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Executive function and childhood stuttering: Parent ratings and evidence from a behavioral task

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ABSTRACT

Purpose: The purpose of this study was to examine the executive function (EF) abilities of preschool children who do (CWS) and do not stutter (CWNS) using a parent-report questionnaire and a behavioral task.

Method: Participants were 75 CWS and 75 CWNS between the ages of 3;0 and 5;11 (years; months). Parents rated their children's EF abilities using the Behavioral Rating Inventory of Executive Function–Preschool Version (BRIEF-P; Gioia, Espy, & Isquith, 2003). Children's ability to integrate cognitive flexibility, inhibitory control, and working memory was measured using a behavioral task, the Head-Toes-Knees-Shoulders (HTKS; Cameron Ponitz, McClelland, Matthews, & Morrison, 2009).

Results: The CWS were judged by their parents as being less proficient in working memory, shift/flexibility, and overall EF than the parents of the CWNS. Children in the CWS group were also 2½ to 7 times more likely than children in the CWNS group to exhibit clinically significant difficulties with EF. Behavioral task findings revealed that 3-year old CWS performed more poorly than their peers on the HTKS. Parental ratings of executive function and working memory were significantly and moderately correlated with receptive and expressive vocabulary skills only for the CWNS group.

Conclusion: CWS have more difficulty with EF in everyday life and may experience early delays in their ability to integrate aspects of attention and EF compared to CWNS.

1. Introduction

The term *executive function* (EF) encompasses a set of related, but distinct cognitive processes, including working memory, inhibitory control, and cognitive flexibility, that allow us to engage in flexible and goal-directed behaviors (Best & Miller, 2010; Fuster, 2008). In recent years, the role of EF in childhood stuttering has attracted growing attention. Although empirical studies are limited in number and scope to draw any firm conclusions, the available evidence seems to suggest that children who stutter (CWS) may exhibit lower EF skills than children who do not stutter (CWNS; e.g., Anderson & Wagovich, 2017; Anderson, Wagovich, & Hall, 2006; Eggers, De Nil, & Van den Bergh, 2013; Eichorn, Marton, & Pirutinsky, in press). Thus, the main purpose of the present study was to further explore the role of EF in childhood stuttering by comparing the performance of preschool-age CWS and CWNS on an EF task that measures children's ability to integrate attentional or cognitive flexibility, working memory, and inhibitory control, as well as parents' perceptions of their children's overall and separate (e.g., inhibition) EF skills. Furthermore, the relationship between overall

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EF skills, separate EF components, and language abilities was examined for both CWS and CWNS, along with stuttering frequency and EF for CWS. To provide context for our study, we begin by discussing the theoretical construct of EF and different ways to assess young children's EF skills. We then present existing empirical evidence regarding the separate components of EF (working memory and inhibitory control) in CWS.

1.1. Executive functioning: Conceptualization and measurement

Executive functioning emerges in infancy (Diamond, 1988) and undergoes rapid, marked improvement across toddlerhood and the preschool-age years (Carlson, 2005; Zelazo, Müller, Frye, & Marcovitch, 2003). It continues to develop throughout adolescence (Best, Miller, & Jones, 2009) and eventually peaks in early adulthood (De Luca et al., 2003). Although EF develops over time, individual differences in EF abilities remain relatively stable throughout life (Miyake & Friedman, 2012).

While not universally agreed upon, many researchers have suggested that, during the preschool years, EF consists of separable but correlated cognitive abilities (Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012; Miyake & Friedman, 2012; cf. Wiebe et al., 2011). As a set of cognitive processes, EF includes the ability to hold and manipulate information in mind (working memory), suppress dominant responses or ignore non-relevant information (inhibitory control), and switch flexibly between strategies, rules, and perspectives in an adaptive manner (cognitive flexibility; Miyake et al., 2000). Of note, cognitive flexibility requires both working memory and inhibitory control and, thus, it tends to be one of the later developing (after 3 years of age) and more advanced components of EF (Davidson, Amso, Anderson, & Diamond, 2006; Garon, Bryson, & Smith, 2008).

It is well documented that EF plays an important role in a variety of outcomes, such as school readiness (Blair, 2002), academic performance (McClelland et al., 2007), psychosocial effects (Ellis, Rothbart, & Posner, 2004), and social adjustment and peer relations (Hughes & Ensor, 2011). Thus, over the past few decades an intense research effort has been devoted to the development of valid and reliable performance- and questionnaire-based assessment measures of young children's EF skills (e.g., Cameron Ponitz, McClelland, Matthews, & Morrison, 2009; Camerota, Willoughby, Kuhn, & Blair, 2016; Carlson, 2005; Garon, Smith, & Bryson, 2014; Gioia, Espy, & Isquith, 2003; Willoughby & Blair, 2011).

Performance-based measures include the administration of tasks where children's accuracy and/or speed of responding are recorded. Some of the most commonly used performance-based measures for preschool-age children include the *Day-Night task* (Gerstadt, Hong, & Diamond, 1994), a measure of inhibitory control, the *Dimensional Change Card Sort Test* (Zelazo, 2006), a measure of cognitive flexibility, and *Digit/Letter Forward/Backward Span* tasks (Alloway, 2007), which measure working memory. While performance-based measures provide valuable information about children's EF skills, they are often criticized for being too limited and unable to capture executive functioning in the "real-world" (Barkley, 2012). Thus, questionnaire-based measures of EF have been developed for parents and teachers, such as the *Behavioral Rating Inventory of Executive Function–Preschool Version* (BRIEF-P; Gioia et al., 2003), in an attempt to provide a more ecologically valid indicator of EF skills in complex, everyday situations.

Although the majority of EF measures for preschool-age children fall into the aforementioned categories (performance- and questionnaire-based measures), some behavioral tasks do not fit neatly into either category. One such task is the *Head-Toes-Knees-Shoulders* (HTKS; Cameron Ponitz et al., 2009) task. Unlike most performance-based tasks, the HTKS integrates multiple EF components—namely, inhibitory control, working memory, and attentional or cognitive flexibility. The HTKS has been used with a large number of children and has good construct validity and reliability (Cameron Ponitz et al., 2008, 2009; Wanless, McClelland, Acock, Chen, & Chen, 2011). To complete the HTKS, children must do the opposite of what the examiner says—for example, when children are asked to "touch their toes," they touch their head and vice versa. Thus, children must not only retain the rules of the task in memory, but they must also inhibit the tendency to give the natural, otherwise correct response (e.g., avoid touching their toes when they are told to "touch your toes") while responding with the opposite response (e.g., touching their head). There is a second part to the task for which a new set of commands ("touch your shoulders," "touch your knees") is added requiring children to flexibly switch between the initial (head/toes) and the newly added (shoulders/knees) sets of rules (i.e., cognitive flexibility). Given these characteristics, it may come as no surprise that performance on the HTKS is moderately to highly correlated with behavioral measures of EF components (cognitive flexibility, inhibitory control, working memory) and parental ratings of attentional focusing and inhibitory control (Cameron Ponitz et al., 2009; Fuhs & Day, 2011; Lan, Legare, Ponitz, Li, & Morrison, 2011; McClelland et al., 2014). The HTKS has also been found to significantly correlate with teacher ratings of self-regulation (McClelland et al., 2007).

