR	8 (8)	70.63 (69.38)	CNRep two-syllable errors (CWS: *M* = 2.38, *SD* = 2.26; CWNS: *M* = 1.25, *SD* = 1.16)	−0.60 (0.48)
				CNRep three-syllable errors (CWS: *M* = 5.38, *SD* = 3.92; CWNS: *M* = 1.29, *SD* = 1.1)	−1.34 (0.53)
				CNRep four-syllable errors (CWS: *M* = 9.13, *SD* = 10.03; CWNS: *M* = 3.88, *SD* = 2.85)	−0.67 (0.49)
Heitmann et al. (2004)	Attention-B	9 (9)	160.92 (163.68)	CPT target hits 1.t (CWS: *M* = 48.44, *SD* = 11.94; CWNS: *M* = 36.00, *SD* = 17.84)	0.78 (0.47)
				CPT target hits 6.t (CWS: *M* = 47.11, *SD* = 11.28; CWNS: *M* = 33.00, *SD* = 16.18)	0.96 (0.48)
				CPT omissions 1.t (CWS: *M* = 1.55, *SD* = 1.94; CWNS: *M* = 2.00, *SD* = 1.87)	0.23 (0.45)
				CPT omissions 6.t (CWS: *M* = 2.80, *SD* = 3.05; CWNS: *M* = 5.00, *SD* = 7.41)	0.37 (0.45)
				CPT nontarget rejections 1.t (CWS: *M* = 1.11, *SD* = 0.78; CWNS: *M* = 1.22, *SD* = 1.20)	0.10 (0.45)
				CPT nontarget rejections 6.t (CWS: *M* = 1.22, *SD* = 1.39; CWNS: *M* = 1.33, *SD* = 1.22)	0.08 (0.45)
				CPT nontarget commission 1.t (CWS: *M* = 4.44, *SD* = 1.50; CWNS: *M* = 3.00, *SD* = 1.73)	−0.85 (0.47)
				CPT nontarget commission 6.t (CWS: *M* = 4.33, *SD* = 1.87; CWNS: *M* = 2.88, *SD* = 1.90)	−0.73 (0.47)
				CPT RT 1.t (CWS: *M* = 312.33, *SD* = 38.53; CWNS: *M* = 292.22, *SD* = 41.80)	−0.48 (0.46)
				CPT RT 6.t (CWS: *M* = 349.66, *SD* = 91.32; CWNS: *M* = 381.44, *SD* = 58.68)	0.39 (0.45)
	Attention-B			DLT nonforced right ear (CWS: *M* = 12.55, *SD* = 2.92; CWNS: *M* = 12.00, *SD* = 3.39)	0.17 (0.45)
				DLT nonforced left ear (CWS: *M* = 10.00, *SD* = 3.31; CWNS: *M* = 10.66, *SD* = 1.93)	−0.23 (0.45)
				DLT forced right–right ear (CWS: *M* = 17.11, *SD* = 4.45; CWNS: *M* = 17.88, *SD* = 3.65)	−0.18 (0.45)
				DLT forced right–left ear (CWS: *M* = 8.88, *SD* = 3.65; CWNS: *M* = 8.22, *SD* = 2.63)	−0.20 (0.45)
				DLT forced left–right ear (CWS: *M* = 13.66, *SD* = 4.35; CWNS: *M* = 14.00, *SD* = 4.27)	0.08 (0.45)
				DLT forced left–left ear (CWS: *M* = 11.44, *SD* = 4.21; CWNS: *M* = 11.88, *SD* = 5.46)	−0.09 (0.45)

(*table continues*)

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Table 1. *(Continued).*

Study	Cognitive construct	*N*, CWS (CWNS)	Age, CWS (CWNS)	Measures, *M*, *SD*, *p* values	Hedges' *g* (*SE*)
Johnson et al. (2012)	Attention-B	12 (12)	58.00 (58.83)	Traditional valid cueing RT (CWS: *M* = 746.60, *SD* = 246.94; CWNS: *M* = 742.13, *SD* = 238.71)	–0.02 (0.39)
				Traditional invalid cueing RT (CWS: *M* = 958.70, *SD* = 326.55; CWNS: *M* = 909.55, *SD* = 267.91)	–0.16 (0.40)
				Overall errors (CWS: *M* = 3.00, *SD* = 2.59; CWNS: *M* = 4.73, *SD* = 3.89)	0.51 (0.40)
Kaganovich et al. (2010)	Verbal STM-FS	18 (18)	49.20 (49.20)	TAPS digit span (CWS: *M* = 7.30, *SD* = 0.60; CWNS: *M* = 8.60, *SD* = 0.60)	–2.12 (0.41)
				TAPS word span (CWS: *M* = 3.60, *SD* = 0.30; CWNS: *M* = 4.30, *SD* = 0.30)	–2.28 (0.42)
Kefalianos et al. (2014)	Attention-PR	138 (1129)	NR	STSC distractibility (CWS: *M* = 15.20, *SD* = 2.40; CWNS: *M* = 15.60, *SD* = 2.60)	–0.16 (0.09)
				STSC persistence (CWS: *M* = 14.20, *SD* = 2.20; CWNS: *M* = 13.30, *SD* = 2.10)	–0.43 (0.09)
Ntourou et al. (2014)	Attention-PR	42 (42)	NR	CBQ-SF attentional focus (CWS: *M* = 4.74, *SD* = 0.97; CWNS: *M* = 4.83, *SD* = 0.99)	–0.09 (0.22)
Oyoun et al. (2010)	Verbal STM-NWR	30 (30)	90.12 (95.16)	two-syllable errors (*p* = .000002)	–1.35 (0.28)
				three-syllable errors (*p* = .006)	–0.73 (0.26)
	Verbal STM-FS	30 (30)	90.12 (95.16)	Digit span (CWS: *M* = 5.03, *SD* = 1.27; CWNS: *M* = 5.93, *SD* = 1.41)	–0.66 (0.26)
				Letter span (CWS: *M* = 3.97, *SD* = 1.10; CWNS: *M* = 4.56, *SD* = 1.33)	–0.48 (0.26)
Pelczarski & Yaruss (2016)	Verbal STM-FS	11 (11)	65.00 (69.00)	CTOPP standard score (CWS: *M* = 7.73, *SD* = 1.4; CWNS: *M* = 10, *SD* = 1.3)	–1.62 (0.48)
	Verbal STM-FS	11 (11)	65.00 (69.00)	CTOPP (forward) digit span (CWS: *M* = 9.27, *SD* = 2.60; CWNS: *M* = 10.60, *SD* = 1.60)	–0.59 (0.42)
Piispala et al. (2016)	Attention-B	11 (19)	97.20 (97.20)	Go/no-go (Go condition only) RT (CWS: *M* = 536.00, *SD* = 50.00; CWNS: *M* = 498.00, *SD* = 64.00)	–0.62 (0.38)
Reilly & Donaher (2005)	Verbal STM-FS	5 (5)	94.20 (101.00)	Oral recall accuracy (CWS: *M* = 36.94, *SD* = 13.04; CWNS: *M* = 68.07, *SD* = 4.88)	–2.86 (0.86)
Sasisekaran & Byrd (2013)	Verbal STM-NWR	14 (14)	140.40 (141.60)	Two-syllable errors (CWS: *M* = 5.28, *SD* = 2.53; CWNS: *M* = 3.12, *SD* = 3.23)	–0.72 (0.38)
				Three-syllable errors (CWS: *M* = 6.02, *SD* = 3.49; CWNS: *M* = 5.76, *SD* = 2.75)	–0.08 (0.37)
				Four-syllable errors (CWS: *M* = 8.02, *SD* = 3.87; CWNS: *M* = 8.60, *SD* = 2.42)	0.17 (0.37)
	Verbal STM-FS	14 (14)	140.40 (141.60)	Forward digit span (CWS: *M* = 9.07, *SD* = 2.64; CWNS: *M* = 10.43, *SD* = 2.56)	–0.51 (0.37)
Schwenk et al. (2007)	Attention-B	13 (14)	NR	Percent camera looks (CWS: *M* = 0.35, *SD* = 0.36; CWNS: *M* = 0.13, *SD* = 0.16)	–0.78 (0.39)
				Duration camera looks (CWS: *M* = 0.30, *SD* = 0.32; CWNS: *M* = 0.48, *SD* = 0.98)	0.24 (0.38)