1.2. Executive function skills and childhood stuttering

The role of EF in childhood stuttering has been the subject of increased attention over the past ten years (Anderson & Wagovich, 2017; Anderson et al., 2006; Eggers et al., 2013; Jones et al., 2017; Spencer & Weber-Fox, 2014). This emphasis is partially motivated by the large body of empirical evidence suggesting a strong relationship between EF and language skills and emotion regulation (Blankson et al., 2013; Gooch, Hulme, Nash, & Snowling, 2013; Hofmann, Schmeichel, & Baddeley, 2012), as language and emotion regulation have been implicated in developmental stuttering (e.g., Jones, Choi, Conture, & Walden, 2014; Ntourou, Conture, & Lipsey, 2011).

A plethora of studies have established an association between young children's executive function skills and their language abilities (Carlson, Davis, & Leach, 2005; Gooch, Thompson, Nash, Snowling, & Hulme, 2016; Kuhn, Willoughby, Vernon-Feagans, & Blair, 2016; Müller, Jacques, Brocki, & Zelazo, 2009). Given that the findings of some studies have suggested that CWS exhibit weaker, but still within the typical range, language abilities compared to normally-fluent controls (Ntourou et al., 2011; cf. Reilly et al., 2013; Watts, Eadie, Block, Mensah, & Reilly, 2017), the close association between EF and language development motivates further study of EF skills in CWS. It may be, for example, that the observed differences between some CWS and CWNS in language abilities are actually a consequence of weaknesses in EF (low EF → low language skills) or that some CWS exhibit lower EF than their normally-fluent peers because their lower language skills negatively impact the development of EF (low language skills → low EF).

Executive functioning during the preschool-age years has also been associated with emotion regulation (Carlson & Wang, 2007; Fuster, 2008) and reactivity (Ferrier, Bassett, & Denham, 2014; Ursache, Blair, Stifter, & Voegtline, 2013). EF is presumed to support emotion regulation (Kopp, 1982, 1989) because to effectively regulate automatically elicited emotional responses, children must inhibit these responses (inhibitory control) and reorient their attention to non-arousing stimuli (attentional shifting). Also, to comply with social norms, children must remember which behaviors are socially acceptable (i.e., engage working memory) while at the same time choose different mechanisms to regulate this behavior. Given that young CWS have been shown to differ from CWNS in emotional processes (Jones et al., 2014; Kraft, Ambrose, & Chon, 2014; Ntourou, Conture, & Walden, 2013) and there is clearly a relationship between emotional processes and EF, the study of the EF in preschool-age CWS is a logical next step in the effort to better understand childhood stuttering.

To date, unlike working memory and inhibitory control, very few studies have examined the role of cognitive flexibility in developmental stuttering (Anderson, Wagovich, & Ofoe, 2015; Hollister, 2015), with only one having been recently published (Eichorn et al., in press). Thus, in the brief literature review that follows, only research concerning the role of working memory and inhibitory control in childhood stuttering will be discussed.

1.2.1. *Working memory skills in children who stutter*

According to Baddeley's (1986, 2003); multi-component model of working memory, there are four components of working memory: two sensory subsystems which are responsible for storing and manipulating visuospatial *(visual-spatial sketchpad*) and verbal (*phonological loop)* information; an *episodic buffer*, which is a temporary storage system that forms a link between long-term memory and working memory; and a *central executive*, which "supervises" information flow to and from the two sensory subsystems.

Most studies that have assessed working memory in CWS have examined phonological working memory (i.e., the phonological loop) using nonword repetition tasks where participants repeat nonwords of various syllable lengths. Some studies found that CWS are less accurate than CWNS in repeating nonwords (Anderson et al., 2006; Hakim & Ratner, 2004; Pelczarski & Yaruss, 2016), while others have failed to find any significant between-talker group differences in nonword repetition performance (Bakhtiar, Abad, & Panahi, 2007; Sasisekaran & Byrd, 2013; Smith, Goffman, Sasisekaran, Weber-Fox, 2012). Of particular interest, Spencer and Weber-Fox (2014) found that children's performance on the *Nonword Repetition Test* (NRT; Dollaghan & Campbell, 1998) was predictive of stuttering persistence, such that the children who continued to stutter performed more poorly on the task than the CWNS and children who recovered from stuttering.

Pelczarski and Yaruss (2014) recently found additional evidence to suggest that young CWS may have weaknesses in phonological working memory using tasks other than nonword repetition. In this study, the CWS performed significantly lower than the CWNS on the Word Blending and Elision subtests of the *Comprehensive Test of Phonological Processing: Ages 5–6* (CTOPP; Wagner, Torgesen, & Rashotte, 1999), which measure phonological awareness. Given the close relationship between phonological awareness and phonological working memory in early childhood (Gathercole, Willis & Baddeley, 1991), the authors interpreted these findings to suggest that young CWS have weaker phonological working memory skills than their normally-fluent peers.

Although no firm conclusions can yet be drawn about the phonological working memory skills of young CWS, existing evidence suggests that these skills may be lower in CWS compared to CWNS. Nevertheless, further investigation of the phonological working memory skills of young CWS is clearly warranted.

1.2.2. *Inhibitory control in children who stutter*

There are three main types of inhibitory control: resisting or suppressing a dominant or natural response in favor of a non-dominant response (*complex prepotent response inhibition*), resisting interference from irrelevant external stimuli (*resistance to distractor interference*), and suppressing irrelevant stimuli from previously learned material (*resistance to proactive interference*; Friedman & Miyake, 2004).

Most studies to date have examined either resistance to distractor interference and/or prepotent response inhibition in CWS using parent-report questionnaires (Eggers, De Nil, & Van den Bergh, 2010; Embrechts, Ebben, Franke, & van de Poel, 2000; Hollister, 2015), computerized reaction-time tasks (Anderson & Wagovich, 2017; Eggers, De Nil, & Van den Bergh, 2012; Eggers et al., 2013), and psychophysiology measures (Piispala, Kallio, Bloigu, & Jansson-Verkasalo, 2016). Findings from studies employing parent-report questionnaires have revealed that the parents of CWS tend to rate their children lower in inhibitory control than the parents of CWNS (Anderson & Wagovich, 2017; Eggers et al., 2010; Embrechts et al., 2000; Hollister, 2015). However, experimental studies of inhibitory control have yielded mixed results, with some indicating that CWS have weaknesses in inhibitory control compared to CWNS (Anderson & Wagovich, 2017; Eggers et al., 2013) and others reporting no such differences (Piispala et al., 2016).

For example, Eggers et al. (2013) examined the inhibitory control abilities of CWS and CWNS using the Go/NoGo task from the Amsterdam Neuropsychological Tasks (De Sonneville, 2009), where children pressed a button whenever they saw a picture on the computer screen of a green man walking (Go stimulus), but not when they saw a picture of a red man standing (No/Go stimulus). Findings revealed that the CWS not only exhibited significantly more premature responses and commission errors (responses to a No-Go stimulus/false alarms) than the CWNS, but also faster reaction times for commission errors. The authors interpreted these findings to suggest that young CWS are more impulsive and present with lower inhibitory control skills than CWNS.

In a more recent study, Anderson and Wagovich (2017) examined inhibitory control in preschool CWS using two computerized tasks that differed in verbal demands. Children completed an explicit verbal response inhibition task, the *grass-snow task* (Carlson &

Moses, 2001), and an implicit verbal response inhibition task, the *baa-meow task*. For both tasks, children heard a word/sound and then had to press the button associated with the opposite word/sound. For example, in the grass-snow task, children pressed the "grass" button when they heard the word "snow" and the "snow" button when they heard the word "grass." Findings revealed that the CWS were less accurate in the implicit task and slower in both the implicit and explicit tasks than the CWNS, suggesting that developmental stuttering may be associated with a reduction in the effectiveness and efficiency of inhibitory control in the verbal domain.

In summary, converging evidence from parent-report questionnaires and performance-based tasks suggest that inhibitory control may be an area of difficulty for CWS. Nevertheless, more research is clearly needed to paint a more holistic and clearer picture of the role of inhibitory control in developmental stuttering.

1.3. Purpose of the study

As previously discussed, research using performance-based (i.e., experimental or behavioral) tasks and parent-report questionnaires has revealed potential differences between CWS and CWNS in at least two out of three components of EF: working memory and inhibitory control. However, these findings are, by no means, conclusive, with some studies showing no differences in EF between talker groups. The variations in findings across studies are likely due to differences in the number of participants, the age ranges of the participants, and the types of measures used to assess EF. Nevertheless, the fact that there are differences in findings across studies motivates further study of EF in CWS. Furthermore, studies have examined only separate EF skills (e.g., inhibition) with no study, to date, having investigated the amalgam of the separate but interdependent EF skills/constructs (working memory, inhibitory control, cognitive flexibility) in young CWS compared to CWNS.

Thus, the main purpose of this study was to compare CWS and CWNS in their overall EF abilities and separate EF components using the BRIEF-P (Gioia et al., 2003), a parental-report assessment of EF for preschool children, and their overall EF skills using the HTKS (Cameron Ponitz et al., 2009), a behavioral task that is designed to measure children's ability to integrate the multiple components of EF (cognitive flexibility, working memory, inhibitory control). The relationship between these two EF measures was also examined, along with the relation of these measures to children's language abilities (for both talker groups) and stuttering frequency (only for CWS).

2. Method

2.1. Participants

Data for the present study were collected as part of a multi-site research project on the role of cognitive and linguistic processes in developmental stuttering at Indiana University and University of Missouri. A total of 75 CWS (52 boys) and 75 CWNS (52 boys), ranging in age from 3;0 to 5;11 (years; months), participated in the study across both sites. All children were native speakers of American English, and none had any difficulties with speech-language (other than stuttering), neurological, hearing, developmental, or intellectual functions per parental report, standardized testing, and/or examiner observation. Four CWS were receiving speech-language services at the time of the study for stuttering.

2.1.1. Talker-group matching

Participants in the two talker groups were matched for age (± 4 months) and gender at each data collection site. The mean age of children in the CWS group was 49.16 months (SD = 10.48) and the mean age of children in the CWNS group was 49.48 months (SD = 9.98), a non-significant difference, $t(148) = 0.19$, $p = 0.85$. Children in each group were also equated for family socio-economic status (SES) based on the Hollingshead's Four-Factor Index of Social Position (Hollingshead, 1975), which takes both paternal and maternal occupation and educational level into account. The mean social position scores for the CWS and CWNS were 49.41 [SD = 13.07; Hollingshead classification II (upper-middle)] and 48.23 [SD = 12.03; Hollingshead classification II (upper-middle)], respectively. A Mann-Whitney nonparametric test revealed no significant difference between talker groups in social position scores, $z = -0.81$, $p = 0.41$.

2.1.2. Talker-group classification criteria

For talker-group classification purposes, a 300-word conversational speech sample was elicited during a 15-minute play-based interaction between each participant and his/her parent(s). Talker group classification criteria are further described below.

2.1.2.1. Children who stutter. Participants were assigned to the CWS group if they (a) exhibited three or more stuttering-like disfluencies [part-word repetitions, single-syllable word repetitions, disrhythmic phonation (sound prolongations, blocks)], on average, per 100 words of conversational speech (Yairi & Ambrose, 1992), and (b) received a total overall score of 11 or above (a severity equivalent of at least "mild" for preschool children) on the *Stuttering Severity Instrument – 4* (SSI-4; Riley, 2009). The mean frequency of stuttering-like disfluencies for the CWS group was 6.55 (SD = 3.55), and their overall SSI-4 score was 16.49 (SD = 3.56), with 51 CWS receiving severity ratings of mild, 23 moderate, and 1 severe. The average parent-reported time since stuttering onset, based on the bracketing procedure (Yairi & Ambrose, 1992), was 15.41 months (SD = 9.39).

2.1.2.2. Children who do not stutter. A participant was considered a CWNS if he/she exhibited fewer than three stuttering-like

Table 1
Mean Standard Scores (Standard Deviation) on Norm-Referenced Speech-Language Tests for Children who Stutter (CWS) and Children who do not Stutter (CWNS).

Speech-Language Test	CWS	CWNS
PPVT-4	113.96 (12.99)	116.77 (9.52)
EVT-2	114.26 (11.77)	115.12 (11.13)
TELD-3	115.25 (13.42)	118.97 (12.23)
GFTA-2	105.92 (9.49)	104.51 (9.94)

Note. PPVT-4: Peabody Picture Vocabulary Test – 4; EVT-2: Expressive Vocabulary Test – 2; TELD-3: Test of Early Language Development-3; GFTA-2: Goldman-Fristoe Test of Articulation-2.

disfluencies per 100 words of conversational speech. The SSI-4 was not administered to the CWNS participants. The mean frequency of stuttering-like disfluencies for the CWNS group was 0.82 (SD = 0.66).

2.1.3. Speech, language, and hearing criteria

To ensure that children's speech and language skills were typically-developing, participants were administered the *Peabody Picture Vocabulary Test – Fourth Edition* (PPVT-4; Dunn & Dunn, 2007), *Expressive Vocabulary Test – Second Edition* (EVT-2; Williams, 2007), *Test of Early Language Development – Third Edition* (TELD-3; Hresko, Reid, & Hamill, 1999), and the "Sounds in Words" subtest of the *Goldman–Fristoe Test of Articulation – Second Edition* (GFTA-2; Goldman & Fristoe, 2000). These standardized, norm-referenced speech and language tests measure children's receptive and expressive vocabulary, receptive and expressive language, and articulation abilities, respectively. All children received a standard score of 85 or higher on each of the four tests (*Note:* an EVT-2 score was not available for one CWS participant because the child refused to participate). A multivariate analysis of variance revealed no significant between-talker group differences on any of the aforementioned measures [PPVT-4: $F(1,147) = 2.32$, $p = 0.13$; EVT-2: $F(1,147) = 0.21$, $p = 0.65$; TELD-3 Spoken Language: $F(1,147) = 0.95$, $p = 0.33$; and GFTA-2: $F(1,147) = 0.98$, $p = 0.32$]. See Table 1 for descriptive information.

Participants were required to pass a bilateral pure tone screening at 20dB HL at 1000, 2000, and 4000 Hz [American Speech-Language-Hearing Association, 1997] to ensure that their hearing was within normal limits. All but two participants completed and passed the hearing screening. The two children (1 CWS, 1 CWNS) who did not complete the hearing screening were uncooperative and, thus, the objective status of their hearing is unknown. However, the parents of these children did not express any concern about their children's hearing and the children did not exhibit any difficulty hearing the instructions during other testing procedures. For these reasons, the two children were included in the study.