(*table continues*)

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Table 1. *(Continued).*

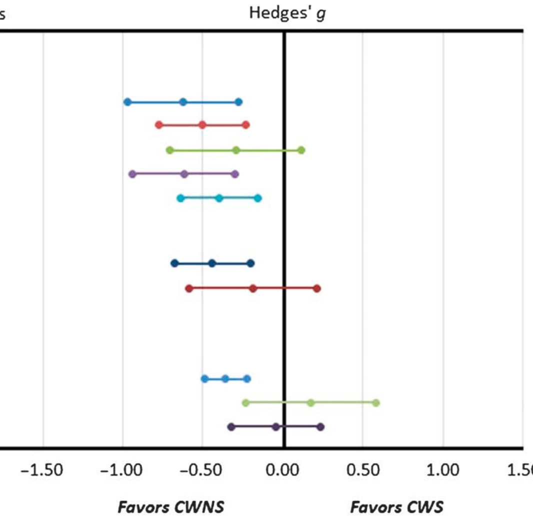
Study	Cognitive construct	*N*, CWS (CWNS)	Age, CWS (CWNS)	Measures, *M*, *SD*, *p* values	Hedges' *g* (*SE*)
Smith et al. (2012)	Verbal STM-NWR	16 (22)	NR	NRT two-syllable errors (p = .74)	0.11 (0.32)
				NRT three-syllable errors (p = .90)	0.04 (0.32)
Vahab et al. (2014)	Verbal STM-NWR	15 (15)	64.20 (66.36)	Two-syllable errors (CWS: M = 30.00, SD = 19.00; CWNS: M = 21.00, SD = 14.00)	–0.53 (0.36)
				Three-syllable errors (CWS: M = 40.00, SD = 21.00; CWNS: M = 30.00, SD = 17.00)	–0.51 (0.36)
Weber-Fox et al. (2008)	Verbal STM-NWR	10 (10)	138.00 (139.00)	NRT two-syllable errors (CWS: M = 1.50, SD = 4.70; CWNS: M = 0.00, SD = 0.00)	–0.43 (0.43)
				NRT three-syllable errors (CWS: M = 4.30, SD = 6.40; CWNS: M = 1.00, SD = 2.10)	–0.66 (0.44)
				NRT four-syllable length (CWS: M = 19.20, SD = 10.30; CWNS: M = 15.60, SD = 8.20)	–0.37 (0.43)

Note. *N* = sample size; Age = mean age in months; PR = parent report; CBQ-SF = Children's Behavior Questionnaire–Short Form (Putnam & Rothbart, 2006); BSQ = Behavioral Style Questionnaire (McDevitt & Carey, 1978); B = behavioral; RT = reaction time; STM = short-term memory; NWR = nonword repetition; CNRep = Children's Test of Nonword Repetition (Gathercole, Willis, Emslie, & Baddeley, 1994); FS = forward span; PST = phonological similarity task; SCT = semantic category task; AADT = auditory-auditory distraction task; VST = visual search task; TMCQ = Temperament in Middle Childhood Questionnaire (Simonds & Rothbart, 2004); SST = stop signal task; SAT = sustained attention task; ANT = Attention Network Test (Fan et al., 2002); CBQ = Children's Behavior Questionnaire (Rothbart et al., 2001); CPT = Continuous Performance Test (Kerns & Rondeau, 1998); DLT = Dichotic Listening Test (Hugdahl & Asbjørnsen, 1991); TAPS = Test of Auditory–Perceptual Skills (Gardner, 1985); NR = not reported; STSC = Short Temperament Scale for Children (Australian Temperament Project, 1990); CTOPP = Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999); NRT = Nonword Repetition Test (Dollaghan & Campbell, 1998).

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Figure 3. Summary effect sizes (Hedges' *g*) and confidence intervals for verbal STM, inhibition, and attention between CWS and CWNS. *LL* = lower limit; *UL* = upper limit; *N* = sample size; CWS = children who stutter; CWNS = children who do not stutter; STM = short-term memory.

Cognitive measures	Hedges' *g* Effect size	95% CI *LL*	95% CI *UL*	*p*-value	*N* CWS	*N* CWNS	Number of studies
Verbal STM							
Nonword repetition measures							
2-syllable length	−0.62	−0.97	−0.28	0.00	116	122	8
3-syllable length	−0.50	−0.77	−0.23	0.00	116	122	8
4-syllable length	−0.30	−0.71	0.12	0.16	43	43	4
Overall nonword repetition	−0.62	−0.94	−0.30	0.00	127	133	9
Forward span measures (winsorized)	−0.39	−0.63	−0.15	0.00	131	131	7
Inhibition							
Parent-report measures	−0.44	−0.67	−0.21	0.00	136	146	5
Behavioral measures	−0.19	−0.59	0.21	0.35	83	83	3
Attention							
Parent-report measures							
Attentional focus/persistence	−0.36	−0.49	−0.23	0.00	339	1340	7
Distractibility	0.17	−0.23	0.58	0.41	251	1280	3
Behavioral measures	−0.04	−0.32	0.23	0.76	94	103	6



comparable at the longer four-syllable length. The significant mean ESs further indicate that the average participant in the CWNS group was more successful than 69%–73% of the CWS group at repeating nonwords of two-syllable and three-syllable lengths. Heterogeneity testing revealed consistency across studies in ES estimates at each nonword length. Visual inspection of the funnel plots revealed a slightly elevated risk of publication bias at all three nonword lengths, particularly at the two-syllable length. At the two-syllable length, however, the adjusted ES (−0.86) was even lower than the observed ES (−0.62). This suggests that the existing studies may have underestimated the difference between the two groups of children at the two-syllable length.

Forward Span Measures

Seven studies examined VSTM in CWS (n = 131) and CWNS (n = 131) using forward span measures. As previously indicated, the ESs for two of these studies were identified as extreme (i.e., greater than 2 *SD*s from the mean of all ESs). Thus, two mean ESs were calculated for forward span on the basis of both the trimmed and winsorized distribution.

The low to medium mean ES estimate (−0.35) for the trimmed distribution, which included five studies with a total of 108 CWS and 108 CWNS, was statistically significant, with a p value of .01 and a 95% CI of −0.61 to −0.08. Heterogeneity testing revealed a nonsignificant Q statistic of 2.93 (p = .57) and a low I^2 index of 0.00%. The adjusted ES from the Duval and Tweedie trim-and-fill procedure was −0.35 (95% CI = −0.61 to −0.08, number of imputed studies = 0).

The mean ES estimate on the basis of the winsorized distribution (131 CWS, 131 CWNS) was also statistically significant and low to medium in strength at −0.39 (p < .001), with a 95% CI of −0.63 to −0.15 (see Figure 3). Heterogeneity testing on the basis of the winsorized distribution revealed a nonsignificant Q statistic of 3.59 (p = .73) and a low I^2 index of 0.00%. The adjusted ES from the Duval and Tweedie trim-and-fill procedure was −0.37 (95% CI = −0.60 to −0.14, number of imputed studies = 1).

Taken together, these findings indicate that, regardless of the distribution, CWS scored more than one third of a standard deviation below CWNS on measures of forward span, with the CWNS group, on average, performing better than approximately 66% of the CWS group. For both distributions, heterogeneity was nearly nonexistent, and there was no significant evidence of publication bias.

Inhibition

Parent Report Measures

Five studies examined the inhibition skills of 136 CWS and 146 CWNS using parent report questionnaires (see Figure 3). The mean ES (−0.44) was medium and statistically significant (p < .001), with a 95% CI of −0.67 to −0.21. This ES indicates that the parents of CWS, as a group, rated their children's inhibition skills almost half a standard deviation below the mean of CWNS. This ES can also be interpreted to suggest that the average child in the CWNS group was judged by their parents as having better inhibition skills than 67% of the children in the CWS group. Heterogeneity testing revealed a nonsignificant Q statistic of 3.11 (p = .54) and a low I^2 index of 0.00%. There was no evidence of publication bias on the basis of visual inspection of the funnel plot (Duval and Tweedie adjusted ES = −0.44, 95% CI = −0.67 to −0.21, number of imputed studies = 0).