2.2. Procedure

The data collection procedure consisted of a play-based conversational interaction between the child and his/her parent (described above), the aforementioned speech-language tests and hearing screening, and the *Head-Toes-Knees-Shoulder* (HTKS) task (Cameron Ponitz et al., 2009), a behavioral measure of executive function. In addition, parents completed the *Behavioral Rating Inventory of Executive Function – Preschool Version* (BRIEF-P; Gioia et al., 2003), a parent-report questionnaire developed to assess preschoolers' everyday EF behaviors. The HTKS and the BRIEF-P are described in more detail below.

2.2.1. Measures of EF

2.2.1.1. Head-Toes-Knees-Shoulder (HTKS) Task. The HTKS is a quick and easy to administer, direct behavioral measure of EF in children aged 3–6 years, which captures the integration of attentional or cognitive flexibility, working memory, and inhibitory control (Lan et al., 2011; McClelland & Cameron, 2012). The psychometric properties of HTKS are robust, with high inter-rater agreement (κ = 0.9; Cameron Ponitz et al., 2009) and evidence for criterion-based validity based on moderate correlations ($r = 0.40 - 0.56$) between HTKS scores and traditional performance-based measures of cognitive flexibility, working memory, and inhibitory control (McClelland et al., 2014). Additional validation of HTKS comes from children's HTKS scores correlating significantly with their inhibitory control skills as rated by their parents (Cameron Ponitz et al., 2009).

The HTKS is divided into two parts, taking approximately 3–5 min to complete. Part I consists of 6 practice and 10 test trials during which children respond to one of two paired commands ("touch your head" or "touch your toes") with the opposite response. For example, when asked to "touch your head," children respond by touching their toes, and when asked to "touch your toes," they respond by touching their head. Two points are awarded for correct responses, 1 point for self-corrected responses, and 0 for incorrect responses.

If children receive a score of 4 or higher on Part I, they move on to Part II where two additional commands are added ("touch your shoulders" and "touch your knees"), thereby incorporating the additional component of cognitive flexibility. After completing 5 practice trials with the new commands, children complete 10 test trials where they have to respond to all four commands. The maximum score possible across the 6 practice trials in Part I[1] and the 20 test trials in Parts I and II is 52, with higher scores indicating

[1] The practice trials of Part I were included in the calculation of the total HTKS score because, as described by Fuhs, Nesbitt, Farran, and Dong (2014), this recommended practice renders HTKS scores more normally distributed and more highly related to other measures of executive functioning.

Table 2
Overview of the Behavior Rating Inventory of Executive Function—Preschool Version Scales (BRIEF–P; Gioia et al., 2003).

BRIEF-P Scales	Description
Inhibit	Impulse control and ability to stop one's own behavior at the appropriate time
Shift	Ability to flexibly transition from one situation, activity, mindset or aspect of a problem to another
Emotional Control	Ability to modulate emotional responses
Working Memory	Ability to retain information in mind in order to complete a task or make a response
Plan/Organize	Ability to manage current and future-oriented task demands within the situational context

stronger executive function skills.

To assess interjudge reliability for this study, the videotaped administrations of the HTKS for 18 randomly selected CWS (9 from the site in Indiana and 9 from Missouri) and 18 randomly selected CWNS (9 from the site in Indiana and 9 from Missouri), representing approximately 24% of the total participant pool, were viewed and scored by the first author who was not present at the original administration of the task. To assess intrajudge reliability, the same individual viewed and scored the videotaped administrations one month later. The correlation coefficient for both interjudge and intrajudge reliability was 0.99. Furthermore, the difference between the scores of the two raters (interjudge reliability), as well as between the initial and the subsequent scores of the same rater (intrajudge reliability) were not statistically significant, $t(35) = 1.08$, $p = 0.28$ (interjudge reliability), $t(35) = 0.12$, $p = 0.91$ (intrajudge reliability), suggesting that the HTKS was administered reliably.

2.2.1.2. Behavioral Rating Inventory of Executive Function—Preschool Version. The BRIEF-P is a 63-item parent-report questionnaire,[2] which measures different aspects of executive function in the everyday lives of children aged 2;0–5;11 (Gioia et al., 2003). Parents rate how often their child exhibits certain behaviors over the past six months using a 3-point Likert scale (i.e., never, sometimes, and often), and their responses to the items are subsequently combined to form five non-overlapping scales: *Inhibit*, *Shift*, *Emotional Control*, *Working Memory*, and *Plan/Organize* (for a brief description of each scale see Table 2). Raw scores for each scale are converted to standardized T scores ($M = 50$, $SD = 10$), with higher scores being indicative of poorer executive function skills and scores ≥ 65 being clinically significant. Scores for each scale are then combined into a *Global Executive Composite* (GEC) score, which is an overall summary measure for EF.

The internal consistency (Cronbach's alpha) of the five scales (Inhibit, Shift, Emotional Control, Working Memory, and Plan/Organize) and the GEC score is high, ranging from 0.80 to 0.95. Likewise, test-retest reliability over an average 4½ week interval ranges from 0.78 to 0.90 (Gioia, Isquith, Kenworthy, & Barton, 2002).

The majority of research concerning the validity of the BRIEF-P has focused on its convergence validity with other EF measures (behavioral tasks and/or parental ratings), with which it should theoretically correlate. For example, Garon, Piccinin, and Smith (2016) reported significant correlations between the BRIEF-P scales and the *Preschool Executive Function Battery* (Garon et al., 2014). The BRIEF-P Inhibit scale, in particular, has been shown to correlate significantly with measures of behavioral inhibition (Guy, Rogers, & Cornish, 2012). In addition, the BRIEF-P GEC scores have been shown to not only correlate with the inhibitory control subscale of the *Children's Behavior Questionnaire* (Rothbart, Ahadi, Hershey, & Fischer, 2001), but also behavioral measures of working memory (Cuevas, Hubble, & Bell, 2012). In general, findings from these studies and others provide evidence to suggest that the BRIEF-P has good convergence validity as a measure of EF.

2.3. Data Analyses

Screening procedures (e.g., outliers, normality, etc.) were conducted prior to analyzing the data to determine if the data met the assumptions needed for parametric testing. Normality was assessed by visually inspecting the standardized residual distributions for each dependent variable. Variables that were found to be not normally distributed, including some of the BRIEF-P scales—namely, the Emotional Control scale—and individual questionnaire items, were analyzed using the nonparametric Mann-Whitney U test (interval level measures) and chi-square test (nominal level measures). Variables that were normally distributed, including the HTKS, BRIEF-P GEC, and the remaining BRIEF-P scales, were examined using parametric analysis of variance and, when the assumption of homogeneity of variance was not met and the variances of the two groups were assumed to be different, Welch's t-tests. Prior to parametric testing, correlational analyses were conducted to examine the relationship between the dependent measures and chronological age and language skills to identify potential covariates for inclusion in the analysis of variance. To minimize the likelihood of false positives when multiple comparisons were conducted, the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995), a less stringent approach than the Bonferroni correction, was employed. Finally, the relationships between the two different EF measures (HTKS, BRIEF-P), the EF and language measures, and the EF measures and stuttering frequency (for the CWS group) were assessed using the more conservative coefficient Spearman's rho, with chronological age serving as a covariate.

[2] The BRIEF-P can also be completed by teachers, daycare providers, or other caregivers. In this study, however, only parents completed the questionnaire.

3. Results

3.1. Between-group differences in a behavioral measure of EF

Twenty-seven CWNS and 35 CWS received fewer than 4 points in Part I of the HTKS and, thus, did not move to Part II. A chi-square test revealed that the proportion of children in the CWS group (46.7%) who only completed Part I of the HTKS did not significantly differ from that of the CWNS group (36.0%), $\chi^2 = 1.76$, $df = 1$, $p = .18$. For both talker groups, the overwhelming majority of the participants (81.5% for the CWNS and 85.7% for the CWS) who did not progress to Part II were younger than 4 years of age.

Between-group differences in the total HTKS score were analyzed using an analysis of covariance (ANCOVA), with talker-group as fixed factor and chronological age (in months) and receptive vocabulary (PPVT-4) as covariates. Chronological age and receptive vocabulary were added as covariates to the analysis because they were significantly correlated with the HTKS ($r_s = -0.62$ and 0.36, $p < 0.001$, respectively).

After controlling for the effects of chronological age and receptive vocabulary, the ANCOVA revealed no significant main effect of talker group on the HTKS (CWS: *estimated marginal mean [EMM]* = 19.17, *standard error [SE]* = 1.43; CWNS: *EMM* = 21.99, *SE* = 1.43), $F(1, 146) = 1.95$, $p = 0.16$, $\eta_p^2 = 0.01$. Not surprisingly, the chronological age covariate, was significant, with older children outperforming younger children on the HTKS, $F(1, 146) = 112.05$, $p < 0.001$, $\eta_p^2 = 0.43$. The receptive vocabulary covariate was also significant, $F(1, 146) = 23.82$, $p < 0.001$, $\eta_p^2 = 0.14$, indicating that children who have better receptive vocabulary skills scored higher on the HTKS than children with weaker receptive vocabulary skills.

To further investigate chronological age, participants were divided into three age groups: 3-year-old (40 CWNS, 42 CWS), 4-year-old (19 CWNS, 18 CWS), and 5-year-old (16 CWNS, 15 CWS). Between-group differences in the total HTKS score were assessed using separate ANCOVAs for the 3- and 4-year-old groups and an ANOVA for the 5-year-old group, with talker group as a fixed factor. For the 3-year-old group, there were significant correlations between the HTKS and chronological age ($r_s = -0.30, p = 0.006$), as well as the HTKS and the PPVT-4 ($r_s = 0.36$, $p < 0.001$), EVT-2 ($r_s = 0.34$, $p = 0.002$), and TELD-3 ($r_s = 0.26$, $p = 0.2$). Thus, these variables were added as covariates to the model. For the 4-year-old group, only chronological age ($r_s = -0.35$, $p = 0.03$) and the PPVT-4 ($r_s = 0.37, p = 0.03$) were significantly correlated with the HTKS and, thus, added as covariates. None of the aforementioned variables were significantly correlated with the HTKS for the group of 5-year-old children (p-values = 0.16–0.48), so no covariates were added to the model.

Results revealed a significant between talker-group difference in the HTKS for the 3-year-old children, $F(1, 78) = 5.82, p = 0.02$, $\eta_p^2 = 0.07$ (CWS: *EMM* = 8.08, *SE* = 1.67, CWNS: *EMM* = 13.88, *SE* = 1.71), but not the 4-year-old, $F(1, 33) = 0.04$, $p = 0.84$, $\eta_p^2 = 0.001$, or the 5-year-old children, $F(1, 29) = 0.01$, $p = 0.93$, $\eta_p^2 < 0.001$, (see Fig. 1). In general, these findings indicate that younger CWS may have difficulty integrating aspects of EF.

To better understand the statistically significant difference between-talker groups for the 3-year-old children, we explored the relationship between the HTKS and the three scales of BRIEF-P that correspond to the HTKS (Shift, Working Memory, Inhibit) for each talker group separately using Spearman's rho. Only for the CWS group was the HTKS score significantly correlated with the BRIEF-P Working Memory scale ($rs = -0.31, p = 0.05$) in the expected direction (CWNS: $rs = -0.18, p = 0.25$). Furthermore, the 3-year-old CWS received significantly higher BRIEF-P Working Memory scores (lower ability) than their normally fluent peers, F (1,

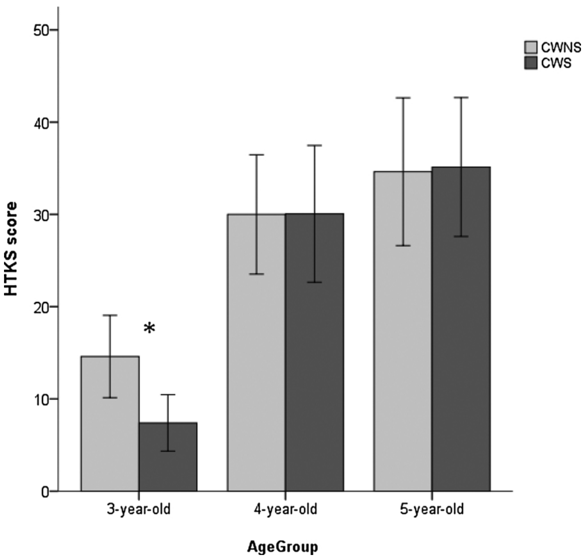

Fig. 1. Mean Head-Toes-Knees-Shoulders (HTKS) score for 3-, 4-, and 5-year-old children who do (CWS) and do not (CWNS) stutter. Error bars represent standard error. *$p < 0.05$.

Table 3
Means (M), Standard Deviations (SD), and p-values for the BRIEF-P Scales and Global Executive Composite (GEC) for Children who Stutter (CWS) and Children who do not Stutter (CWNS).

Measure	CWS	CWNS	*p-value*	*Cohen's d*
BRIEF-P Scales				
Inhibit	52.24 (11.77)	50.88 (8.69)	0.42	0.13
Shift	50.83 (8.17)0	47.07 (6.77)	0.007	0.50
Emotional Control	50.25 (11.01)	46.97 (8.07)	0.11	0.34
Working Memory	55.61 (11.42)	51.43 (9.22)	0.01	0.40
Plan/Organize	53.29 (11.41)	50.57 (8.51)	0.10	0.27
BRIEF-P GEC	53.01 (11.41)	49.39 (8.22)	0.03	0.36

Note. BRIEF-P: Behavior Rating Inventory of Executive Function—Preschool Version.

80) = 4.18, $p = 0.04$ (CWS: $M = 56.33$, $SD = 10.92$; CWNS: $M = 51.75$, $SD = 9.26$), which suggests that the poorer performance of the 3-year-old CWS on the HTKS may be attributed to differences in working memory skills.

3.2. Between-group differences in a parent report measure of EF

Levene's tests for homogeneity of variance were significant for three of the five BRIEF-P scales: Inhibit, F (1, 148) = 6.96, $p = 0.01$, Working Memory, F (1, 148) = 3.77, $p = 0.05$, Plan/Organize: F (1, 148) = 5.06, $p = 0.03$, and the Global Executive Composite (GEC), F (1, 148) = 8.98, $p = 0.003$, the composite score from all five BRIEF-P scales. Thus, between-talker group differences in the three scales and the GEC were assessed using Welch's t test. Results revealed no significant difference between the CWS and CWNS in Inhibit, $t(136.23) = 0.65$, $p = 0.42$, and Plan/Organize, $t(136.86) = 2.74$, $p = 0.10$. However, the CWS scored significantly higher on the Working Memory scale $t(141.71) = 6.10$, $p = 0.01$, and overall GEC, $t(134.51) = 4.99$, $p = 0.03$, than the CWNS (see Table 3). Thus, the CWS were judged by their parents as being less proficient in working memory and overall EF than the parents of the CWNS.