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Behavioral Measures

Three studies examined inhibition in 83 CWS and 83 CWNS using behavioral tasks. The mean ES estimate was low at −0.19 and not statistically significant ($p = .35$), with a 95% CI of −0.59 to 0.21. Heterogeneity testing revealed a nonsignificant Q statistic of 3.25 ($p = .20$) and a low I^2 index of 38.50%. The funnel plot analysis revealed no evidence of publication bias (Duval and Tweedie adjusted ES = −0.19, 95% CI = −0.59 to 0.21, number of imputed studies = 0).

Attention

Parent Report Measures: Attentional Focus/Persistence

As depicted in Figure 3, seven studies examined attentional focus/persistence in 339 CWS and 1,340 CWNS using parent report questionnaires. The Hedges' *g* ES was statistically significant at −0.36 ($p < .01$), with a 95% CI of −0.49 to −0.23. Thus, the parents of CWS, as a group, rated the attentional focusing/persistence skills of their children more than one third of a standard deviation below the mean of CWNS. The mean ES further suggests that the average child in the CWNS group was judged by their parents as scoring better than 64% of the CWS group. Heterogeneity analysis revealed a statistically nonsignificant *Q* statistic, $Q = 4.69$, $p = .58$, and an I^2 index of 0.00%, indicating low variability in ES estimates across studies. Visual inspection of the funnel plot (Duval and Tweedie adjusted ES = −0.36, 95% CI = −0.49 to −0.23, number of imputed studies = 0) indicated no evidence of publication bias.

Parent Report Measures: Distractibility

Three studies examined distractibility in 251 CWS and 1,280 CWNS. The mean ES (0.17) did not reach significance ($p = .41$), with a 95% CI of −0.23 to 0.58. Heterogeneity testing revealed a significant Q statistic of 11.30 ($p < .01$) and a high I^2 index of 82.29%. The relatively small number of studies that examined distractibility likely contributed to the high degree of variability in ES estimates across studies. Visual inspection of the funnel plot indicated no risk of publication bias (Duval and Tweedie adjusted ES = 0.17, 95% CI = −0.23 to 0.58, number of imputed studies = 0).

Behavioral Measures

Six studies with a total of 94 CWS and 103 CWNS examined attention using behavioral tasks. The mean ES estimate was small (−0.04) and statistically nonsignificant ($p = .76$), with a 95% CI of −0.32 to 0.23. Heterogeneity testing further revealed a nonsignificant Q statistic of 4.31 ($p = .51$) and a low I^2 index of 0.00%. Visual inspection of the funnel plot (Duval and Tweedie adjusted ES = 0.15, 95% CI = −0.16 to 0.46, number of imputed studies = 3) showed some evidence of potential publication bias. The adjusted ES (0.15) was higher than the observed ES (−0.04), suggesting that the existing studies may have underestimated the between-groups difference in behavioral measures of attention. However, the adjusted ES was positive in direction, giving CWS a slight, albeit statistically insignificant, advantage over that of CWNS (approximately one seventh of a standard deviation above the mean).

Discussion

The goal of this study was to examine the role of VSTM, inhibition, and attention in developmental stuttering, given the disparate findings in the literature on this topic. To achieve this goal, a meta-analytic review was conducted to summarize both published and unpublished research completed between 2000 and 2016 on the aforementioned cognitive processes in CWS. This review yielded three main findings. First, CWS performed more poorly compared with CWNS on measures of VSTM. Second, the inhibition skills of CWS were lower than CWNS based on parent report measures, but not behavioral measures. Third, CWS scored lower than CWNS on some aspects of attention when measured using parent report questionnaires, but there were no between-groups differences in the behavioral measures. What follows is a further discussion of these main findings.

Verbal Short-Term Memory

Present findings indicate robust differences between CWS and CWNS in VSTM, as measured via both nonword repetition and forward span measures. The magnitude of the difference between the two groups of children was within 1 *SD* of the mean, suggesting that although VSTM may be depressed in CWS, it is not likely to represent a clinically meaningful source of difficulty for most CWS. In other words, the VSTM skills of CWS, as a group, are not necessarily disordered but, rather, simply not as robust as those of CWNS.

For nonword repetition, the results indicated that, when compared with CWNS, CWS performed significantly more poorly overall and at the two-syllable and three-syllable length, but not at the four-syllable length. In fact, after adjusting the ES estimate for publication bias, findings suggest that the between-groups difference at the two-syllable length may even be an underestimation (original ES = −0.62, adjusted ES = −0.86). The lack of between-groups difference at the four-syllable length may be attributed to ceiling effects, which reflect the upper limits of performance due to constraints on the amount of information that can be held in the phonological store (Anderson et al., 2006; Hakim & Ratner, 2004). That is, it seems reasonable to suggest that the four-syllable length may have been equally challenging for both CWS and CWNS alike, resulting in no significant difference between the two groups of children at this longer syllable length.

As previously indicated, VSTM clearly plays a role in the ability to repeat a nonword because children must be able to hold the nonword in the phonological store long enough to be able to repeat it successfully (e.g., Archibald & Gathercole, 2007). Nevertheless, other processes, such as

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

the ability to perceive and efficiently interpret the acoustic features of the speech sounds (auditory processes), form representations or frameworks sensitive to the distinct speech sound sequences (phonological processes), and the ability to articulate the phonological sequence (speech motor processes) also contribute to successful nonword repetition performance (Bishop, Bishop, Bright, Delaney, & Tallal, 1999; Estes et al., 2007; Gathercole, 2006). Although when storing, retrieving, and articulating the phonological sequences, there is limited access to long-term lexical and sublexical knowledge (Baddeley et al., 1998).

Like nonword repetition measures, CWS performed significantly more poorly on forward span measures compared with CWNS. As will be recalled, forward span measures examine the ability to recall sequential units of meaningful verbal information (e.g., words, digits, letters) in the order in which the items are presented (Richardson, 2007). When repeating a series of words, digits, or letters, the child must temporarily hold the items in mind (i.e., phonological store) and match them to their stored lexical and sublexical representations in the mental lexicon. These representations are then transformed into an articulatory plan that is eventually realized as overt speech (Gathercole, Hitch, Service, & Martin, 1997). Thus, forward span measures differ from nonword repetition in that the child has greater access to long-term lexical and sublexical knowledge, which may facilitate retrieval. Although there are other substantive differences between nonword repetition and forward span measures, some of which favor the former and, others, the latter, both clearly place a demand on children's VSTM skills (Archibald & Gathercole, 2007).

Interestingly, the ability of CWS to repeat nonwords may, according to Spencer and Weber-Fox (2014), be predictive of stuttering recovery or persistence. This supposition is based on their finding that young children who continued to stutter (n = 19) were less successful in their ability to repeat nonwords than children who eventually recovered from stuttering (n = 21) and that this ability significantly predicted whether children persisted or recovered from stuttering. These two groups of CWS, however, performed similarly on two forward span tasks (digits and words), and neither of these tasks predicted persistence or recovery. Because the two CWS groups differed in nonword repetition, but not forward span, the authors argued that it is not the VSTM component of nonword repetition that has predictive value for persistence but, rather, it is the phonological processing component. One problem with this interpretation, however, is that the nonword repetition and forward span tasks used in this study were not quite comparable in level of difficulty. Research has consistently revealed that VSTM for digits is better than words and the recall of both digit and word sequences are superior to nonwords (Jones & Macken, 2015). Thus, it is possible that the authors did not find differences between the two groups of CWS on the forward span tasks and that these tasks did not predict persistence/recovery because they were simply not challenging enough to detect subtle differences in performance. As a result, it is not entirely clear, on the basis of this study alone, which nonword repetition component(s) was (were) contributing to stuttering persistence. More research is clearly needed.

Given that VSTM and word learning share a similar underlying architecture (Acheson & McDonald, 2009; Archibald & Gathercole, 2007; Bishop, North, & Donlan, 1996; Gathercole & Baddeley, 1990), any weaknesses that impact VSTM could potentially influence a child's ability to learn new words. As previously described, one component of Baddeley's (1986, 2003) model of working memory is the phonological loop, which consists of the phonological store, a temporary storage system for verbal information. When learning a new word, children must perceive the novel phonological sequence, accurately form a representation of that sequence in the phonological store (i.e., VSTM), and, then, transform that temporary representation into a more stable phonological representation in long-term memory (Brown & Hulme, 1996; Gathercole, 2006). Thus, the ability to form robust phonological representations depends on VSTM; if a child is unable to maintain these representations in VSTM, then they cannot be properly transformed into long-term memory. Indeed, in support of this relationship, research has revealed that children with weak VSTM skills have reduced vocabulary skills compared with children with stronger VSTM skills (Gathercole, Service, Hitch, Adam, & Martin, 1999; Gathercole, Willis, Emslie, & Baddeley, 1992; Majerus, Poncelet, Greffer, & Van der Linden, 2006).

In the stuttering literature, some researchers have reported that CWS have weaknesses in receptive and expressive vocabulary compared with CWNS (e.g., Anderson & Conture, 2000; Bernstein Ratner & Silverman, 2000; Ntourou et al., 2011). Findings from experimental studies have also revealed that, when compared with CWNS, CWS may have difficulty forming and/or retrieving phonological and lexical representations (Anderson, 2008; Byrd, Conture, & Ohde, 2007; Hartfield & Conture, 2006; Pellowski & Conture, 2005). Thus, given the relationship between VSTM and word learning, findings of less-than-robust vocabulary skills in CWS could be a consequence of weaknesses in VSTM, as observed in this study.

Inhibition

Present findings indicate that CWS have significantly lower inhibition skills compared with CWNS, especially when measured using parent report questionnaires. Like VSTM, the magnitude of the difference between the two groups in parent report inhibition was within 1 *SD* of the mean, suggesting that the lower inhibition skills in CWS are likely subclinical in nature. That there were no significant differences between CWS and CWNS in behavioral measures of inhibition should be viewed with caution, given that only three behavioral studies were qualified for inclusion in this analysis. Nevertheless, there are some differences in the way in which inhibition is viewed depending on how it is measured, which could have contributed to the inconsistency in findings across parent report and behavioral

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

measures (cf. “Behavioral versus Parent-Report Measures of Inhibition and Attention” below).

Of the five studies that examined parent report inhibition, four used the CBQ, and one used the Temperament in Middle Childhood Questionnaire (Simonds & Rothbart, 2004), which was adapted for older children from the CBQ. The Inhibitory Control dimension of the CBQ and Temperament in Middle Childhood Questionnaire measure simple prepotent response inhibition or the ability to suppress or resist an inappropriate response in new, changing, and/or stressful situations (Rothbart, Ahadi, & Hershey, 1994). For instance, if an unanticipated change occurs in the environment, a child with lower inhibition skills may have difficulty keeping internal or external stimuli from interfering with an activity he or she is engaged in, thereby impacting his or her ability to respond appropriately. Similarly, a child with lower inhibition skills may find it difficult to stop an activity when told to do so because of the natural tendency to continue the activity (Eggers, De Nil, & Van den Bergh, 2013). Thus, from a self-regulatory point of view, the parents of CWS rated their children as having more difficulty suppressing irrelevant stimuli or ongoing behavior in novel situations than the parents of CWNS.

Unlike parent report measures of inhibition, behavioral measures of inhibition are more variable in the type of inhibition being measured and the specific tasks used to measure them. As previously indicated, there are three main types of inhibition (prepotent response inhibition, resistance to distractor interference, and resistance to proactive interference), which can be assessed using a variety of different measures (Garon et al., 2008; Miyake et al., 2000). For example, of the three behavioral studies that qualified for inclusion in the present meta-analysis, Anderson and Wagovich (2017) measured complex response inhibition, whereas Eggers et al. (2013) examined simple response inhibition. These studies not only measured different types of inhibition, but they also differed in the mode of presentation. For example, the tasks used by Anderson and Wagovich were auditorily presented, whereas the stimuli used by Eggers et al. were visual. It may be that, in the laboratory setting, CWS have difficulty with one type of inhibition (e.g., complex response inhibition) but not others (e.g., simple response inhibition), or perhaps, they struggle when stimuli are presented in the auditory domain but not the visual domain. Regardless, when findings on the basis of different types of inhibition, tasks, and/or modalities are averaged across studies in a meta-analysis, they could effectively cancel each other out, resulting in a nonsignificant ES.

Despite the inconsistency in findings across parent report and behavioral measures, present findings suggest that inhibition may be an area of weakness for CWS. While there are multiple ways in which weaknesses in inhibition could potentially affect stuttering, one possibility, as suggested by Anderson and Wagovich (2017), is that it could affect the ability of CWS to effectively and/or efficiently suppress the production of incorrect speech plans during speech monitoring. Accordingly, disfluencies would then ensue as CWS attempt to manage these conflicts (i.e., attempting to suppress incorrect speech plans in favor of correct ones) in the speech monitoring system. Of course, the notion that excessive disfluencies may be associated with speech monitoring is not new, as this system has featured prominently in several theoretical accounts of stuttering, namely, the covert repair hypothesis (Postma & Kolk, 1993) and the vicious cycle hypothesis (Vasić & Wijnen, 2005). However, these accounts differ from that suggested by Anderson and Wagovich in that the core problem for individuals who stutter in the covert repair hypothesis is with phonological encoding and hypersensitive error monitoring in the vicious cycle hypothesis.

Attention

Findings from this meta-analysis revealed a significant difference in parent report attention between the two groups of children, with the parents of CWS rating their children lower in attentional focus/persistence, but not distractibility than the parents of CWNS. Like VSTM and inhibition, the magnitude of the difference between CWS and CWNS in attentional focus/persistence suggests that the attentional difficulties of CWS, as a group, may be subclinical.

At first glance, that CWS were rated significantly lower than CWNS in parent report attentional focus/persistence but not distractibility may appear incompatible because one might assume that a child who is less focused would be more easily distracted. However, attentional focus/persistence and distractibility are not considered to be opposite sides of the same construct by authorities, such as Thomas and Chess (1977). In their classic theory of temperament, Thomas and Chess defined *attentional focus/persistence* as the length of time in which a child engages in an activity and continues even when faced with obstacles or distractions. For example, a young child with good attentional focus/persistence would likely work on a puzzle until it is completed, even if it is difficult, whereas the child with weak attentional focus/persistence would likely give up on the puzzle. *Distractibility*, on the other hand, is defined as the ease with which external stimuli interferes with a child’s ongoing behavior. For example, a young child who is highly distractible might be easily diverted from a tantrum if another activity is suggested, whereas the less distractible child would likely continue with the tantrum. A child could have difficulty maintaining their attention for longer periods of time but not be susceptible to distractions during the time in which they were engaged. Conversely, a child may be able to maintain his or her attention during an activity over the long haul but still be distracted by events in the environment.

Although attentional focus/persistence and distractibility need not work in tandem, it is possible that distractibility did not reach significance in this meta-analysis because of the small sample size (only three studies qualified for inclusion in this analysis) and the large amount of heterogeneity associated with this analysis. With respect to the

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

latter, a large amount of heterogeneity across studies can affect statistical power, thereby reducing the chances of detecting significant differences that may exist between the two groups (Higgins et al., 2003).

The fact that parents rated their CWS as having less attentional focus/persistence skills than CWNS warrants consideration. Attentional focus/persistence is a necessary component in the pursuit of goal-directed behaviors (Garon et al., 2008), including those involved in speech-language production. During speech-language production, attentional focus is needed to concentrate on and monitor speech-language processing during different speaking situations (Levelt, 1992). According to the WEAVER++ model (Levelt, Roelofs, & Meyer, 1999; Roelofs, 1997, 2008), attentional resources are distributed through the word production process, from the word planning level to the phonological encoding level. However, if an individual has difficulty with speech-language planning or is attempting to produce complex language, he or she may compensate for this difficulty by reallocating attentional resources from one level of production to another (Roelofs & Piai, 2011). As a result, the ability to monitor other aspects of speech-language production may be affected. For example, if undue attentional resources are focused on speech monitoring and not at the discourse level, CWS may attempt to correct even minor speech errors, which could result in disruptions (i.e., stuttering) in the forward flow of speech (Vasić & Wijnen, 2005).