For the Emotional Control scale, visual inspection of the standardized residual distribution and the P-P plot indicated a non-Gaussian distribution. Therefore, data were examined using the Mann-Whitney U nonparametric test, which revealed no significant between-talker group difference in Emotional Control, $z = -1.59$, $p = 0.11$.

The remaining BRIEF-P scale (Shift) met the assumptions of normality and homogeneity of variance and was, therefore, assessed using an ANCOVA, with talker group as a fixed factor. The Shift scale was significantly correlated with the PPVT-4 ($r = -0.19$, $p = 0.02$), EVT-2 ($r = -0.0.24$, $p = 0.004$), TELD-3 ($r = -0.29$, $p < 0.001$), and chronological age ($r = 0.18$, $p = 0.02$), and, thus, these variables were added as covariates in the model. Results revealed a significant talker-group difference with the CWS having significantly higher Shift scores than their fluent peers, F (1, 143) = 7.50, $p = 0.007$, $\eta_p^2 = 0.05$. These findings indicate that the parents of the CWS rated their children as having more difficulty with flexibly adapting to new situations/activities/mindsets than the parents of the CWNS.

Ancillary analyses were also conducted to examine the relationship between talker group and clinically significant T-scores (scores higher than 65 or 1½ SD above the population norm) and talker group differences in responses to individual BRIEF-P questions/items. Chi-square tests revealed that more CWS than CWNS exhibited clinically significant T-scores in all five BRIEF-P scales, as well the GEC. As shown in Table 4, children in the CWS group were 2½ to 7 times more likely than children in the CWNS group to exhibit clinically significant difficulties with executive function.

Furthermore, parent responses to the 63 BRIEF-P questionnaire items were compared for each group of children using Mann-Whitney U tests, with p-values adjusted for multiple comparisons using the Benjamini-Hochberg procedure. The CWS group demonstrated significantly elevated responses to the following three questions compared to the CWNS group: Item 36, *"Reacts more strongly to situations than other children"* (Emotional Control), $z = -3.19$, $p = 0.001$; Item 42, *"Has trouble finishing tasks such as games,*

Table 4
Percentage of Children who Stutter (CWS) and Children who do not Stutter (CWNS) with T-scores in the Clinical Range for the BRIEF-P Scales and Global Executive Composite (GEC).

	Talker Group			
	CWS	CWNS	χ^2	*p*
BRIEF-P Scales				
Inhibit	17.33%	6.67%	4.04	0.04
Shift	9.33%	1.33%	4.75	0.03
Emotional Control	10.67%	2.67%	3.86	0.05
Working Memory	21.33%	4%	10.18	0.001
Plan/Organize	13.33%	4%	4.13	0.04
BRIEF-P GEC	14.67%	4%	5.04	0.02

Note. BRIEF-P: Behavior Rating Inventory of Executive Function—Preschool.

Table 5
Spearman's rho Correlations, Partialled out for Chronological Age, for the BRIEF-P (Scales and Global Executive Composite [GEC]) and HTKS for Children who Stutter (CWS) and Children who do not Stutter (CWNS).

	BRIEF-P					
	GEC	Inhibit	Shift	Emotional Control	Working Memory	Plan/Organize
HTKS – CWS	−0.14	−0.15	−0.09	−0.10	−0.15	−0.13
HTKS – CWNS	−0.13	−0.17	−0.01	−0.17	−0.19	0.01

Note. BRIEF-P: Behavior Rating Inventory of Executive Function—Preschool Version Global Executive Composite; HTKS: Head-Toes-Knees-Shoulder Task.

puzzles, pretend play activities" (Working Memory), $z = -3.03$, $p = 0.002$; and Item 45, *"Resists change of routine, food, places, etc"* (*Shift*), $z = -3.24$, $p = 0.001$.

3.3. Relationship between behavioral and parent-report measures of EF

The relationship between the behavioral (HTKS) and parent-report (BRIEF-P) measure of EF was analyzed for each group of children with the effect of chronological age partialled out. As shown in Table 5, the correlations between the HTKS and the five scales (Inhibit, Shift, Emotional Control, Working Memory, Plan/Organize) of the BRIEF-P, along with the GEC, were not statistically significant and weak/small in magnitude for both the CWS and CWNS, based on Cohen's (1988) guidelines for small (0.10), medium (0.30), and large (0.50) correlation coefficients.

3.4. Relationship between language abilities and EF

The relationship between language abilities (PPVT-4, EVT-2, TELD-3) and EF skills, as measured using the HTKS and BRIEF-P, was analyzed for each group of children using Spearman's rho, with chronological age serving as a covariate. As shown in Table 6, both the CWS and CWNS exhibited multiple significant correlations in the expected positive direction. All statistically significant correlations are small to medium in magnitude, with the exception of the correlation between HTKS and PPVT-4 for the CWS, which is medium to large in magnitude ($rs = 0.46$). The relationship between the HTKS and all three language measures was significant for both the CWS and CWNS. The relation between the BRIEF-P GEC, which is comparable to the HTKS in that both are integrative measures of EF, and the three language measures was also significant for the CWNS. However, the only language measure that correlated significantly with the BRIEF-P GEC for the CWS was the TELD-3.

3.5. Relationship between stuttering frequency and EF skills for CWS

Spearman's rho correlation, with chronological age serving as a covariate, revealed a non-significant relationship between the frequency of stuttering-like disfluencies and HTKS scores for CWS ($rs = -0.20$, $p = 0.09$). The correlation between the percentage of stuttering-like disfluencies and the overall BRIEF-GEC score also failed to achieve statistical significance and was low in magnitude ($rs = -0.13$, $p = 0.27$). Similarly, stuttering frequency was not significantly correlated with any of the five BRIEF-P scales (Inhibit: $rs = -0.11$, $p = 0.32$; Shift: $rs = -0.10$, $p = 0.40$; Emotional Control: $rs = 0.03$, $p = 0.77$; Working Memory: $rs = -0.08$, $p = 0.50$; Plan/Organize: $rs = -0.10$, $p = 0.39$). Thus, EF skills, as measured by both the BRIEF-P and HTKS, do not seem to be correlated with

Table 6
Spearman's rho Correlations, Partialled out for Chronological Age, for Executive Function and Language Measures for Children who Stutter (CWS) and Children who do not Stutter (CWNS).

	PPVT-4		EVT-2		TELD-3	
Measures	CWS	CWNS	CWS	CWNS	CWS	CWNS
BRIEF-P Scales						
Inhibit	−0.07	−0.12	−0.09	−0.33**	−0.19	−0.23*
Shift	−0.24*	−0.23*	−0.24*	−0.23*	−0.35**	−0.02
Emotional Control	−0.07	−0.11	−0.03	−0.24*	−0.09	−0.14
Working Memory	−0.08	−0.23*	−0.13	−0.38***	−0.27*	−0.38***
Plan/Organize	−0.08	−0.15	−0.13	−0.19	−0.24*	−0.09
BRIEF-P GEC	−0.11	−0.29**	−0.14	−0.40***	−0.25*	−0.29**
HTKS	0.46***	0.30**	0.30**	0.32**	0.27*	0.23*

Note. PPVT-4: Peabody Picture Vocabulary Test–4; EVT-2: Expressive Vocabulary Test–2; TELD-3: Test of Early Language Development-3; BRIEF-P: Behavior Rating Inventory of Executive Function—Preschool Version Global Executive Composite; HTKS: Head-Toes-Knees-Shoulder Task.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

the frequency of stuttering-like disfluencies for CWS.