Unlike parent report attention, there were no significant differences between the two groups of children on behavioral measures of attention. However, behavioral measures of attention are like inhibition in that different types of attention can be assessed using a variety of different tasks and sensory modalities. For example, some researchers used a visual search task to examine shifting/focused attention (Johnson et al., 2012), whereas others used a dichotic listening test to measure shifting/sustained attention (Heitmann, Asbjørnsen, & Helland, 2004). Thus, it is possible that CWS could have weaknesses in one aspect of attention, such as attention shifting, but then have strengths in other components like sustained attention. Likewise, CWS could potentially have difficulties with both sustained and selective attention but only when stimuli are presented auditorily, not visually. As with behavioral inhibition, these potential differences could, in effect, be "wiped out" in a meta-analysis when ESs are averaged across all studies, regardless of type of attention studied, the tasks used, and the sensory modality that's being tapped into. Of course, to examine all possible permutations, one must have a sufficient amount of studies to analyze. Perhaps, with ongoing research, this may one day be a possibility.

Behavioral Versus Parent Report Measures of Inhibition and Attention

Given the inconsistencies in findings between behavioral and parent report measures of inhibition and attention in the present meta-analysis, it is not surprising to learn that some researchers have suggested that these measures assess different aspects of cognition. For example, behavioral measures are thought to tap into the efficacy of cognitive processing abilities (i.e., the "algorithmic mind"), whereas parent report measures access the "reflective mind," which is concerned with the individual's goals and the actions and beliefs associated with them (e.g., Toplak et al., 2013). Other researchers have suggested that behavioral measures may be more sensitive to children's behaviors in novel events, whereas parent report measures are more sensitive to children's emotional reactions and goals (Kagan & Fox, 2006).

In addition to potential differences in the underlying construct being measured, there are other ways in which behavioral and parent report measures differ. Behavioral measures are typically performed in the laboratory. Thus, they are often contrived, designed for short periods of time, performed in mildly stressful conditions in the presence of a stranger (i.e., experimenter), and lacking in ecological validity (Chen & Schmidt, 2015). Therefore, children may behave differently in the laboratory than they would in a natural, more familiar environment. With behavioral measures, there is also the possibility that other variables, such as other cognitive skills or contextual factors (e.g., motivation or fatigue), will influence children's performance (Samyn, Roeyers, Bijttebir, Rosseel, & Wiersema, 2015).

Parent report measures, on the other hand, are based on observations that are conducted in the home and other settings (e.g., the store, and play dates). As a result, cognitive abilities can be assessed in a wider range of contexts for a longer period, with no overt instructions or practice to maximize performance (Samyn et al., 2015). One major drawback of parent report measures, however, is that parents may be prone to misinterpreting behaviors and/or biased reporting, given that they are emotionally involved with their children (Seifer, Sameroff, Dickstein, Schiller, & Hayden, 2004). It can also be difficult for parents to subjectively respond to questions concerning cognitive processes that are rapidly evolving in young children (Kagan, 1992; Stifter & Dollar, 2016).

These differences between behavioral and parent report measures may have contributed to the inconsistent findings of this meta-analysis in which CWS were found to differ from CWNS in parent report measures of attention and inhibition but not in behavioral measures of these same constructs. For example, as suggested by Ntourou, Anderson, and Wagovich (2018), a child may have no difficulty performing a simple behavioral attention or inhibition task that lasts less than 5 min in a controlled environment (i.e., laboratory) but then struggle when they must engage these same skills for a longer period of time in daily life where the environment is much less controlled. Of course, it is also possible that the CWS failed to differ from their normally fluent peers in behavioral measures of inhibition and attention because the two groups of children really do exhibit comparable skills in these areas.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Limitations and Caveats

There are three limitations/caveats to the present meta-analysis. First, some subdivisions, namely, behavioral inhibition and parent report distractibility, contained a relatively small number of studies, which could have potentially increased the risk of bias due to low statistical power. Caution is, therefore, recommended when interpreting these findings. Second, not all studies controlled for family SES, which has been showed to be correlated with children's performance on cognitive measures (Duncan, Yeung, Brooks-Gunn, & Smith, 1998; Noble, Norman, & Farah, 2005). Not controlling for SES in some studies that were included in the meta-analysis may have masked potential differences in performance between the two groups and, ultimately, influenced the overall results. Third, as may be recalled, publication bias refers to the tendency for studies with negative results to be less likely to be published than those with positive results. Thus, if fewer studies with negative results are being published, then it is less likely that these studies will be identified and included in a meta-analysis, thereby affecting the results. In this study, we attempted to reduce the potential impact of publication bias by including unpublished studies and using the trim-and-fill method (Duval & Tweedie, 2000) to recalibrate the funnel plots and reestimate the ESs, if publication bias was suspected based on visual inspection. That said, in the field of speech-language pathology, it is essential that we not only increase our awareness of the potential effect of publication bias on research and clinical practice but also encourage the reporting of neutral or negative results in studies (Joober, Schmitz, Annable, & Boksa, 2012). Furthermore, access to and publication of well-designed, but low-powered studies, even if exploratory, should be encouraged to remediate the potential for bias (Joober et al., 2012).

Conclusions

Over the past decade, findings from mostly small individual studies that have examined VSTM, inhibition, and attention in CWS and CWNS have been inconsistent. A systematic meta-analysis has the advantage of increased statistical power over that of individual studies and can also examine variability between studies (Borenstein et al., 2009). This meta-analysis was, therefore, conducted to achieve more clarity concerning the role of these cognitive processes in developmental stuttering. It is important to examine these cognitive processes in CWS because they are critical for the development of domain-specific processes, such as those associated with speech and language.

Findings revealed that CWS, as a group, performed more poorly than CWNS on measures of VSTM, parent report inhibition, and parent report attentional focus/persistence. There were no significant between-groups differences in behavioral measures of inhibition and attention. These inconsistent findings may be due to greater methodological variability and/or smaller sample sizes in the behavioral measures compared with the parent report measures. Potential differences in the underlying constructs being measured and contextual factors between parent report and behavioral measures may have also played a role in the inconsistent findings.

Although the weaknesses CWS exhibited on measures of VSTM, inhibition, and attentional focus/persistence were subclinical in nature, meaning that they are not likely to have a significant effect on their ability to function in everyday life, such differences could still have a meaningful effect on the onset, development, and/or persistence of developmental stuttering. In this way, subtle weaknesses in EF and attention could, at least theoretically, affect the development of speech, language, and motor skills, which have all been implicated to one degree or another in developmental stuttering, because they are all intrinsically linked (Anderson & Wagovich, 2014). That is, it may be that some of the vulnerabilities that have been found in the speech, language, and motor skills of CWS are a consequence of weaknesses in EF and/or attention, rather than the skills themselves. Although this meta-analysis provides the strongest evidence, to date, to suggest that CWS may have difficulty with EF and attention, more research is clearly needed. Perhaps, within the next decade (or two), we will be even closer to better understanding the role of these processes in developmental stuttering.

Acknowledgments

This research was supported by a grant awarded to the second author from the National Institute on Deafness and Other Communication Disorders, National Institute of Health (RO1DC012517).

References

References marked with an asterisk (*) indicate studies included in the meta-analysis.

Acheson, D. J., & McDonald, M. C. (2009). Verbal working memory and language production: Common approaches to the serial ordering of verbal information. *Psychological Bulletin, 135,* 50–68.

Anderson, J. D. (2008). Age of acquisition and repetition priming effects on picture naming of children who do and do not stutter. *Journal of Fluency Disorders, 33,* 135–155.

*__Anderson, J. D., & Bates, J. E.__ (2007). Temperament, parenting styles, and childhood stuttering. In J. Au-Yeung & M. Leahy (Eds.), *Proceedings of the fifth world congress on fluency disorders: Research, treatment, and self-help in fluency disorders: New horizons* (pp. 179–185). Dublin, IE: International Fluency Association.

Anderson, J., & Conture, E. (2000). Language abilities of children who stutter: A preliminary study. *Journal of Fluency Disorders, 25,* 283–384.

*__Anderson, J. D., Pellowski, M. W., Conture, E. G., & Kelly, E. M.__ (2003). Temperament characteristics of young children who stutter. *Journal of Speech, Language, and Hearing Research, 46,* 1221–1233.

*__Anderson, J. D., & Wagovich, S. A.__ (2017). Explicit and implicit verbal response inhibition in preschool-age children who stutter. *Journal of Speech, Language, and Hearing Research, 60,* 836–852.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

*Anderson, J. D., & Wagovich, S. A. (2010). Relationship among linguistic processing speed, phonological working memory, and attention in children who stutter. *Journal of Fluency Disorders, 35,* 216–234.

Anderson, J. D., & Wagovich, S. A. (2014, November). *A domain-general approach to understanding the multifactorial nature of childhood stuttering*. Paper presented at the annual convention of the American Speech-Language-Hearing Association, Orlando, FL.

*Anderson, J. D., Wagovich, S. A., & Hall, N. (2006). Nonword repetition skills in young children who do and do not stutter. *Journal of Fluency Disorders, 31,* 177–199.

*Anderson, J. D., Wagovich, S. A., & Hill, B. A. (2014, November). *Do children who stutter have weaknesses in verbal short-term memory?* Poster session presented at the annual convention of the American Speech-Language-Hearing Association, Orlando, FL.

Anderson, J. D., Wagovich, S. A., & Ofoe, L. (2015, November). *Cognitive flexibility in developmental stuttering*. Poster presented at the annual meeting of the American Speech-Language-Hearing Association, Denver, CO.

Archibald, L. M. D., & Gathercole, S. E. (2007). Nonword repetition and serial recall: Equivalent measures of verbal short-term memory? *Applied Psycholinguistics, 28,* 587–606.

Australian Temperament Project. (1990). *Short Temperament Scale for Children*. Unpublished manuscript.

Baddeley, A. D. (1986). *Working memory*. Oxford, United Kingdom: Clarendon Press.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4,* 417–423.

Baddeley, A. D. (2002). Fractionating the central executive. In D. Stuss & R. Knight (Eds.), *Principles of frontal lobe function* (pp. 246–260). New York, NY: Oxford University Press.

Baddeley, A. D. (2003). Working memory: Looking back and looking forward. *Neuroscience, Nature Review, 4,* 829–839.

Baddeley, A. D. (2004). Working memory. In D. A. Balota & E. J. Marsh (Eds.), *Cognitive psychology: Key readings* (pp. 355–361). New York, NY: Psychology Press.

Baddeley, A. D. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology, 63,* 1–29.

Baddeley, A. D., Gathercole, S. E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105,* 158–173.

Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8,* 485–493.

*Bakhtiar, M., Ali, D. A. A., & Sadegh, S. P. M. (2007). Nonword repetition ability of children who do and do not stutter and covert repair hypothesis. *Indian Journal of Medical Sciences, 61,* 462–470.

Bernstein Ratner, N., & Silverman, S. (2000). Parental perceptions of children's communicative development at stuttering onset. *Journal of Speech, Language, and Hearing Research, 43,* 1252–1263.

Bishop, D. V. M., Bishop, S. J., Bright, P., Delaney, T., & Tallal, P. (1999). Different origin of auditory and phonological processing problems in children with language impairment: Evidence from a twin study. *Journal of Speech, Language, and Hearing Research, 42,* 155–168.

Bishop, D. V. M., North, T., & Donlan, C. (1996). Nonword repetition as a behavioral marker for inherited language impairment: Evidence from a twin study. *The Journal of Child Psychology and Psychiatry, 37,* 391–403.

Blair, C., & Peters Razza, R. (2007). Relating effort control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78,* 647–663.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2005). Comprehensive Meta-Analysis (Version 2.0) [Computer software]. Englewood, NJ: Biostat.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. West Sussex, United Kingdom: Wiley.

Brown, G. D. A., & Hulme, C. (1996). Nonword repetition, STM, and age-of-acquisition versus pronunciation-time limits in immediate recall for forgetting-matched acquisition: A computational model. In S. E. Gathercole (Ed.), *Models of short-term memory* (pp. 129–148). Hove, United Kingdom: Psychology Press.

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33,* 205–228.

Byrd, C. T., Conture, E. G., & Ohde, R. N. (2007). Phonological priming in young children who stutter: Holistic versus incremental processing. *American Journal of Speech-Language Pathology, 16,* 43–53.

Campoy, G., & Baddeley, A. (2008). Phonological and semantic strategies in immediate serial recall. *Memory, 16,* 329–340.

Carlson, S. M., Mandell, D., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40,* 1105–1122.

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72,* 1032–1053.

Chen, X., & Schmidt, L. A. (2015). Temperament and personality. In M. E. Lamb & R. M. Lerner (Eds.), *Handbook of child psychology and developmental science* (pp.152–200). Hoboken, NJ: Wiley.

*Chou, F. (2014). *Behavioral and electrophysiological observations of attentional control in children who stutter* (Doctoral dissertation, University of Iowa). Retrieved from http://ir.uiowa.edu/etd/4593

*Clark, C. E., Conture, E. G., Walden, T. A., & Lambert, W. (2015). Speech-language dissociations, distractibility, and childhood stuttering. *American Journal of Speech-Language Pathology, 24,* 480–503.

Coady, J. A., & Evans, J. L. (2008). Uses and interpretations of non-word repetition tasks in children with and without specific language impairments. *International Journal of Language & Communication Disorders, 43,* 1–40.

Coe, R. (2002, September). *It's the effect size stupid: What effect size is and why it is important*. Paper presented at the Annual Conference of the British Educational Research Association, Exeter, England.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cragg, L., & Nation, K. (2008). Go or no-go? Developmental improvements in the efficiency of response inhibition in mid-childhood. *Developmental Science, 11,* 819–827.

Davidson, M., Amso, D., Anderson, L., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44,* 2037–2078.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135–168.

Diamond, A., Briand, L., Fossella, J., & Gehlbach, L. (2004). Genetic and neurochemical modulation of prefrontal cognitive functions in children. *American Journal of Psychiatry, 161,* 125–132.