4. Discussion

From its emergence in infancy, EF underpins children's cognitive, social, and emotional development and continues to support the ability to learn, adapt, and engage in goal-directed behaviors across the lifespan (Diamond, 2013). Given the reported differences between young CWS and CWNS in language abilities and emotion regulation (Ntourou et al., 2011; Jones et al., 2014) and the role that EF plays in the development of these skills (Carlson et al., 2005; Ferrier et al., 2014), it is not surprising that certain components of EF (working memory and inhibitory control) have attracted interest among researchers as potential contributors to the onset and/or manifestation of childhood stuttering.

To date, studies using parent-report questionnaires and experimental tasks have provided some evidence to suggest that phonological working memory and inhibition may be reduced in young CWS compared to CWNS (Anderson & Wagovich, 2017; Anderson et al., 2006; Eggers et al., 2013). Although this line of research has not yielded conclusive findings, it has nevertheless motivated further study of these two EF components in stuttering. Unlike working memory and inhibition, the evidence concerning the role of cognitive flexibility in childhood stuttering is scant and, to our knowledge, the ability of CWS to integrate components of EF has never been studied.

Thus, in the present study, we attempted to address this gap in the literature by using a standardized parent-report rating scale (BRIEF-P) and a behavioral task (HTKS) that requires the integration of the different components of EF. We also examined patterns of association between EF and language in CWS and CWNS and between EF and stuttering frequency in CWS.

4.1. Stuttering and EF

4.1.1. Parental rating of EF

With regard to our first goal, which was to determine if CWS differ from their fluent peers in EF, we found that parental ratings of EF were generally poorer for the CWS group compared to the CWNS group, as indexed by higher BRIEF *Global Executive Composite* scores. Also, the parents of the CWS rated their children poorer on two of the five scales that contribute to the composite score—namely, working memory and shifting—than the parents of the CWNS.

The fact that the CWS scored significantly higher (poorer ability) than the CWNS on the BRIEF-P Working Memory scale suggests that weaknesses in working memory may not be limited to just the storage and/or manipulation of phonemes (e.g., Anderson et al., 2006), but also to other types of verbal information, such as commands, which are usually longer in length and carry meaningful syntactic and semantic information. Items in the BRIEF-P Working Memory Scale also tap into children's ability to retain information in memory to complete simple or multi-step tasks (e.g., "When given two things to do, remembers only the first or last."), even when presented more than once (e.g., "Repeats the same mistakes over and over even after help is given."), in everyday settings where environmental and/or other cues might be available. Thus, present findings not only corroborate those of previous studies, which are based on experimental/behavioral tasks, but also extend these laboratory findings to include complex "real world" situations.

Furthermore, parents of CWS rated their children poorer on the BRIEF-P Shift scale than parents of CWNS. As briefly summarized in Table 2 and more fully described in the BRIEF-P manual (Gioia et al., 2003, p.17), important aspects of shifting include "the ability to make transitions, problem-solve flexibly, switch or alternate attention, and change focus from one mindset or topic to another." Thus, the finding that CWS were rated as having more difficulty with shifting than CWNS is consistent with previous findings showing that CWS are rated by their parents as less adaptable to change (Anderson, Pellowski, Conture, & Kelly, 2003; Howell et al., 2004; cf. Lewis & Goldberg, 1997) and less adept at shifting attention from one activity/task to another (Eggers et al., 2010).

In addition to scoring lower in overall EF abilities, data from this study, as depicted in Table 4, also revealed that the parents of the preschool-age CWS were significantly more likely to rate their children in the clinically significant range on all five domains of the BRIEF-P (inhibit, shift, emotional control, working memory, and plan/organize) than the parents of the CWNS. To our knowledge, this is one of the few, if not the only, piece of empirical evidence, based on a reliable and ecologically valid measure of EF in everyday life (Garon et al., 2016; Mahone & Hoffman, 2007), to suggest that CWS may be more likely than their fluent peers, to have frank deficits in inhibition, shifting, emotional control, working memory, and/or planning in everyday life.

Contrary to expectations, there was no statistically significant between-talker group difference in BRIEF-P Inhibit. As described in the BRIEF-P manual (Gioia et al., 2003), this scale refers to one's "ability to inhibit, resist, or not act on an impulse and the ability to stop his or her own behavior at the appropriate time" (p. 17), and it correlates highly with the Hyperactivity-Impulsivity scale of the ADHD Rating Scale-IV, Preschool Version (McGoey, Bradley-Klug, Crone, Shelton, & Radcliffe, 2000). Thus, our finding seems to contradict those of other studies that have reported CWS being more impulsive than CWNS based on parent-report questionnaires (Embrechts et al., 2000; cf. Eggers et al., 2010) and performance on a Go/NoGo task (Eggers et al., 2013).

Likewise, the CWS did not differ from their normally fluent peers in BRIEF-P Emotional Control, indicating that CWS are not more emotionally labile than CWNS. On the surface, this finding appears to contradict the growing literature suggesting that CWS are more emotionally reactive and less able to regulate their emotions than CWNS (for a review, see Jones et al., 2014). However, careful examination of the description of this scale (e.g., "Children with difficulties in this domain may have overblown emotional reactions to seemingly minor events", p. 18) and some of the individual questions that comprise it (e.g., "*Has explosive, angry outbursts*") reveals that this scale may be capturing noticeable, infrequent emotional reactions, not the everyday emotional arousal that is often triggered by internal and external stimuli, which has been the focus of the stuttering literature. Nevertheless, it is noteworthy that when compared to the CWNS, the CWS presented with statistically significant elevated responses on three test items, one of which ("*Reacts* *more strongly to situations than other children*") is related to emotional reactivity and emotional regulation processes, while the other two (*"Has trouble finishing tasks such as games, puzzles, pretend play activities"* and *"Resists change of routine, food, places, etc"*) tap into working memory and shifting, respectively

4.1.2. Behavioral Task (HTKS)

Children's ability to coordinate aspects of EF was measured using the HTKS. There were significant differences between the CWS and CWNS on the HTKS, but only for the 3-year-olds. Thus, the young CWS found it more challenging than their fluent peers to perform a behavioral task that requires the coordination of cognitive flexibility, working memory, and inhibitory control. Closer inspection of the data further suggested that this difference in performance may be attributed to differences in working memory, a finding consistent with the BRIEF-P results. Thus, the young CWS may have had difficulty successfully completing the HTKS because they struggled to retain and/or retrieve task-related instructions/rules from short-term memory. The fact that only the young CWS had difficulty with the HTKS further suggests that their early difficulties with EF coordination may resolve over time. This latter interpretation is admittedly speculative, given that it is based on a cross-sectional design. To more fully assess the hypothesis that young CWS have difficulties with EF coordination that subside over time, changes in individual children's performance on the HTKS would have to be examined longitudinally, starting at 3 years of age and going up to 5 years of age.

4.1.3. Summarizing and reconciling the evidence from the BRIEF-P and HTKS

The aforementioned discussion, which focused on differences in EF abilities between preschool-age CWS and CWNS on the BRIEF-P and HTKS, has yielded somewhat contradictory results. According to parental report, the preschool-age CWS exhibited lower EF skills than their peers, whereas only the 3-year-old CWS performed significantly lower than their fluent peers on the behavioral EF task. Furthermore, there were no significant correlations between the HTKS and BRIEF-P for both groups of children.