Dollaghan, C., & Campbell, T. F. (1998). Nonword repetition and child language impairment. *Journal of Speech, Language, and Hearing Research, 41,* 1136–1146.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Duncan, G. J., Yeung, W. J., Brooks-Gunn, J., & Smith, J. R. (1998). How much does childhood poverty affect the life chances of children? *American Sociological Review, 63,* 406–423.
Durlak, J. A. (2003). Basic principles of meta-analysis. In M. C. Roberts & S. S. Ilardi (Eds.), *Handbook of research methods in clinical psychology* (pp. 196–209). Malden, MA: Blackwell.
Duval, S. J., & Tweedie, R. L. (2000). Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics, 56,* 455–463.
*Eggers, K.** (2012). *Temperament characteristics of children with developmental stuttering: From parent questionnaire to neuropsychological paradigms* (Doctoral thesis, Katholieke Universiteit Leuven and Tilburg University). Retrieved from http://pure.uvt.nl/ws/files/1456864
*Eggers, K., De Nil, F. L., & Van den Bergh, B.** (2010). Temperament dimensions in stuttering and typically developing children. *Journal of Fluency Disorders, 35,* 355–372.
*Eggers, K., De Nil, F. L., & Van den Bergh, B.** (2012). The efficiency of attentional networks in children who stutter. *Journal of Speech, Language, and Hearing Research, 55,* 946–959.
Eggers, K., De Nil, F. L., & Van den Bergh, B. (2013). Inhibitory control in childhood stuttering. *Journal of Fluency Disorders, 38,* 1–13.
*Embrechts, M., Ebben, H., Franke, P., & van de Poel, C.** (2000). Temperament: A comparison between children who stutter and children who do not stutter. In H. G. Bosshardt, J. S. Yaruss, & H. F. M. Peters (Eds.), *Proceedings of the third world congress on fluency disorders: Theory, research, treatment, and self-help* (pp. 557–562). Nijmegen, the Netherlands: University of Nijmegen Press.
Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128,* 309–331.
Espy, K. A. (1997). The Shape School: Assessing executive function in preschool children. *Developmental Neuropsychology, 13,* 495–499.
Espy, K. A., & Bull, R. (2005). Inhibitory processes in young children and individual variation in short-term memory. *Developmental Neuropsychology, 28,* 669–688.
Espy, K. A., Bull, R., Martin, J., & Stroup, W. (2006). Measuring the development of executive control with the Shape School. *Psychological Assessment, 18,* 373–381.
Estes, K. G., Evans, J. L., & Else-Quest, N. (2007). Differences in the nonword repetition performance of children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research, 50,* 177–195.
Fan, J., McCandliss, B. D., Sommers, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14,* 340–347.
Friedman, N. P., & Miyake, A. (2004). The relation among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology, 133,* 101–135.
Gardner, M. F. (1985). *TAPS Test of Auditory–Perceptual Skill.* San Francisco, CA: Children's Hospital of San Francisco.
Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134,* 31–60.
Gathercole, S. E. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics, 27,* 513–543.
Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29,* 336–360.
Gathercole, S. E., & Baddeley, A. D. (1996). *The Children's Test of Nonword Repetition*. London, United Kingdom: Psychological Corporation.
Gathercole, S. E., Hitch, G. J., Service, E., & Martin, A. J. (1997). Phonological short-term memory and new word learning in children. *Developmental Psychology, 13,* 65–77.
Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology, 40,* 177–190.
Gathercole, S. E., Service, E., Hitch, G. J., Adams, A. M., & Martin, A. J. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology, 13,* 65–77.
Gathercole, S. E., Willis, C. S., Emslie, H., & Baddeley, A. D. (1994). Phonological memory and vocabulary development during the early school years: A longitudinal study. *Developmental Psychology, 28,* 887–898.
Gerstadt, C., Hong, Y., & Diamond, A. (1994). The relationship between cognition and action: Performance of 3 ½ –7 year old children on a Stroop-like day–night test. *Cognition, 53,* 129–153.
*Hakim, H., & Ratner, N. B.** (2004). Nonword repetition abilities of children who stutter: An exploratory study. *Journal of Fluency Disorders, 29,* 179–199.
Hartfield, K., & Conture, E. (2006). Effects of conceptual and perceptual aspects of lexical priming on picture-naming of children who stutter: A preliminary study. *Journal of Fluency Disorders, 31,* 303–324.
Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Orlando, FL: Academic Press.
*Heitmann, R. R., Asbjørnsen, A., & Helland, T.** (2004). Attentional functions in speech fluency disorders. *Logopedics, Phoniatrics, Vocology, 29,* 119–127.
Henry, L. (2012). *The development of working memory in children*. London, United Kingdom: SAGE Publications, Ltd.
Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analysis. *Biomedical Journal, 327,* 557–560.
Hollister, J. E. (2015). *Effortful control and adaptive functioning in school-age children who stutter* (Unpublished doctoral dissertation). University of Iowa, Iowa City, IA. Retrieved from http://ir.uiowa.edu/etd/1850
Huedo-Medina, T. B., Sánchez-Meca, J., Marín-Martínez, F., & Botella, J. (2006). Assessing heterogeneity in meta-analysis: Q statistic or I^2 index? *Psychological Methods, 11,* 193–306.
Hugdahl, K., & Asbjørnsen, A. (1991). *Dikotisk lyssning til CV-stavelser* [Dichotic listening to CV syllables: Manual]. Stockholm, Sweden: Psykologiforlaget.
Hughes, C., & Graham, A. (2002). Measuring executive functions in childhood: Problems and solutions? *Child and Adolescent Mental Health, 7,* 131–142.
Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44,* 2017–2036.
Hunter, J. E., & Schmidt, F. L. (2004). *Methods of meta-analysis: Correcting error and bias in research findings* (2nd ed.). Thousand Oaks, CA: Sage.
Jarrold, C., & Tam, H. (2011). "Rehearsal and the development of working memory." In P. Barrouillet & V. Gaillard (Eds.), *Cognitive development and working memory: A dialogue between Neo-Piagetian theories and cognitive approaches*. Hove, United Kingdom: Psychology Press.
*Johnson, K. N., Conture, E. G., & Walden, T. A.** (2012). Efficacy of attention regulation in preschool-age children who stutter:

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

A preliminary investigation. *Journal of Communication Disorders, 45,* 263–278.
Jones, G., & Macken, B. (2015). Questioning short-term memory and its measurement: Why digit span measures long-term associative learning. *Cognition, 144,* 1–13.
Joober, R., Schmitz, N., Annable, L., & Boksa, P. (2012). Publication bias: What are the challenges and can they be overcome? *Journal of Psychiatry and Neuroscience, 37,* 149–152.
Kagan, J. (1992). Temperament contributions to emotion and social behavior. In M. S. Clark (Ed.), *Emotion and social behavior. Review of personality and social psychology* (Vol. 14, pp. 99–118). Thousand Oaks, CA: Sage.
Kagan, J., & Fox, N. (2006). Biology, culture, and temperamental biases. In W. Damon, R. Lerner, & N. Eisenberg (Eds.), *Handbook of child psychology, Volume III. Social, emotional, and personality development* (6th ed., pp. 99–166). New York, NY: Wiley.
*__Kaganovich, N., Wray, A. H., & Weber-Fox, C.__ (2010). Nonlinguistic auditory processing and working memory update in pre-school children who stutter: An electrophysiological study. *Developmental Neuropsychology, 35,* 712–736.
Kane, M., & Engle, R. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47–70.
*__Kefalianos, E., Onslow, M., Ukoumunne, O. C., Block, S. D., & Reilly, S.__ (2014). Stuttering, temperament, and anxiety: Data from a community cohort ages 2–4 years. *Journal of Speech, Language, and Hearing Research, 57,* 1314–1322.
Kerns, K. A., & Rondeau, L. A. (1998). Development of a continuous performance test for preschool children. *Journal of Attention Disorders, 2,* 229–238.
Kochanska, G. (2002). Committed compliance, moral self, and internalization: A mediational model. *Developmental Psychology, 38,* 339–351.
Lappin, J. S., & Eriksen, C. W. (1966). Use of a delayed signal to stop a visual reaction time response. *Journal of Experimental Psychology, 72,* 805–811.
Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21,* 59–80.
Levelt, W. J. M. (1992). Assessing words in speech production: Stages, processes and representations. *Cognition, 42,* 1–22.
Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22,* 1–38.
Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. Thousand Oaks, CA: Sage.
Majerus, S., Poncelet, M., Greeffe, C., & Van der Linden, M. (2006). Relations between vocabulary development and verbal short-term memory: The relative importance of short-term memory for serial order and item information. *Journal of Experimental Child Psychology, 93,* 95–119.
Martin-Rhee, M. M., & Bialystok, E. (2008).The development of two types of inhibitory control in monolingual and bilingual children. *Bilingual Language and Cognition, 11,* 81–93.
McDevitt, S. C., & Carey, W.B. (1978). The measurement of temperament in 3–7 year old children. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 19,* 245–253.
Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development, 75,* 1373–1386.
Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24,* 167–202.
Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49–100.
Mullane, J. C., Corkum, P. V., Klein, R. M., McLaughlin, E. N., & Lawrence, M. A. (2011). Alerting, orienting, and executive attention in children with ADHD. *Journal of Attention Disorders, 15,* 310–320.
Müller, K. F., Briel, M., D'Amario, A., Kleijnen, J., Marusic, A., Wager, E., . . . Bassler, D. (2013). Defining publication bias: Protocol for a systematic review of highly cited articles and proposal for a new framework. *Systematic Reviews, 2,* 34.
Müller, U., Zelazo, P. D., Hood, S., Leone, T., & Rohrer, L. (2004). Interference control in a new rule use task: Age-related changes, labelling, and attention. *Child Development, 75,* 1594–1609.
Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8,* 74–87.
*__Ntourou, K., Anderson, J. D., & Wagovich, S. A.__ (2014, November). *Executive function skills in preschool-age children who stutter: Evidence from parent-report questionnaires and a behavioral task*. Poster session presented at the annual convention of the American Speech-Language-Hearing Association, Denver, CO.
Ntourou, K., Anderson, J. D., & Wagovich, S. A. (2018). Executive function and childhood stuttering: Parent ratings and evidence from a behavioral task. *Journal of Fluency Disorders, 56,* 18–32.
Ntourou, K., Conture, E. D., & Lipsey, M. W. (2011). Language abilities of children who stutter: A meta-analytical review. *American Journal of Speech-Language Pathology, 20,* 163–179.
*__Oyoun, H. A., El Dessouky, H., Shohdi, S., & Fawzy, A.__ (2010). Assessment of working memory in normal children and children who stutter. *Journal of American Science, 6,* 562–569.
*__Pelczarski, K. M., & Yaruss, J. S.__ (2016). Phonological memory in young children who stutter. *Journal of Communication Disorders, 62,* 54–66.
Pellowski, M. W., & Conture, E. G. (2005). Lexical priming in picture naming of young children who do and do not stutter. *Journal of Speech, Language, and Hearing Research, 48,* 278–294.
Pelphrey, K., & Reznick, J. (2002). Working memory in infancy. *Advances in Child Development and Behavior, 31,* 173–227.
Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 21,* 73–89.
*__Piispala, J., Kallio, M., Bloigu, R., & Jansson-Verkasalo, E.__ (2016). Delayed N2 response in Go condition in a visual Go/Nogo ERP study in children who stutter. *Journal of Fluency Disorders, 48,* 16–26.
Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25–42.
Posner, M. I., Rothbart, M. K., Sheese, B. E., & Voelker, P. (2014). Developing attention: Behavioral and brain mechanisms. *Advances in Neuroscience*. Online only. https://doi.org/10.1155/2014/405094
Postma, A., & Kolk, H. H. J. (1993). The covert repair hypothesis; Prearticulatory repair processes in normal and stuttered disfluencies. *Journal of Speech and Hearing Research, 36,* 472–487.
Pozuelos, J. P., Paz-Alonso, P. M., Castillo, A., Fuentes, L. J., & Rueda, M. R. (2014). Development of attention networks and their interactions in childhood. *Developmental Psychology, 50,* 2405–2415.
Putnam, S. P., & Rothbart, M. K. (2006). Development of short and very short forms of the Children's Behavior Questionnaire. *Journal of Personality Assessment, 87,* 102–112.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx

Ravizza, S. M., & Carter, C. S. (2008). Shifting set about task switching: Behavioral and neural evidence for distinct forms of cognitive flexibility. *Neuropsychologia, 46,* 2923–2935.
Raz, A., & Buhle, J. (2006). Typologies of attentional networks. *Nature, 7,* 367–379.
*__Reilly, J., & Donaher, J.__ (2005). Verbal working memory skills of children who stutter: A preliminary investigation. *Contemporary Issues in Communication Sciences and Disorders, 32,* 38–42.
Reynolds, G. D., & Romano, A. C. (2016). The development of attention systems and working memory in infancy. *Frontiers in Systems Neuroscience, 10,* 1–12.
Richardson, J. T. E. (2007). Measures of short-term memory: A historical review. *Cortex, 43,* 635–650.
Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition, 64,* 249–284.
Roelofs, A. (2008). Dynamics of the attentional control of word retrieval: Analyses of response time distributions. *Journal of Experimental Psychology, General, 137,* 303–323.
Roelofs, A., & Piai, V. (2011). Attention demands of spoken word planning: A review. *Frontiers in Psychology, 2,* 1–14.
Rothbart, M. K., Ahadi, S. A., & Hershey, K. L. (1994). Temperament and social behavior in childhood. *Merrill-Palmer Quarterly, 40,* 21–39.
Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at 3–7 years: The Children's Behavior Questionnaire. *Child Development, 72,* 1394–1408.
Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2005). Publication bias in meta-analysis. In H. R. Rothstein, A. J. Sutton, & M. Borenstein (Eds.), *Publication bias in meta-analysis: Prevention, assessment and adjustments* (pp. 1–7). Chichester, United Kingdom: Wiley.
Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia, 42,* 1029–1040.
Rueda, M. R., & Posner, M. I. (2013). Development of attention networks. *The Oxford Handbook of Developmental Psychology, 1,* 683–705.
Rushworth, M. F. S., Passingham, R. E., & Nobre, A. C. (2005). Components of attentional set-switching. *Experimental Psychology, 52,* 83–98.
Samyn, V., Roeyers, H., Bijttebir, P., Rosseel, Y., & Wiersema, J. R. (2015). Assessing effortful control in typical and atypical development: Are questionnaires and neuropsychological measures interchangeable? A latent-variable analysis. *Research in Developmental Disabilities, 36,* 587–599.
*__Sasisekaran, J., & Byrd, C. T.__ (2013). Nonword repetition and phoneme elision skills in school-age children who do and do not stutter. *International Journal of Language & Communication Disorders, 48,* 625–639.
*__Schwenk, K. A., Conture, E. G., & Walden, T. A.__ (2007). Reaction to background stimulation of preschool children who do and do not stutter. *Journal of Communication Disorders, 40,* 129–141.
Seifer, R., Sameroff, A., Dickstein, S., Schiller, M., & Hayden, L. C. (2004). Your own children are special: Clues to the sources of reporting bias in temperament assessments. *Infant Behavior & Development, 27,* 323–341.
Simonds, J., & Rothbart, M. K. (2004, October). *The Temperament in Middle Childhood Questionnaire (TMCQ): A computerized self-report measure of temperament for ages 7–10*. Poster session presented at the Occasional Temperament Conference, Athens, GA.
*__Smith, A., Goffman, L., Sasisekaran, J., & Weber-Fox, C.__ (2012). Language and motor abilities of preschool children who stutter: Evidence from behavioral and kinematic indices of nonword repetition performance. *Journal of Fluency Disorders, 37,* 344–358.
Spencer, C., & Weber-Fox, C. (2014). Preschool speech articulation and nonword repetition abilities may help predict eventual recovery or persistence of stuttering. *Journal of Fluency Disorders, 41,* 32–46.
St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59,* 745–759.
Stifter, C., & Dollar, J. (2016). Temperament and developmental psychopathology. In D. Cicchetti (Ed.), *Developmental psychopathology: Vol. 3, Risk, resilience, and intervention* (3rd ed., pp. 545–607). New York, NY: Wiley.
Tam, H., Jarrold, C., Baddeley, A. D., & Sabatos-DeVito, M. (2010). The development of memory maintenance: Children's use of phonological rehearsal and attentional refreshment in working memory tasks. *Journal of Experimental Child Psychology, 107,* 306–324.
Thomas, A., & Chess, S. (1977). *Temperament and development*. New York, NY: Brunner/Mazel.
Thorn, A. S. C., Gathercole, S. E., & Frankish, C. R. (2005). Redintegration and the benefits of long-term knowledge in verbal short-term memory: An evaluation of Schweickert's (1993) multinomial processing tree model. *Cognitive Psychology, 50,* 133–158.
Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *The Journal of Child Psychology and Psychiatry, 54,* 131–143.
*__Vahab, M., Shojaei, K., Ahmadi, A., & Nasiri, M.__ (2014). Phonological working memory in 4–8 year old Persian children who stutter. *Journal of Rehabilitation Sciences and Research, 1,* 92–96.
Vasić, N., & Wijnen, F. (2005). Stuttering as a monitoring deficit. In R. J. Hartsuiker, R. Bastiaanse, A. Postma, & F. Wijnen (Eds.), *Phonological encoding and monitoring in normal and pathological speech* (pp. 226–247). Hove, United Kingdom: Psychology Press.
Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Science, 12,* 418–424.
Wager, T. D., Jonides, J., & Reading, S. (2004). Neuroimaging studies of shifting attention: A meta-analysis. *NeuroImage, 22,* 1679–1693.
Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *Comprehensive Test of Phonological Processing*. Austin, TX: Pro-Ed.
*__Weber-Fox, C., Spruill, J. E., III, Spencer, R., & Smith, A.__ (2008). Atypical neural functions underlying phonological processing and silent rehearsal in children who stutter. *Developmental Science, 11,* 321–337.
Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology, 44,* 575–587.
Yairi, E., & Ambrose, N. (2013). Epidemiology of stuttering: 21st century advances. *Journal of Fluency Disorders, 38,* 66–87.
Zelazo, P. D., & Müller, U. (2010). Executive function in typical and atypical development. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (2nd ed., pp. 574–603). Malden, MA: Blackwell.
Zelazo, P. D., Müller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function in early childhood. [Monograph]. *Social Research in Child Development, 68,* 1–137.
Zelazo, P. D., & Reznick, J. S. (1991). Age-related asynchrony of knowledge and action. *Child Development, 62,* 719–735.

Downloaded From: https://jslhr.pubs.asha.org/ by a ReadCube User on 07/13/2018
Terms of Use: https://pubs.asha.org/ss/rights_and_permissions.aspx