At first glance, these findings may appear problematic for the validity of these measures and interpretation of the findings. However, these discrepancies are likely due to differences in the nature of these measures; studies have consistently demonstrated poor agreement between performance- and questionnaire-based measures of EF in clinical (Bodnar, Prahme, Cutting, Denckla, & Mahone, 2007; Conklin, Salorio, & Slomine, 2008) and non-clinical (Liebermann, Giesbrecht, & Müller, 2007) populations.

Performance-based tasks, like the HTKS, typically measure children's ability to produce simple responses in laboratory settings, whereas parent (or teacher)-report questionnaires (e.g., BRIEF-P) measure more complex behaviors produced in real-world situations. According to Toplak, West, and Stanovich (2013), performance-based tasks assess the efficiency with which an individual recruits EF processes in the context of a specific task, during a short time window, and with the examiner directing the elicited behavior. On the other hand, parent-report questionnaires of EF (i.e., BRIEF-P) are less restrictive and evaluate how well a child performs in real-life activities and, thus, provide an ecologically valid indicator of competence in complex, everyday contexts (Roth, Isquith, & Gioia, 2005). Toplak and his colleagues also propose that parent-report questionnaires assess EF at a reflective level of functioning. The reflective level is concerned with the individual's goals and actions based on those goals, rather than the examiner's. Thus, performance-based measures would seem to provide an indication of processing efficiency and are more procedurally oriented, whereas parent-report questionnaires are more goal oriented.

These differences between performance-based measures and parent-report questionnaires suggest that contextual and/or methodological factors play a role in how EF skills are manifested. Thus, the lack of convergence in the present findings between the HTKS and BRIEF-P should not be construed as suggesting that the two tasks are measuring different skills, but rather that they are measuring the same skills in different contexts. For example, a child may be able to perform reasonably well on a 5-min EF task that requires a simple response (e.g., touching their toes when they are told to touch their head), but then struggle to exhibit strong EF skills in everyday life where the demands may be higher and last longer than 5 min (e.g., transitioning from a desired to a non-desired activity immediately upon being asked to do so by the teacher/caregiver).

The finding that preschool-age CWS may exhibit more difficulties with EF than their fluent peers when these skills are measured by parent-report more so than when these abilities are measured by a behavioral task is supported by the findings of a recent meta-analysis on the attention and EF skills of CWS (Ofoe, Anderson, & Ntourou, 2017). Ofoe and colleagues found that CWS, when compared to CWNS, exhibited weaknesses in inhibitory control and attention based on parent-report measures, but not behavioral measures. The mean effect sizes for the parent-report measures were statistically significant and small to medium in magnitude. One potential interpretation of these findings is that preschool-age CWS have more difficulty than CWNS employing EF abilities in the service of goal-directed actions in complex everyday real-world situations, but not in the completion of short, structured, adult-directed tasks.

4.2. Relationship between language skills and EF

As previously indicated, several studies have examined one or more components of EF in young CWS (e.g., Eggers et al., 2013). Although most of these studies used standardized language tests to ensure that participants did not present with language delays/disorders, one study examined the relationship between language abilities and EF skills (using behavioral measures) in young CWS (Anderson et al., 2006). Anderson and her colleagues examined the relationship between overall language skills, receptive and expressive vocabulary, and phonological working memory abilities, measured using a nonword repetition task. Contrary to the authors' hypotheses and the numerous studies establishing a relationship between nonword repetition and language skills in young children (e.g., Gathercole, 2006; Hoff, Core, & Bridges, 2008; Metsala, 1999), neither CWNS nor CWS exhibited a significant relationship between nonword repetition scores and standard scores for overall language and receptive and expressive vocabulary.

The present study extended this area of investigation by assessing the relationship between different aspects of EF and language skills. Findings indicated that both the CWS and CWNS exhibited significant correlations between language and EF skills, as measured by the HTKS and BRIEF-P. For example, correlations with moderate effect sizes between receptive and expressive vocabulary and EF skills, measured with the HTKS task, were reported for both talker groups. This finding of a close relation between vocabulary knowledge and performance on the HTKS aligns well with previous findings (e.g., Wanless et al., 2011) and provides additional evidence for the important role of EF in supporting the development of language skills during the preschool-age years (Weiland, Barata, & Yoshikawa, 2014). Furthermore, the ability to integrate cognitive flexibility, inhibitory control, and working memory may help children stay focused and self-regulated during testing, resulting in better performance on standardized language tests. Thus, EF skills not only support language growth during the preschool-age years, but also equip children with the necessary skills to meet test-taking demands.

While both CWS and CWNS exhibited significant correlations between vocabulary and EF skills, as measured by the HTKS task, the correlations between vocabulary and BRIEF-P GEC scores were significant (moderate effect) only for the CWNS group. Although research concerning the relation between vocabulary and BRIEF-P GEC scores in typically developing children is scant (Trainor, 2012), one would expect the relationship to exist for the CWS group too. The reason for this lack of association is not entirely clear.

Furthermore, the correlations between receptive and expressive vocabulary and the BRIEF-P working memory scale were significant (moderate effect) only for the CWNS group. Thus, although CWS and CWNS performed similarly on the two vocabulary measures (EVT-2, PPVT-4), the close and dynamic relationship between word learning and working memory that has been theorized (Baddeley, Gathercole, & Papagno, 1998) and documented in typically developing preschool-age children (Roman, Pisoni, & Kronenberger, 2014; Wolfe & Bell, 2004) was evident only for the CWNS group. This finding, however, is consistent with that of Anderson et al. (2006) and may indicate subtle differences between CWS and CWNS in the role that working memory plays in vocabulary acquisition.

5. Conclusion

In sum, findings from this study provide further evidence to suggest that executive functioning, especially as measured by a standardized parent-report questionnaire, may play a role in developmental stuttering. The BRIEF-P, in particular, proved to be sensitive to differences in EF skills between the preschool-age CWS and CWNS. Given that empirical exploration of the association between executive function and developmental stuttering is still in its infancy, it is difficult to comment on the clinical importance of these differences. That said, findings based on BRIEF-P are unequivocal in suggesting that more CWS than CWNS present with clinically significant difficulties in EF skills. Thus, although we must proceed with caution when applying these findings to everyday clinical practice, clinicians could consider introducing standardized parent-report scales of EF as part of the fluency diagnostic for young CWS. The favorable properties of the BRIEF-P, such as its ecological validity, ease of its completion, and sound psychometric properties, make it viable for clinical use. Such an assessment may reveal concomitant EF difficulties in some CWS that may need to be considered when developing a comprehensive, holistic treatment plan.

6. Future Directions

Future studies may include reports from informants in different environments to strengthen the validity of this study's findings and determine whether the overall EF difficulties of CWS are present across different environments or are context-bound. Furthermore, such an investigation would help determine whether different environments (home vs. school) place varying demands on certain EF skills. For example, a highly structured classroom environment might place less demands on some EF skills, such as planning and inhibitory control, but greater demands on other EF skills, such as working memory, given that students are often asked to complete various multi-step tasks in a relatively timely manner. A less structured home environment, on the other hand, might place higher demands on planning and inhibitory control. Also, to more strongly elucidate whether young CWS's poorer performance on the HTKS results mainly from weaknesses in working memory or difficulty integrating the different EF processes, participants' HTKS performance could be correlated with other performance-based measures of working memory, inhibitory control, and cognitive flexibility at each measurement occasion/data collection time point.

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